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draft environmental statement

related to operation of

BISON BASIN PROJECT

OGLE PETROLEUM, INC.

JUNE 1980

DOCKET NO. 40-8745

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U. S. Nuclear Regulatory Commission • Office of Nuclear Material Safety and Safeguards

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DRAFT ENVIRONMENTAL STATEMENT

related to the

Ogle Petroleum, Inc.

BISON BASIN PROJECT

(Fremont County, Wyoming)

Docket No. 40-8745

June 1980

Prepared by the
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

SUMMARY AND CONCLUSIONS

This Draft Environmental Statement was prepared under the direction of the staff of the U.S. Nuclear Regulatory Commission (NRC) and issued by the Commission's Office of Nuclear Material Safety and Safeguards.

1. This action is administrative.

2. After an assessment of concerns, alternatives, and the addition of license conditions as discussed below, the proposed action is the issuance of a Source Material License to Ogle Petroleum, Inc., which, on August 10, 1979, applied to the NRC for an NRC Source Material License to construct and operate in Fremont County, Wyoming, an in situ leach uranium mine and recovery plant designed to produce 4.54×10^5 kg (1.0×10^6 lb) of U_3O_8 at a rate not to exceed 1.8×10^5 kg/year (4.0×10^5 lb/year).

   The project site consists of about 308 ha (761 acres) approximately 80 km by air (50 miles) south of Riverton and about 48 km by air (30 miles) southwest of Jeffrey City, Wyoming.

   The applicant proposes to mine in situ uranium ore contained in the Laney member of the Green River formation, using sodium carbonate/bicarbonate solution and an oxidizing agent injected and recovered through a complex of well patterns. Each well pattern will consist of six injection wells surrounding a central production well. Eacn production well will be pumped at a rate between 34 to 45 liters/min (9 to 12 gpm), and enough patterns will be operated to supply up to 4550 liters/min (1200 gpm) of uranium-containing solution to an onsite extraction and concentrating plant producing the final product (U_3O_8). Only about 16 ha (40 acres) are proposed for mining. A total of 5.4 ha (13.5 acres) will be excavated for building and equipment foundations and for evaporation ponds. An additional 17 ha (43 acres) will undergo surface disturbance during well-field development and operation.

   The applicant proposes to restore the groundwater system to its former potential use (and as close to baseline as reasonably achievable) after mining is complete by recycling mined formation water through a reverse osmosis cleanup system and back into the formation until satisfactory water quality has been reached. The above-ground solid wastes produced by the mining process are defined as by-product material by the Uranium Mill Tailings Radiation Control Act; they will be removed to a licensed disposal site.

3. Concerns receiving special attention are listed in detail in Sect. 1.5, Results of the Scoping Process. These concerns include staff, public, and individual issues for which analysis and assessment were necessary. The major categories of concern 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 and paleontological resources;

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

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

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

   f. the socioeconomic effects of the project.

No comments were received suggesting disapproval 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 pit or deep mine the ore body and have the ore processed at an existing mill. The staff considers this 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 siting alternatives,
      - alternative of processing in an existing mill, and
      - alternatives specific to in situ leaching, 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. The geological and hydraulic conditions at the site 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 virtually impermeable rock layers.

   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 contains the following conditions:

   a. The applicant shall implement the monitoring programs specified and recommended in Sect. 4.4.

   b. The wastes from solution mining activities shall be finally disposed of off site at a licensed disposal facility as described in Sect. 4.6.3.

c. The applicant shall minimize total groundwater usage by improving his reverse osmosis treatment unit water recovery rate to an efficiency as high as reasonably achievable, as discussed in Sects. 2.3.10.3 and 4.3.2.

d. The applicant shall implement a groundwater restoration program on mined-out well fields in accordance with the general plan discussed in Sect. 2.3.10.3 and the criteria discussed in Sect. 4.3.1.

e. The applicant shall packer test wells (or the equivalent) after completion to ensure casing and cement integrity and shall document the results as discussed in Sect. 2.3.10.1.

f. The applicant shall monitor well injection processes as specified in Sect. 2.3.10.1 and maintain such pressures below 0.63 psi/ft of depth.

g. The applicant shall develop and conduct a program to better determine radon releases from well-field surge tanks, as mentioned in Sect. 4.4.2.4.

h. The applicant shall establish a program that shall include written procedures and instructions to control all activities discussed in items a through f.

i. 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 approval of NRC for the activities.

j. 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 NRC an acceptable analysis of the problem and a plan of action to eliminate or significantly reduce the harmful effects or damage.

k. Prior to disturbing any land, including topsoil removal, outside the area surveyed for any solution-mining-related activities, including site decommissioning, the licensee shall have an archaeological survey of the area performed and shall submit the results to the NRC for review. The licensee shall not proceed with any land disturbance until the NRC has evaluated the report and given the applicant approval to proceed.

l. The applicant shall notify the NRC and the Wyoming State Archaeologist when any artifacts of earlier culture are encountered during site preparations or operations. Further activity in the immediate area shall be deferred until a determination of their significance by the NRC is completed. Mitigating measures, if needed, to preserve them shall be proposed by the licensee.

m. The applicant shall provide surety that funds will be available for aquifer restoration, surface reclamation, decommissioning, and final waste disposal.

n. Though the geologic information submitted by the applicant was gathered in the area of the first mine unit, the information is considered to be representive of the entire site. The applicant shall provide additional geologic information as specified in Sects. 3.6.2.3. 3.7.1.3 and 4.2 to confirm the continuity of geologic characteristics over the entire site prior to mining fields beyond unit one.

o. The applicant shall mine sequentially; commencing restoration of each mined out unit as mining begins in other fields or as soon as it is practicable.

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) could exceed State and Federal standards but would not be expected to harm living plants, animals, or humans. The staff recommends that the applicant submit plans to mitigate such emissions to the Wyoming Division of Environmental Quality.

   b. The project site and all surrounding land are used for grazing. Wildlife at the site includes antelope, sage grouse, rabbits, and coyotes. Evaporation ponds and building sites will occupy fewer than 5.4 ha (13.5 acres), and areas fenced to exclude wildlife and livestock cover a 5-ha (12-acre) rectangle. This amount of land use for five years will have an insignificant effect on land use. Well-field development, operation, and restoration on an additional 17 ha (43 acres) will also have no appreciable effect on land use. All disturbed areas will be reclaimed after project termination to original use condition or better.

   c. The total use of groundwater from the Laney member of the Green River formation is estimated to be about 2.96×10^5 m^3 (240 acre-ft) over the five-year project lifetime. Groundwater in the mining zone will temporarily be degraded during operation of the well fields. Restoration should return this water to a condition consistent with premining potential use or 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 radiation dose to the nearest members of the general public will be insignificant as shown in the following table:

Dose commitments to individuals from radioactive releases from the Bison Basin Project

Location	Exposure pathway	Dose (millirems)[a]			
		Total body	Bone	Lung	Bronchial epithelium[b]
Nearest residence (11 km ENE)	Inhalation	1.9E−2[c]	1.8E−2	1.2	1.7
	Immersion in air	8.8E−3	1.0E−2	8.4E−3	
	Ground surface	2.8E−3	3.3E−3	2.9E−3	
	Total	3.1E−2	3.1E−2	1.2	
Sweetwater Station (30 km NNE)	Inhalation	5.0E−3	4.5E−3	3.1E−1	3.1E−1
	Immersion in air	3.3E−3	3.8E−3	3.1E−3	
	Ground surface	1.0E−3	1.1E−3	1.0E−3	
	Total	9.3E−3	9.4E−3	3.1E−1	

[a] 1 millirem = 0.01 millisievert.

[b] Doses to the bronchial epithelium result from the inhalation of short-lived radioactive daughters of ^{222}Rn.

[c] Read as 1.9×10^{-2}.

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 damage to the environment.

7. The position of the NRC is as follows:

Solution mining (in situ leaching) of uranium is a developing technology. Uncertainties regarding environmental impacts, particularly with respect to groundwater contamination and the effectiveness of groundwater restoration techniques, have been recognized. The applicant has provided initial evidence that groundwater restoration can be achieved from the pilot-scale test program (Sect. 4.3.2). Furthermore, the scope of the proposed project is sufficiently limited in size to enable continued development of solution mining technology without significant environmental risk.

As a further control, the applicant will initially be restricted to mining the first and second mining units until aquifer restoration in the first mining unit has been demonstrated to the satisfaction of the NRC.

The position of the NRC is that, after weighing the environmental, economic, technical, and other benefits of the Bison Basin 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 Source Material License amendment to the applicant, subject to conditions presented above.

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1. PURPOSE OF AND NEED FOR ACTION

1.1 INTRODUCTION

This Draft Environmental Impact Statement is issued by the U.S. Nuclear Regulatory Commission (NRC), Office of Nuclear Material Safety and Safeguards, in response to the request by Ogle Petroleum, Inc., for the issuance of an NRC Source Material License authorizing operation of the proposed Bison Basin 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 Bison Basin Project will be operated by the applicant.

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, and aesthetically 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 NRC Division of Waste Management has prepared this detailed Statement on the foregoing considerations with respect to the application for a Source Material License for the above project.

In accordance with 10 CFR Part 40, Section 31, the applicant has submitted an Environmental Report[1] to the NRC pursuant to the license application. In conducting the required NEPA review, Commission representatives (the staff) met with the applicant to discuss items of information in the Environmental Report, 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 meeting 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, Ogle Petroleum, Inc., on August 10, 1979, applied to the NRC for an NRC Source Material License to construct and operate an in situ leach uranium mine and recovery plant in Fremont County, Wyoming. This project, hereafter referred to as the Bison Basin Project, is designed to produce 4.54×10^5 kg (1.0×10^6 lb) of U_3O_8 at a rate not to exceed 1.8×10^5 kg/year (4.0×10^5 lb/year). Solution mining (in situ leaching) of uranium is a new and developing technology. To aid the reader in achieving a better overall understanding of the proposed project, a glossary of terms abstracted from the International Glossary of Hydrology[2] is included.

The project site consists of about 308 ha (761 acres) approximately 80 km by air (50 miles) south of Riverton and about 48 km by air (30 miles) southwest of Jeffrey City, 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.

The applicant proposes to mine in situ uranium ore contained in the Laney member of the Green River formation, using sodium carbonate/bicarbonate solution and an oxidizing agent injected and recovered through a complex of well patterns. Each well pattern will consist of six injection wells surrounding a central production well. Each production well will be pumped at a rate between 34 to 45 liters/min (9 to 12 gpm), and enough patterns will be operated similtaneously to supply up to 4550 liters/min (1200 gpm) of uranium-containing solution to an onsite extraction and concentrating plant producing the final product (U_3O_8).

The applicant proposes to restore the groundwater system to its premining potential use (as close to baseline as reasonably achievable) after mining is complete by recycling mined formation water through a reverse osmosis cleanup system and back into the formation until satisfactory water quality has been reached. 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 State of Wyoming Department of Environmental Quality 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 will be in effect 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 Department of Environmental Quality, Land Quality Division. This document will also contain specific well-field monitoring programs and groundwater restoration criteria as required by the State of Wyoming.

A performance bond is required for reclamation. The State will also require a performance bond for groundwater restoration.

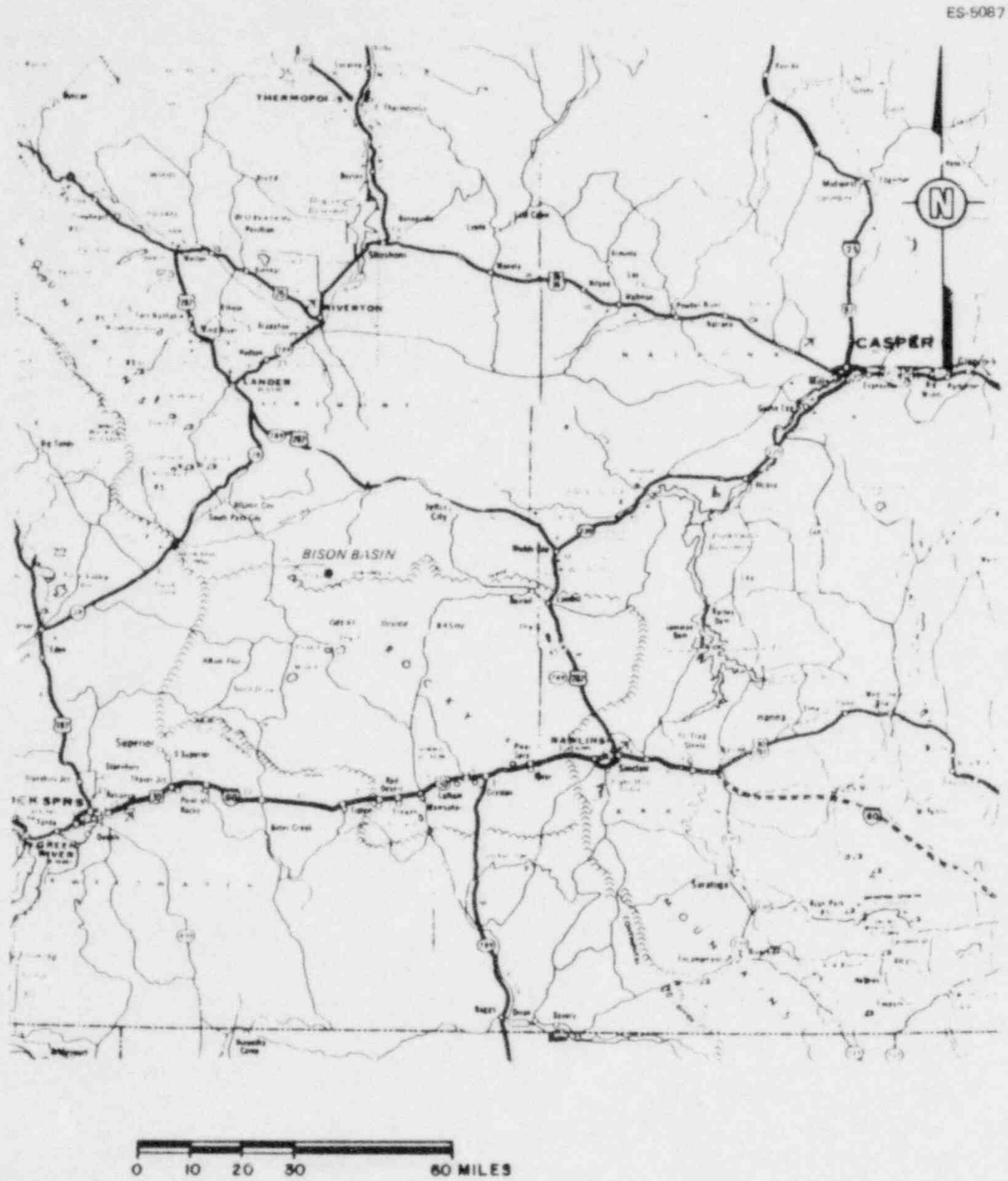

Fig. 1.1. Map of the region surrounding the Bison Basin Project. <u>Source</u>: Western Nuclear, Inc., *Report 3, Environmental Effects of Present and Proposed Tailings Disposal Practices, Split Rock Mill, Jeffrey City, Wyoming*, vol. 1, prepared by D'appolonia Consulting Engineers, Inc., October 1977, adapted from Fig. 2-1.

1.4 NEED FOR ACTION

Among the alternative actions available to the NRC is the denial of a Source (By-Product) Material License to the applicant (see Sect. 2.1). The staff considers this option not in the public interest. This view is substantiated by the Executive Summary of the "Workshop on Concepts of Uranium Resources and Producibility," National Academy of Sciences, Washington, D.C., 1978, which states:

> Nuclear energy for use in electric power generation has been assigned a significant role in the National Energy Plan now under development. More than 65 light-water reactors provided about 12 percent of the United States electricity in 1977. Although federal estimates of future nuclear power growth rates have declined dramatically in the last two years, the Department of Energy (DOE) expects nuclear power output to grow to at least 380 gigawatts by the year 2000. However, the deep concern for nuclear proliferation and terrorism around the world, combined with a reported availability of adequate uranium resources for a light-water-reactor economy, have led to executive decisions to defer plutonium breeder development and to delay the reprocessing of spent nuclear fuel for secondary recovery of fissionable components. Yet, the combination of anticipated energy requirements and national security needs make the magnitude and timely availability of the United States domestic uranium resources a technical subject of commanding national interest.
>
> In 1976 domestic uranium concentrate production (short tons U_3O_8) was 12,750 tons; in 1977 it was nearly 15,000 tons. To meet uranium supply requirements now anticipated for electric power generation, production will have to double within the next five years and reach about 45,000-50,000 tons annually by 1990. Inasmuch as the highest level of production achieved in the United States has been less than 18,000 tons of U_3O_8,* a remarkable growth performance will be required from the uranium exploration and production industry. Whether this growth performance can be met and whether the National Energy Plan objectives for nuclear power will be realized now appear to depend on optimistic and constructive interactions among the mining industry, the utilities, government decision makers, and the general public.

Within this apparent need, denial of a Source 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 CRF Part 1501.7, the NRC followed the scoping process to identify significant issues to be analysed and discussed in the DES. In order to establish the significant issues, not only was the NRC staff consulted, but a public notice concerning the DES was published, comments from interested parties were requested, and the NRC conducted a public scoping meeting. During review of the Environmental Report for the proposed project, the NRC staff identified major areas of concern which would require careful assessment in the Environmental Statement.

1. Potential adverse effects should be considered and mitigating measures proposed to eliminate such effects insofar as possible (Sect. 4.4).

2. Solid waste disposal alternatives should be considered in detail, and the prime consideration should be disposal of radioactive solid wastes in a manner that will prevent potential human exposure for the foreseeable future (Sect. 2.3.10).

3. Water use during mining and aquifer restoration should be monitored with the intention of minimizing water usage (discharged to the evaporation ponds and lost by evaporation) within the constraints imposed by the need to prevent and correct leachate excursions during mining and to minimize water used for aquifer restoration (Sects. 2.3.10, 4.2, 4.3, and 4.4.2.5).

4. The applicant's aquifer restoration tests on the mined pilot area (experimentally mined zone) and the design of the water treatment system proposed for restoration should provide reasonable assurance that the mined aquifer can be restored to its original potential use (Sects. 2.3.10 and 4.3).

5. Planned operating procedures and monitoring and mitigating measures should provide reasonable assurance that excursions (leachate escape) will not occur; and, in case of accidental excursions, procedures are available to clean up contaminated zones outside the area to be mined (Sects. 4.4 and 4.4.2.5).

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*Actual production in 1975 was 18,400 tons of U_3O_8.

6. The wells should be properly designed, installed, and tested so that accidental leachate intrusion into nonmining regions will not occur (Sect. 2.3.10).

In addition, the staff planned to discuss measures to be taken by the applicant to comply with applicable local, State, and Federal regulations in sufficient detail to ensure that such requirements would be met.

The NRC also issued a Federal Register notice as required under the CEQ Rules and Regulations effective July 30, 1979.[3] This notice requested comments by interested parties on the project and set a public scoping meeting date of November 1, 1979, in Riverton, Wyoming.

At the scoping meeting the applicant summarized the proposed project, and comments were solicited from the attendees. The staff also requested additional written comments. Specific issues raised at the scoping meeting were

1. What is the expected project lifetime (Sect. 2.3.1)?
2. Can groundwater be restored (Sect. 4.3)?
3. Is there a risk of subsidence (Sect. 4.5.2)?
4. Can wastes be disposed of offsite (Sects. 2.3.6.1, 2.3.10.4, 2.3.10.5, and 4.6.3)?
5. What quantities of groundwater will be used (Sects. 4.5.3.2, 4.8.3.2, and 4.9.1.2)?
6. What will be the weight of waste quantities (Sects. 2.3.10.4 and 4.6.3)?
7. Where will U_3O_8 slurry be shipped (Sects. 2.3.10.2 and 4.6.2.1)?
8. Will existing roads be improved (Sects. 3.4 and 4.5.3.1)?
9. Where will site electric power come from (Sects. 2.3.10.2 and 3.4)?
10. Where will evaporation ponds be located, and how will they be protected from flooding (Sect. 2.3.10.4)?
11. What are fencing requirements, and will fencing affect migratory game (Sect. 4.5.2)?
12. Will archaeological and paleontological resources be affected (Sect. 3.5.2.2)?
13. Will the project affect the proposed Continental Divide trail (Sect. 3.5.2.1)?
14. How will roads be maintained (Sects. 4.6.1.7 and 4.6.1.9)?

The staff later received comments from several Wyoming State agencies transmitted through the office of the Governor.

The cover letter requested careful scrutiny of the potential surface and groundwater impacts and more detailed examination of the socioeconomic impacts (Sect. 3). Comments by the Geological Survey of Wyoming suggested updating and clarifying some of the information in the applicant's Environmental Report. Units of the Wyoming Department of Environmental Quality suggested enumerating types and quantities of air emissions (Sect.3), the need for a solid waste disposal site, and a thorough critique on issues related to groundwater. These items are also of particular concern to the staff.

Concerns identified in comment letters from the U.S. Department of the Interior - Fish and Wildlife Service, Bureau of Land Management, Bureau of Mines, Bureau of Indian Affairs, and the Geological Survey are summarized as follows:

1. the effect of the mining operation on both availability and quality of water (Sects. 3.6.2.5, 4.3.1, 4.3.2, 4.3.3, 4.4.1.1, 4.4.2.3, 4.5.3.2, 4.8.3.2, and 4.9.1.2),
2. the impact of the mining operation, fencing, roads, human activities, and possible windblown contaminants on wildlife (Sects. 4.5.2, 4.5.3.1, 4.5.6.1, 4.5.6.2, and 4.6),

3. potential effects on archaeological and paleontological resources and the proposed Continental Divide trail (Sect. 3.5.2.2 and 3.5.2.3),

4. impacts of road buildings, maintenance, and use (Sects. 4.5.2, 4.5.3.1, 4.5.6.1, and 4.5.6.2),

5. final disposal plans for evaporation pond wastes and the quantities of such wastes (Sects. 2.3.10.4 and 2.3.10.5),

6. adverse impacts on the Wind River Indian Reservation (Sect. 4.9.2)

7. potential effects on wildlife from contact with wastewater-evapor..ion ponds or from waste seepage into groundwater aquifers (Sects. 4.4.1.1, 4.4.2.1, 4.4.2.3, 4.5.3.1, and 4.5.7),

8. well injection pressures and potential effects (Sects. 2.3.10.1 and 4.5.2), and

9. disposal of drill cuttings from wells (Sect. 2.3.10.4).

In addition, the staff was reminded of the necessity of consultation with the Fish and Wildlife Service on endangered species and the Historic and Archaeological clearance responsibilities. These agencies had already been contacted by the staff.

The comment letter of the National Wildlife Federation (November 8, 1979) listed no concerns not covered above with the exception of a request for a Generic Environmental Impact Statement (GEIS) for in situ uranium mining. Though a GEIS is not being planned, an NRC position paper relating to in situ mining is planned.

The Wyoming Outdoor Council suggested earlier notification of scoping meetings and the establishment of a local source for available public information on such projects. The NRC will provide earlier notification and is using the Fremont County Public Library as a local source of public information.

The staff has addressed each of the above comments on the Bison Basin Project in the appropriate section of the Environmental Impact Statement as noted by each comment. No comments were received suggesting disapproval of the project.

REFERENCES FOR SECTION 1

1. Ogle Petroleum, Inc., *Environmental Report for U.S. Nuclear Regulatory Commission, Source Material License Application, Production Scale In Situ Mine, Wyoming*, August 1979. Hereafter in this Environmental Statement, the applicant's Environmental Report will be cited as ER followed by a specific volume, section, page, figure, table, appendix, or supplement number. Docket No. 40-8745.

2. World Meteorological Organization and United Nations Educational Scientific and Cultural Organization, *International Glossary of Hydrology*, Report WMO/OMM/BMO No. 385, 1974.

3. *Fed. Regist.* 43(230): 56005 (1979), paragraph 1508.22.

2. ALTERNATIVES . .LUDING THE PROPOSED ACTION

2.1 ALTERNATIVE OF NO LICENSING ACTION

Amoung the alternative actions available to tne 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 the alternative discussed below in this section.

The yellow cake produced by the Ogle Petroleum, Inc., 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 yellow cake produced by the proposed solution mining project, failure to license this project would only result in foreign demand being filled by other domestic or foreign mills that could be producing uranium for use in the United States. 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 are cleaner burning than coal and 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 tne 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 and consumes twice as much energy per capita as does West Germany, which has a similar standard of living.[1] In 1978, the United States consumed approximately 78 quads of energy (1 quad = 10^{15} Btu); about 92% of this energy was supplied by three fossil fuels -- oil, natural gas, and coal.[2] Approximately 75% of U.S. energy needs are supplied by natural gas and oil; however, because the domestic supplies of these valuable resources are limited (about 8% proven reserves are oil and gas), the amount of oil imported from foreign sources has increased, undermining our military and economic security.[2] There is a disparity between availability and use of fossil fuel energy sources in the United States (Table 2.1).

Table 2.1. Reserves and current use of energy sources in the United States

	Proven U.S. energy reserves economically recoverable (%)	Total U.S. energy contributed by each energy resource (%)
Coal	78	19
Oil	4	49
Gas	4	26
Nuclear	14	4
Hydro	0	2

Source: U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review*, Report DOE/EIA-0035/5, May 1978.

Despite concentrated efforts to (1) slow down consumption of oil and natural gas, (2) increase usage of coal-burning facilities, and (3) further the utilization of nonconventional energy sources, energy demand forecasts indicate that, by the year 2000, approximately 43% of our energy will still be supplied by oil and gas, 21% by coal, and only a small percentage (~7%) by other fuels (Table 2.2).

Table 2.2. Forecast of gross energy use for 1980, 1985, and 2000

Fuel	1980		1985		2000	
	10^{12} Btu	Percent of gross	10^{12} Btu	Percent of gross	10^{12} Btu	Percent of gross
Coal	17,150	19.7	21,250	20.6	34,750	21.3
Petroleum	41,040	47.1	45,630	44.1	51,200	31.3
Natural gas	20,600	23.6	20,100	19.4	19,600	12.0
Oil shale			870	0.8	5,730	3.5
Nuclear power	4,550	5.2	11,840	11.4	46,080	28.2
Hydropower and geothermal power	3,800	4.4	3,850	3.7	6,070	3.7
Total	87,140	100.0	103,540	100.0	163,430	100.0

Source: U.S. Bureau of Mines, *United States Energy Through the Year 2000*, Washington, D.C., December 1975.

Of the more than 78 quads of energy consumed in the United States in 1978, over 22 quads were used to produce electric energy. An estimated 12.5% of this electrical energy was generated using nuclear fuels. Oil and gas contributed 16.5 and 13.8%, respectively, and coal was used for producing 44.3%. In spite of rapidly rising prices and dwindling and/or unreliable sources of supply, the demand for oil and natural gas to generate electric power has increased about 14.5% from 1975 through 1978.[3] The domestic and global use of oil has continued to expand despite their shrinking availability and OPEC pricing policies; however, its use for electrical power generation should decline in the future because the price of oil more than doubled during 1979. (President Carter has recently proposed that utilities be required to reduce their demand for petroleum products by 50% by 1990.) Therefore, it is apparent that, of the resources currently used in electric-power-generating stations (coal, uranium, oil, gas, and hydro), an increasing part of U.S. electrical energy needs will have to be met by coal and/or uranium — at least until the end of this century. Although coal and uranium resources are adequate for foreseeable energy needs, major expansion of both uranium and coal production will be required because neither of these fuels alone can supply future energy requirements. Additionally, because of the time lag between initial extraction and actual use 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-fired 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 and the Carter administration have 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 from present levels [approximately 590 x 10^6 t (650 x 10^6 tons) per year] to approximately 1.1 x 10^9 t (1.2 x 10^9 tons) by 1985.[4,5] The major expansion of coal production will likely be in the west [from approximately 83 x 10^6 t (92 x 10^6 tons) in 1974 to about 345 x 10^6 t (380 x 10^6 tons) in 1985] 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 to those for coal because of the much higher energy content of uranium fuel. Approximately 227 t (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 t (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, and domestic production capabilities

The need for uranium in commercial reactors in the United States depends on two factors:

1. Installed nuclear reactor capacity. Estimates presented in *Additions to Generating Capacity 1979-1988 for the Contiguous United States* indicate that 110,000 MWe of nuclear generating capacity will be added to present capacity and will supply 22% of the total electrical energy consumed by 1988.[6] This recent forecast of nuclear capacity requirements is lower than some previous projections because of recent drops in the demand for electricity, new regulatory requirements, and increased nuclear power plant construction costs. 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 12.5%). New fossil fuel plants will provide 50.8%. The considerable uncertainty inherent in forecasting electricity demand, the unpredictable path of government nuclear-related policies and programs (breeder reactors, spent fuel reprocessing, and waste disposal), 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 uranium-235 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 uranium-235 remaining in the enrichment tails, the residual uranium from which some of the uranium-235 has been removed. Therefore, change in enrichment policy, such as changing the amount of uranium-235 left in the tailings or the required delivery time of U_3O_8 to the enrichment plant, will change U_3O_8 requirements.

A comparison between the quantity of U_3O_8 required to meet the projected reactor demand and the estimated domestic uranium available (Table 2.3 and Fig. 2.1) indicates that currently known reserves and probable resources should be adequate to support installed capacity through the year 2000 and the expected lifetime (40 years) of the reactors.

Table 2.3. Uranium (U_3O_8) resources in the United States

Cost category[a] ($/lb)	Known reserves (tons)	Potential resources (tons)		
		Probable[b]	Possible[c]	Speculative[c]
15	290,000	415,000	210,000	75,000
30	690,000	1,005,000	675,000	300,000
50	920,000	1,505,000	1,170,000	550,000

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

[b]Probable resources have not been drilled and sampled as extensively as known reserves.

[c]Possible and speculative resources have been estimated by inference from geologic evidence and limited sampling.

Source: U.S. Department of Energy, *Statistical Data of the Uranium Industry*, Report GJO-100(79), Washington, D.C., Jan. 1, 1979.

Table 2.3 presents estimates of quantities of uranium available at different recovery cost levels. Assuming reserves recoverable at a forward cost of production up to $66/kg ($30/lb) of U_3O_8, the Department of Energy (DOE) estimated that in January 1979 the total of all variously known categories of uranium resources was approximately 3.32×10^6 t (3.66×10^6 tons).[7] An estimated 1.7×10^6 t (1.9×10^6 tons) of uranium resources with forward costs up to $110/kg ($50/lb) of U_3O_8 consisted of known reserves; that is, drilling and sampling have established the existence of these deposits beyond reasonable doubt. Uranium recoverable as a by-product of phosphate fertilizer and copper production is estimated to be 109×10^3 t (120×10^3 tons) through the year 2000.[7] Approximately 4.7×10^5 t (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 t (4×10^9 tons) of U_3O_8 from seawater for an estimated cost of between $660/kg ($300/lb) and $680/kg ($750/lb).[8,9] 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; supplementary fuel was needed for the necessary conversion to ash. No uranium has been recovered as a by-product 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.[10]

The design capacity of the 20 conventional uranium mills operating in 1978 was about 39,800 t (43,810 tons) of ore per day. With an average ore grade of 0.13% and an average mill recovery rate of about 90.6% (the rate varied from 80 to 97% for individual mills), 15,260 t (16,820 tons) of U_3O_8 were produced, or 91% of possible production. The 18 mills that operated in 1977 produced approximately 13,000 t (14,500 tons) of U_3O_8, generating about 8.8×10^6 t (9.8×10^6 tons) of tailings.[11] This output represents about 75% of total capacity. [At 100% capacity, these mills could have produced about 17,750 t (19,500 tons) of uranium oxide.]

Although most uranium is produced via conventional acid or alkaline leaching processes, unconventional methods are used for some production. Such methods include solution mining, percolation leaching of ore in piles or vats, and uranium recovery from mine water, copper-dump leach liquor, or wet-process phosphoric acid effluents. Production of U_3O_8 by these methods totaled about 1515 t (1670 tons) in 1978 and was expected to reach about 5440 t (6000 tons) by 1982.[8]

The percentage of uranium production from solution mining was 3% in 1977 and increased slightly in 1978. The efficiency of recovery is difficult to ascertain, but it is estimated to be less than can be achieved via conventional mining and milling. Also, solution mining can be used only under specific geological conditions. Because of these uncertainties, the contribution of solution

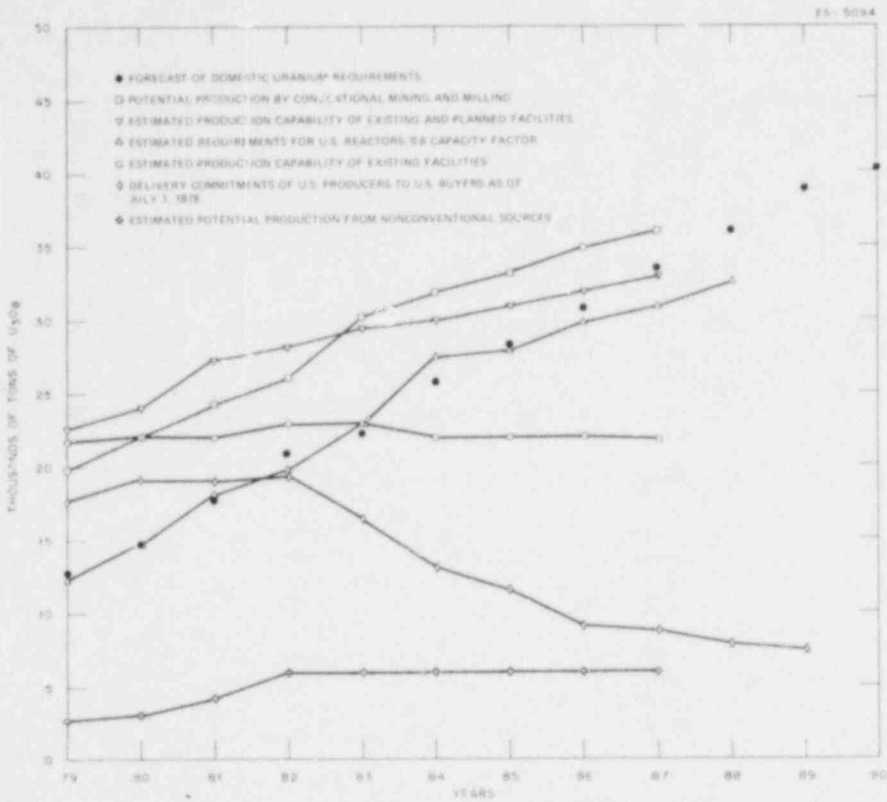

Fig. 2.1. Comparison of U_3O_8 required to meet projected reactor demand with estimated domestic uranium available. Source: U.S. Department of Energy, *Forecast of Domestic Uranium Requirements*, Report GJO-108(78), Grand Junction, Colo., Oct. 17-18, 1978, p. 15.

mining to total uranium production is difficult to predict. The DOE has projected that solution mining production will peak at 4000 t (4400 tons) of U_3O_8 per year by 1990 and hold at about 2500 to 3500 t (3000 to 4000 tons) per year through the year 2000.[11] The total production by this method is expected to be about 76,000 t (84,000 tons) through the year 2000.

Two sources from which by-product uranium is being recovered are copper-mining leach liquors and wet-process phosphoric acid. Of the two, phosphoric acid manufacture (for fertilizer) is receiving the most emphasis. Prediction of the amounts of U_3O_8 that will be recovered from phosphate production is extremely difficult, primarily because of the dependence of acid availability on the fertilizer markets.[12] However, demand for fertilizer in the world market should increase with demands for increased food production, and this increased demand, in turn, should result in increased phosphate mining in the United States. Currently, U_3O_8 recovery is about 180 t (200 tons) per year from phosphate operations but is predicted to reach 1800 t (2000 tons) per year by 1985 and about 7000 t (8000 tons) by 2000 for a total of about 73,000 t (81,000 tons) through the year 2000.[11]

During the last 15 years, the U.S. Bureau of Mines in Salt Lake City and several private companies have extensively tested recovery of uranium from copper-dump leachate, which frequently contains 1 to 12 parts of U_3O_8 per million parts of solution. Several commercial uranium recovery operation projects are in the planning stage. If all of these facilities are built with sufficient capacity to process all of the dump leachate from related copper mining activities, recovery of from 450 to 900 t (500 to 1000 tons) of U_3O_8 per year is expected.[12]

The extraction of uranium from product streams in copper milling is expected to contribute only fractionally to the future supply of U_3O_8.[12]

A DOE survey of U.S. uranium production, production capability, and marketing activity indicated that U.S. production of U_3O_8 for nuclear-powered electric generation plants should exceed annual requirements until 1982 without planned expansions. Contracted imports of U_3O_8 will exceed contracted exports by a considerable margin over the next few years. Through 1990, cumulative contracted imports of U_3O_8 are 33,000 t (36,400 tons), with approximately 50% of future contracted imports coming from Canadian sources, compared to cumulative exports of 14,050 t (15,500 tons) from 1966 to 1988. Some of the imported U_3O_8 may be reexported. Only 2360 t (2600 tons) of U.S. production from 1980 to 1988 is for export.

Supplies of U_3O_8 from the United States (including domestic and foreign inventories and contract commitments) will exceed DOE enrichment feed requirements until about 1983. Current estimates of production and demand are shown in Fig. 2.1. The data used by the staff to estimate U_3O_8 demand are shown in Tables 2.4 and 2.5. Table 2.6 lists the results.

2.2.1.5 Comparison of health effects of the uranium fuel cycle and the coal fuel cycle

Research conducted by the NRC[13] comparing the health effects associated with the coal fuel cycle (mining, processing, fuel transportation, power generation, and waste disposal) and 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 2.7).

Excess morbidity and injury rates for 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 nonfatal cases (Table 2.8).

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. 13, 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. 13, p. 13).

2.2.2 Solar, geothermal, and synthetic fuels

Estimates reported in the *National Energy Outlook*[5] 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 commercially 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 governmental incentives. A maximum of 6% of projected 1990 energy requirements is expected to be derived from solar, geothermal, and synthetic fuel resources combined.

Table 2.4. Nuclear generating capacity additions

Year	Pressurized-water reactor (MW)	Boiling-water reactor (MW)	Gas-cooled reactor (MW)	Total	Sum total[a]	Number of units	Generating capacity (GWe)[b]
1979	5,157	1,813	200	7,170	57,000	8	57
1980	5,731	3,753		9,484	66,484	10	61
1981	9,683	3,400		13,083	79,567	12	74
1982	10,043	1,525		11,618	91,185	12	87
1983	9,942	3,655		13,597	104,782	12	100
1984	7,417	9,829		17,246	122,028	16	112
1985	6,115	4,607		10,722	132,750	9	127
1986	6,945	3,504		10,449	143,199	9	141
1987	6,890	1,055		7,445	150,644	7	154
1988	6,604	2,238		8,842	159,486	8	167
Total	74,377	35,379	200	110,156		103	

[a] Includes capacity previously operating.

[b] U.S. Nuclear Regulatory Commission, *Draft Generic Environmental Impact Statement on Uranium Milling*, Report NUREG-0511, Washington, D.C., April 1979. There are 71 units listed at the end of 1978.

Source: U.S. Department of Energy, Economic Regulatory Administration, *Additions to Generating Capacity, 1979–1988, for the Contiguous United States*, Report DOE-ERA-0020/1 (rev. 1), October 1979 (for all data except last column—see footnote *b*).

Table 2.5. Specific energy comparison of boiling-water-reactor vs pressurized-water-reactor base data [megawatt-years (electric) per standard ton of U_3O_8]

Cycle	Boiling-water reactor	Pressurized-water reactor
1	1.30	1.63
2	2.90	2.78
3	2.79	2.97
4	2.82	3.06
5	3.41	3.46
6	2.92	3.16
7	4.32	3.33
8	3.07	3.05
9	2.50	3.53
10	3.17	2.74
Initial	1.30	1.63
Remaining cycle average	3.10	3.12

Source: Nuclear Assurance Corporation, *Uranium Utilization Experience in Light-Water Reactors*, Report COO-34012-1, prepared for the Department of Energy, 1979.

Table 2.6. Standard tons of U_3O_8 required annually for reactor fuel[a]

Year	For refueling	For initial cycle	Total
1979	9,613	2,735	12,350
1980	10,997	3,842	14,800
1981	12,826	5,134	18,000
1982	15,351	4,401	19,800
1983	17,592	5,347	22,900
1984	20,215	7,267	27,500
1985	23,542	4,377	27,900
1986	25,611	4,174	29,800
1987	27,627	3,023	30,700
1988	29,063	3,464	32,500
1989	30,769	Unknown	

[a] Calculated using a 0.6 capacity factor, one cycle per year, and data from Tables 2.4 and 2.5.

Table 2.7. Current energy source exce · 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[d] (U.S. population for nuclear effects, regional population for coal effects)	0.24–0.25[a,e]	0.14–0.46[b,f]	0.10[c,g]	0.64–4.6[h]	1.1–5.4
Coal fuel cycle					
Regional population	0.35–0.65[e]	0–7[f]	1.2[g]	13–110[h]	15–120
Ratio of coal to nuclear				(all nuclear) (with coal power)	32-260[i] 14-22

[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]U.S. population for nuclear effects; regional population for coal effects.

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

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

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

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

[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.

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. .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.[4] 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 2.8. 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[e]	1.7–4.1[f]	13–14[b]	1.3–5.3[g]	0.55[h]	17–24
	(U.S. population for nuclear effects; regional population for coal effects)				
Coal fuel cycle					
Regional population	20–70[f]	17–34	10–100[g]	10[h]	57–210
Ratio of coal to nuclear:				(all Nuclear)	4.1-15[i]
				(with coal power)	3.4-8.8

[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]U.S. population for nuclear effects; regional population for coal effects.

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

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

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

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

[j]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. (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 action proposed by the applicant along with alternative methods for recovering uranium from the available ore source and compares the potential environmental effects of the various recovery procedures.

2.3.1 Summary of the proposed activity

The applicant proposes to construct an in situ leach uranium mine and recovery plant in Fremont County, Wyoming, about 80 km (50 miles) by air south of Riverton and about 48 km (30 miles) by air west of Jeffrey City. The site consists of about 308 ha (761 acres) including all of Section 25, T27N, R97W, and part of Section 30, T27N, R96W (Fig. 2.2).

The proposed operation at the Bison Basin site will recover approximately 4.5×10^5 kg (1×10^6 lb) of U_3O_8 from about 16 ha (40 acres) over an estimated three-year period. Aquifer restoration and site reclamation are expected to require an additional two years.

A central processing plant using state-of-the-art extraction technology will recover the uranium from a sodium bicarbonate/carbonate lixiviant. Most of the resulting barren (uranium-depleted) lixiviant will be refortified with carbonate and oxidant and recycled to the ore zone. A small amount of barren lixiviant is withdrawn from circulation and impounded in an evaporation pond after treatment. Withdrawal from the production wells will be maintained at a rate slightly higher than injection as a means of preventing or limiting the spread of leach solution out of the ore zone.

Upon completing leaching activities, the lixiviant remaining in the ore zone will be removed, and and the water quality within the ore horizon will be restored to its original potential use (as close to baseline as reasonably achievable on a parameter by parameter basis). This restoration will be done by withdrawal of lixiviant or contaminated waters, treatment of the recovered solution to acceptable quality by chemical and physical means, and reinjection of the treated water into the ore zone. Pumping rates will be controlled during restorating ensure confinement of contaminated liquids to the mined zone.

Leaching and restoration activities will generate solid and liquid wastes, both of which will be impounded in ponds. The waste ponds will be lined with clays or polymeric materials to minimize seepage.

Reclamation procedures for surface areas of the site will meet applicable NRC, State, and local requirements. 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, using disposal techniques in accordance with NRC and/or State agency regulations that require isolation from the environment. All affected surface areas will be reclaimed.

2.3.2 Description of the ore body

2.3.2.1 Physical shape and area

The ore body proposed to be mined by the in situ solution mining method contains proved recoverable reserves of about 4.5×10^5 kg (1×10^6 lb) of uranium (as U_3O_8) within the 308-ha (761-acre) project area. Exploratory drilling, not yet completed, has indicated that additional minable reserves within the project area may exist. The presently proved ore body covers about 16 ha (40 acres) (Fig. 2.2). The average depth of the ore body below the land surface is about 116 m (380 ft).

The host rock is the basal sandstone of the Laney member of the Green River formation of Lower Eocene age and is designated as the "D" unit. This unit is confined above by a mudstone, having a persistent calcareous layer and below by a thick mudstone layer. The average thickness of the "D" sand is about 4.6 m (15 ft), and the ore thickness within the "D" sand averages about 1.9 m (6.3 ft). The average ore grade to be mined is approximately 0.07% U_3O_8.

2.3.2.2 Ore genesis

The "D" zone host sandstone is part of a larger system of sandstone channels that coalesce a few kilometers east of the project area. This large channel, 23 to 46 m (75 to 150 ft) thick, was a major drainage system that originated somewhere in the paleo Granite or Green Mountains and carried oxidizing uranium-charged waters into the Great Divide Basin.

The smaller sand channels, including the project host sand, are 1.5 to 9 m (5 to 30 ft) thick and dovetail into the intervening mudstones, which become increasingly thick to the west. The small channels contain both oxidized and reduced areas and are characterized by gray unaltered colors when reduced and yellow, orange, and red colors when oxidized. It is at the interface of these areas that uranium mineralization is found in geochemical roll-front deposits.

The principal reductants responsible for the precipitation of uranium from paleo stream and groundwaters were carbonaceous organic matter and metallic pyrite. These reductants are estimated to be 1.5 to 3% of the volume of the host formation.

ES-5097

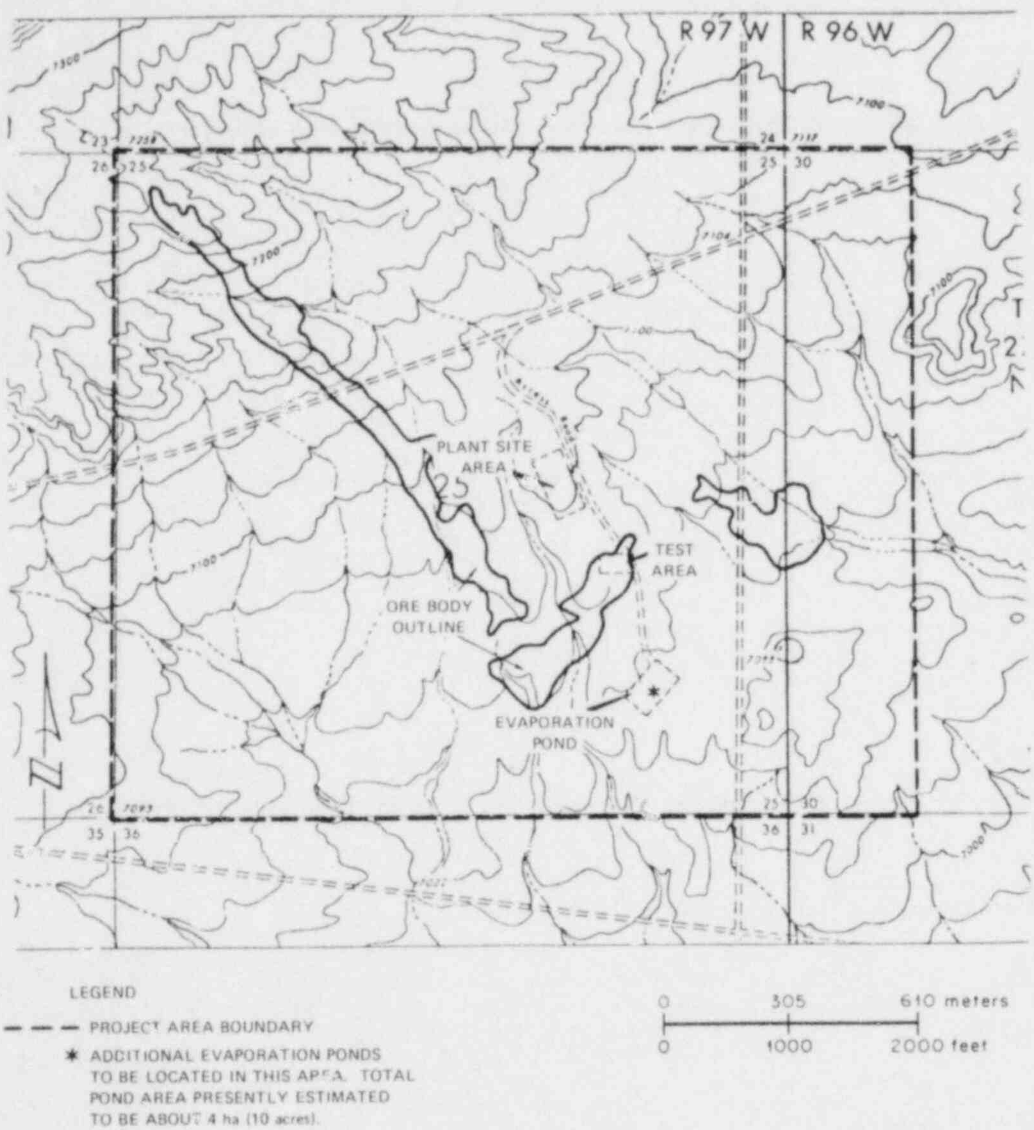

Fig. 2.2. Outline of the uranium ore body at the Bison Basin Project site. Source: ER, Fig. 2.1-4.

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 a number of 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 accounts for about 40% of the costs for producing uranium concentrates);[14] 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, such as solution mining, are in the developmental stage.

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[14] (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).[15] 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 yellow cake 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 x 10^6 t (13.8 x 10^6 tons) of uranium ore produced in the United States.[7] Surface-mined ores accounted for about 46% of the total annual uranium concentrate production, estimated at 16,770 t (18,490 tons) of U_3O_8.[7]

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.[16] 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 are not usually 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).[15] 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.[15] 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.[12,15,17] Compared with other commercially 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 deeper, 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.[7]

Because of varying ore body characteristics (size, shape, depth, and ore grade), many alternative underground mining techniques have evolved.[14] Simple adits or inclined entries driven into a canyon wall or sloping ground are sometimes used to access small ore deposits.[15] 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 430 m (1400 ft)].[15] Typically, the shaft is circular, compartmented, concrete lined, and up to 4.3 m (14 ft) in diameter.[16] 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 are used to support tunnels extending from the shaft.[15] 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.[16] 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 0.75 to 11 m^3/min (200 to 3000 gpm).[15] 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 miners' health.[15] 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 Unconventional mining methods

In situ leaching with acidic or alkaline lixiviants

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.[18] 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 (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 are generated which require controlled disposal; 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).

*Solution mining is a general term describing the extraction of minerals in liquid form. The solution may only contain 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 by-products, and other materials in the mineral deposit dissolved in the process.

3. The ore deposit must be extensive enough to ify 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 lay virtually impermeable, such as shales, siltstones, or mudstones. To select well loca and the inflow-effluent rates, the direction and velocity of the regional water flow should also be known.[15]

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.[15] 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).

Bacterial leaching

Bacterial leaching, an alternative solution mining method, has been successfully used to extract uranium from underground mines in Canada. This technique, which usually involves the flooding of worked-out and/or caved mine areas with water, is based on the leaching action of bacterially produced sulfuric acid and ferric sulfate.[15] Widespread use of bacterial leaching in the United States is not expected to occur for several reasons:[15]

1. Pyrite and sulfur must be present in the ore (most presently known ore reserves in the United States lack sufficient quantities of pyrite).

2. A relatively long time is required for efficient leaching.

3. The presence of calcium carbonate negates the leaching action by neutralizing the acid produced. Many U.S. ore reserves are highly alkaline.

Borehole hydraulic mining

Borehole hydraulic mining, another form of solution mining, uses pressurized water flow, injected via wells, to slurry the ore. The solid-liquid mixture is then brought to the surface and is processed in conventional uranium mills, giving rise to the same tailings management disposal problems as with underground or pit mining.

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, depending 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 s n to ensure sufficient contact with the uranium-dissolving reagent. Conventional crushing e ipment usually reduces the size of the ore particles to less than 1.9 cm (0.75 in.). Grindin is usually accomplished by rod or ball mill, the ore being ground to approximat ly 28 mesh fc acid leaching, or to approximately 200 mesh for alkaline leaching.[15] 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.[19]

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.[15] 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. 19). 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.[19] 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.[19] Heap leaching does not require a large capital expenditure for equipment, and manpower requirements are minimal.[15] 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.[19] 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.[19] A pile is abandoned 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 [averaging about 116 m (380 ft)], 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, the staff estimates that approximately 41 m^3 of overburden would have to be removed for each kilogram of yellow cake 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. 12). 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 yellow cake 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 and in situ bacterial leaching require the conventional mining of ore, the methods are eliminated as not economically feasible. Both hydraulic borehole and 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 Bison Basin 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 less severe than the impacts associated with conventional open-pit and underground uranium mining. The in situ leaching method has several 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 950 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 or otherwise restricting them from contaminating the surface and subsurface environment, the mine site can probably be returned to unrestricted use within a relatively short time.

6. 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 may prove to have a less severe impact on groundwater 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 to reduce its impact on the groundwater, such as stopping the entire operation and then pumping all wells. 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.

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 is to transfer these wastes to an active mill tailings disposal site.

2.3.6.2 Mill tailings disposal

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

Objectives to be attained in tailings disposal programs

A satisfactory tailings disposal program should 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 and resulting decay daughters),

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 of and covering the tailings.

Various tailings disposal programs that, when properly implemented, will meet the above objectives have been a topic of NRC study.[12]

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 the flexibility in plant location.

2.3.7.2 Mill siting alternatives

The following factors are among those considered in selecting and evaluating mill sites:

1. accessibility, but with limited public exposure (population doses);

2. proximity to producing mines and known ore bodies for reducing haulage costs and decreasing the impacts associated with ore transport;

3. geotechnical, meteorological, and hydrological factors. (1) direction and intensity of prevailing winds, (2) presence of mineral resources, (3) subsurface structural stability, (4) availability of tailings impoundment construction materials, (5) adequate quantity and quality of materials available for reclaiming the tailings disposal area and other disturbed surface areas, and (6) suitable surface hydrology characteristics;

4. topographical factors such as surface suitability for construction of facilities with minimum alteration of terrain and the size of the drainage area above the tailings impoundment;

5. proximity to natural and man-made areas that could be adversely affected by the construction, operation, and reclamation activities related to the project;

6. existence of unique habitats that might support protected, threatened, or endangered species; and

7. availability of housing and other services to employees.

The staff has determined that the most important factors to be considered during the site-selection process are those that ensure an acceptable tailings management program.

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 \$11 to \$22/kg (\$5 to \$10/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.[20] 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. 20, 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 Al, Fe, Cu, Zn, Zr, Se, As, V, and Mo). Excessive precipitation of calcium sulfate ($CaSO_4$) may also cause plugging of the leaching channels.[19] 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.[19]

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, 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).[20]

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 these techniques have not been applied to full-scale commercial operations, groundwater restoration technology is still in the developmental stage. Preliminary results based on the 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. 20, 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. 20, 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, prior to 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 is expected to continue to require the implementation of active restorative means, such as groundwater sweeping, 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 aquifer thickness x (porosity/100%). For all mining units of the proposed Bison Basin Project, the affected volume is approximately:

$$(16.2 \text{ ha}) \times (4.6 \text{ m average thickness}) \times (25\%) = 185{,}000 \text{ m}^3 ,$$

or

$$(40 \text{ acres}) \times (15 \text{ ft average thickness}) \times (25\%) = 150 \text{ acre-ft} .$$

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[20] or hydrogen ion from acid lixiviants[21]) 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 needed to restore the proposed mining units by groundwater sweeping. The relative scale of the proposed Bison Basin operation may be similar to that of the Exxon Highland Project, where it is estimated that seven pore volumes[22] will be sufficient to restore the ore zone after sodium carbonate leaching. During the pilot-scale restoration test at the Bison Basin site, just over eight pore volumes of clean water were circulated through the ore body to accomplish restoration.[23] Assuming that similar restoration behavior would occur with groundwater sweeping, the withdrawal of eight pore volumes would represent a consumptive use of about 1.5×10^6 m^3 (1200 acre-ft) of water during the life of the plant. If produced over a period of five years, this quantity of wastewater would require nearly 29 ha (70 acres) of evaporation ponds for disposal.

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 is drawn from a U.S. Bureau of Mines (USBM) study of groundwater restoration technology.[24]

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 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 (mid-1978 dollars) is $0.26 per 1000 liters ($0.99 per 1000 gal).[24]

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.[24] By adding multiple stages, salt removal in excess of 90% is possible[25] with a loss of less than 10% of the feedwater to the brine.[26] Although some redesign may be required, commercial ED equipment is available for application to restoration activities.[24] From the USBM study, the total cost of ED treatment is estimated to be $0.36 per 1000 liters ($1.35 per 1000 gal). However, for large-scale operations at high TDS levels, the cost advantage of RO technology vanishes.[25,26] 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 liters (1000 gal) of water. However, multistage flash evaporation or vapor recompression evaporation reduce 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 liters (90 to 420 kWh per 1000 gal).[25]

   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 liters (26 to 90 kWh per 1000 gal).[25]

   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.[27] 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/sec (5 x 10^6 gal/d) of acid mine drainage by multistage flash evaporation cited operating costs of $1.17 per 1000 liters ($4.42 per 1000 gal).[24] Total costs would exceed that figure. Vapor compression evaporation would also be expensive.[26,27] The staff considers evaporation energy intensive and uneconomic compared to 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.[24] 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.[28] Besides the recovered dissolved solids and contaminants, the regen-

eration 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 $0.79 per 1000 liters ($3.00 per 1000 gal).[24] 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.[24,25] 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.[24] Further development is necessary to define the merits of freeze separation.

   At this time only RO or ED is recommended by the staff for use in aquifer restoration.

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 ($CaSO_4$, $CaSO_3$, 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 As, Cd, Fe, Pb, Mn, Hg, Se, Si, Ag, Th, and Zn. Contaminants such a Cr, Cu, Mo, U, and V form soluble complexes or are otherwise soluble at high pH and may be only partially removed by lime precipitation.[20,29,30] 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[31] and vanadium[32] 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.[30]

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[20,24] as potentially effective reducing agents. Anaerobic bacteria may also be used to establish reducing conditions in an aquifer.[24] 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 (Na, Ca, Mg, SO_4, HCO_3, CO_3, Cl) are not significantly affected by this treatment.[20] 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.[21]

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 Bison Basin Project is of the sodium carbonate/bicarbonate type, ion adsorption by clays is not expected to affect restoration. The restoration of the research and development 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.

2.3.10 Details of the applicant's proposed operation

2.3.10.1 Well field

Well-field design and operation

Ogle Petroleum, Inc., proposes to employ a seven-spot pattern comprised of six injection wells surrounding one central recovery well. The distance between wells is presently estimated to be 15 m (50 ft), and the average production per recovery well will be from 49 to 65 m^3/d (9 to 12 gpm). The injection rates will vary with the hydrology and the geometrical configuration of the well field but will average about 33 m^3/d (6 gpm), having a probable range of from 22 to 38 m^3/d (4 to 7 gpm). Injection pressures are expected to range from 60 to 100 psi. These injection pressures are in the same range as other in situ mining operations in the State.[28,32] The staff estimates that a value of 0.63 psi/ft could initiate hydraulic fractures based on lithostatic pressure only. This figure represents a minimum value and is somewhat conservative. Actual pressures required for fracturing will exceed this value. However, the applicant will monitor injection wellhead pressures to assure that this minimum value is not greatly exceeded during production. Operational experience could cause Ogle Petroleum, Inc., to deviate from this basic seven-spot well-pattern design.

The seven wells are collectively termed a production cell. The production cells to be in production at any one time constitute a mining unit. Any isolated section of the ore body, regardless of size, may be referred to as a pod. During mining, recovery wells and injection wells may reverse functions to take advantage of the flow-path alterations and improved oxidation potential.

The first mining unit to be put into production will be an isolated pod in the southeastern part of the proved ore body, which includes the research and development project site (Figs. 2.3 and 2.4). Mining the first unit will take about one year.

The first mining unit is projected to have fewer wells than will the subsequent units. The first unit (Fig. 2.4) contains 90 recovery wells and 169 injection wells, or a total of 259 wells, and covers about 4.7 ha (11.6 acres). The pregnant leach solution pumping rate from the first mining unit is projected to be about 2.7×10^3 to 4.4×10^3 m^3/d (500 to 800 gpm), as compared with a planned flow rate of up to 6.5×10^3 m^3/d (1200 gpm) for subsequent mining units. The first mining unit embraces the 0.37-ha (0.93-acre) research and development tract. Some

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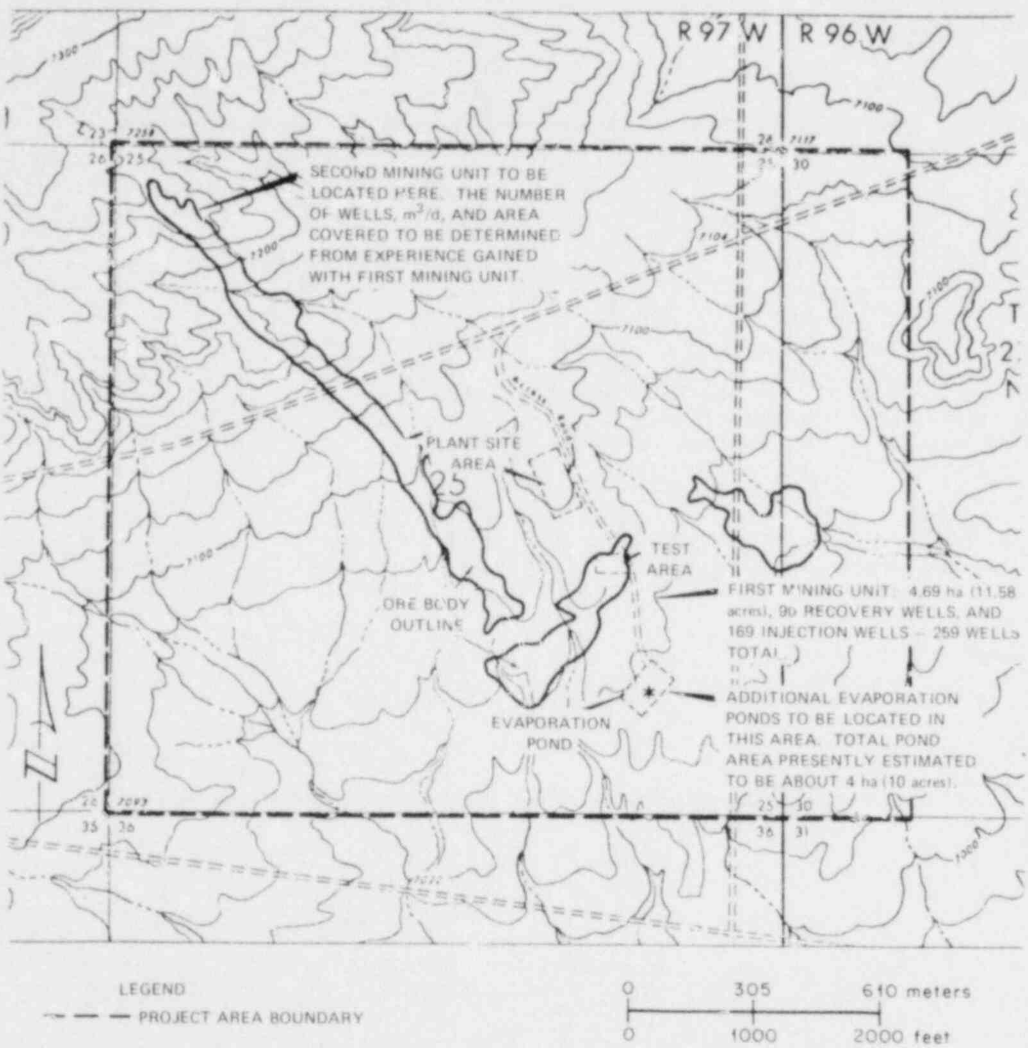

Fig. 2.3. Bison Basin Project mining plan. For a detailed view of first mining unit, see Fig. 2.4. Source: ER, Fig. 3.2-1.

minor alteration of the well-field pattern in this area will probably be made, depending on how much uranium is leached in the test area during the research and development operation.

After completion of primary production in the first mining unit, about one pore volume of formation water from the first unit will be pumped to the second mining unit. In this transfer the water may be routed through ion exchange columns to remove some of the residual mobilized uranium. During the transfer, lixiviant from the spent mining unit will be pumped into injection wells in the inner portion of the virgin mining unit. Simultaneously, groundwater will be drawn from the outer recovery wells of the virgin field and pumped into the outer injection wells of the spent mining unit. Water quality parameters (conductivity and uranium and sodium content) will be monitored in the virgin field. When the monitored parameters indicate the beginning of lixiviant breakthrough, the transfer will be terminated (Fig. 2.5) and aquifer solution mining will commence in the second mining unit. It is presently planned that this

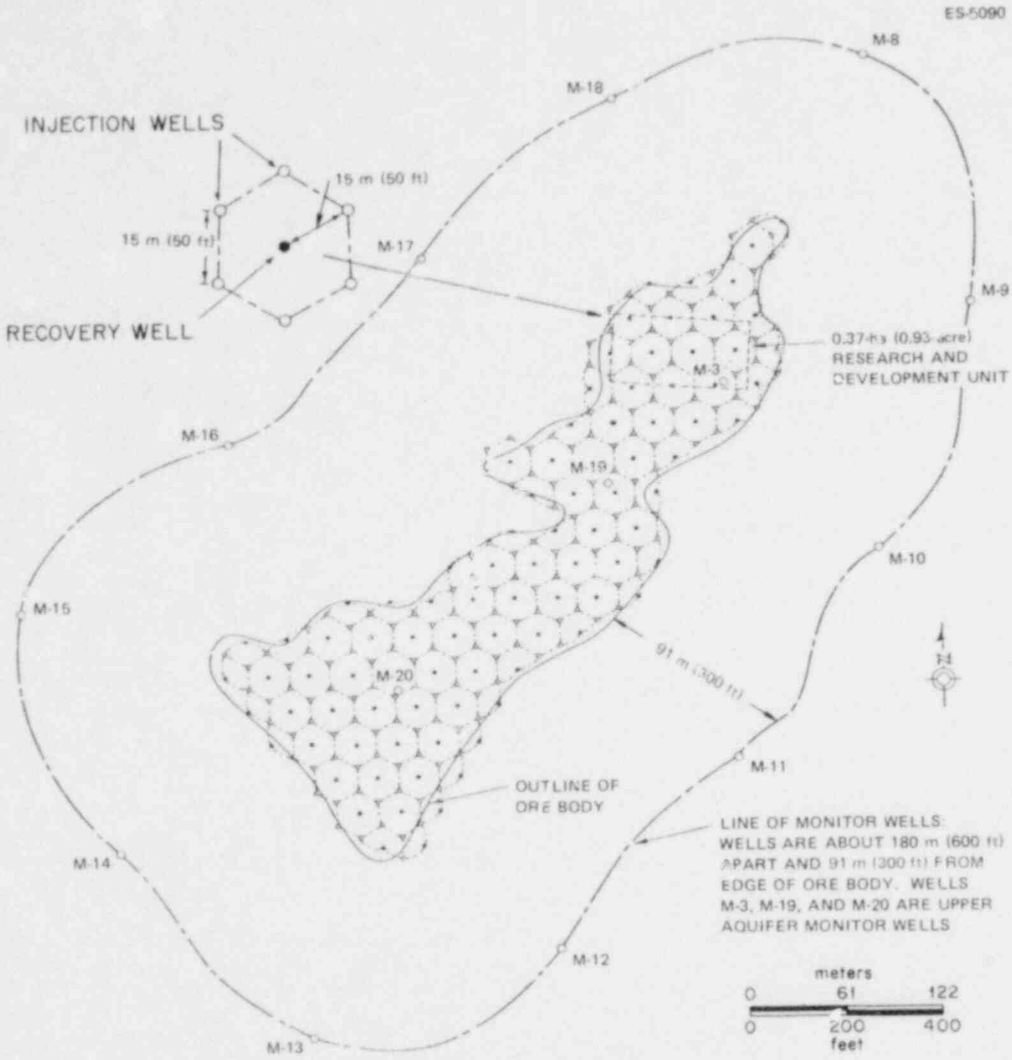

Fig. 2.4. Detailed view of first mining unit of the Bison Basin Project. Source: ER, Fig. 3.2-2.

water exchange or transfer between spent and virgin mining units will be utilized throughout the life of the project.

Although the total number of production and injection wells required to solution-mine the Bison Basin ore body will depend on local hydrologic conditions and estimates from results of the research and development operation, well requirements to mine the presently defined ore body [about 16 ha (40 acres)] are as follows:

Recovery wells	320
Injection wells	620
Total	940

In addition, drilling and completion of monitor wells to detect any possible excursions within the host sandstone formation have been proposed. Monitor wells are proposed to be located no more than 91 m (300 ft) from the edge of the ore body being mined and will be spaced not more

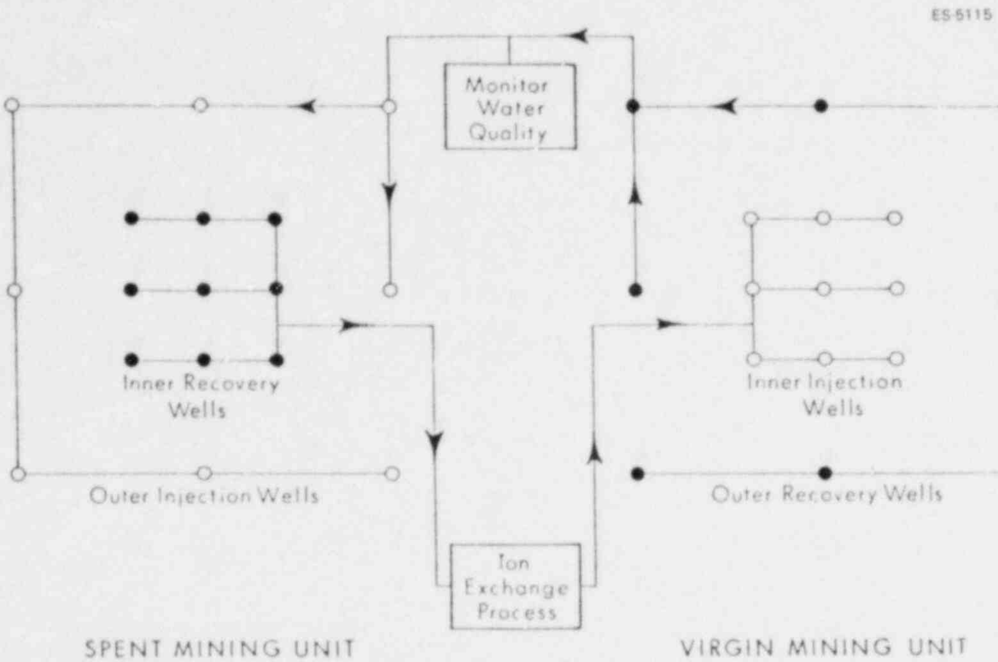

Fig. 2.5. Solution transfer plan. Source: ER, Fig. 3.2-3.

than 122 to 183 m (400 to 600 ft) apart. The exact number and location of monitor wells will be specified in the mining plan approved by the Wyoming Department of Environmental Quality.

Approximately 15 upper aquifer monitor wells will be completed within the mining area. Construction of monitor wells in the next aquifer below the formation to be mined is not planned at this time because of the impermeable characteristics and extent in depth of the lithology below the ore body.

Exploratory drilling has indicated that as much as 31 m (95 ft) of mudstone underlies the ore body. Two sandy intervals underlying the ore-body sands have also been penetrated. Because they are very sinuous, are laterally discontinuous, and vary greatly in thickness over short intervals, they probably represent abandoned stream channels. The staff agrees with the applicant that these sandy intervals do not merit monitoring. In addition, it has been determined that no aquifer exists for at least 79 m (260 ft) below the ore zone.

Well construction

Ogle Petroleum, Inc., uses a method of drilling and completing injection and recovery wells which was very satisfactory during previous field operations. Both the injection and recovery wells are drilled and completed to the same specifications so that they can be interchanged. A schematic of a typical well completion is shown in Fig. 2.6.

Wells will first be drilled out from 11 to 13 cm (4.5 to 5 in.) in diameter to a depth of approximately 1.5 m (5 ft) above the "D" zone sandstone. By using 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 17.1 to 19.7 cm (6.75 to 7.75 in.) with a larger drilling bit.

After the larger diameter hole is finished, a 10- to 13-cm (4- to 5-in.) internal diameter casing will be emplaced in the hole. The casing will be constructed of polyvinylchloride or fiberglass materials and connected with either glue or mechanical 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.

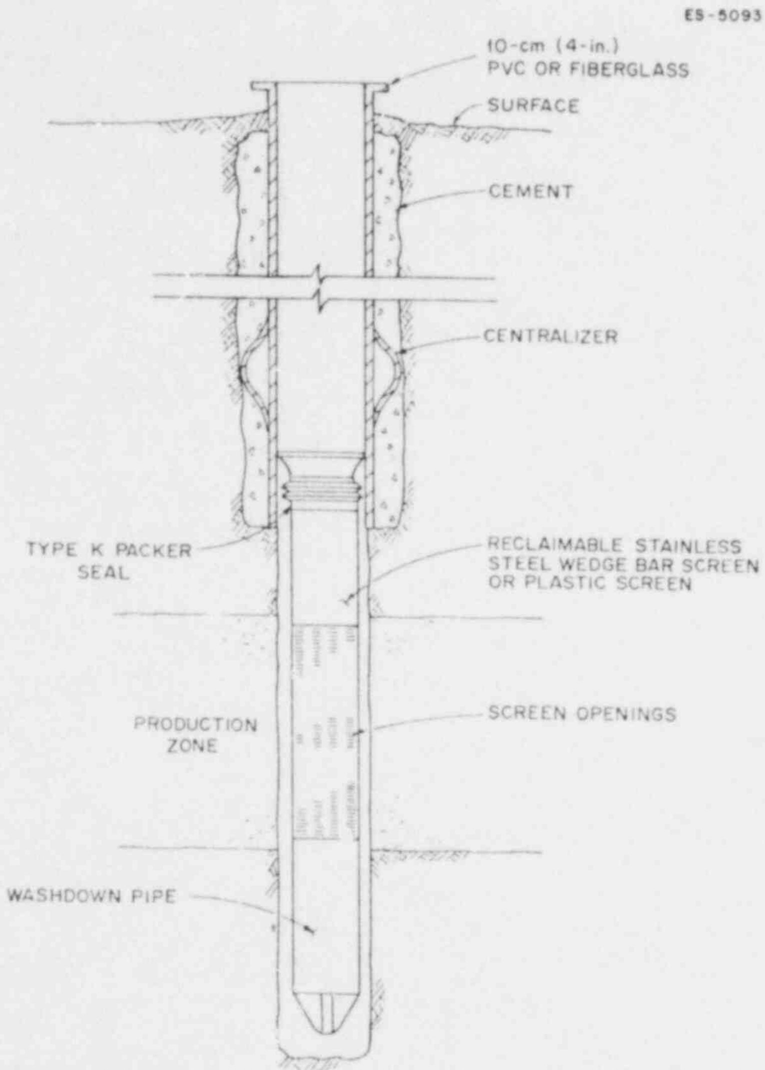

Fig. 2.6. Schematic of typical well completion. Source: ER, Fig. 3.2-4.

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 — enough to fill the entire annular area — will be pumped. The cement will be a light slurry, with bentonite added to stop the cement from settling. Calcium chloride will 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 styrofoam wash down 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 "D" zone host sandstone. The hole extension will be drilled with a nonclogging 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 5 to 7.6 cm (2 to 3 in.) in diameter and will have a packer that is compatible to 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 and clean up the ore body sandstone across from the screen openings.

The final well cleanup or completion will be accomplished by using the stringer rod in combination with washing and air bubbling cycles. The pressure will gradually be increased 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 shall packer test the well for integrity and report the results to the NRC. The details will be a condition of the license.

Well abandonment

Production, injection, and monitor wells will be properly abandoned by filling the casing with mud from the bottom of the hole to within about 3.7 m (12 ft) of the land surface. The casing from 3.7 m below the surface to within approximately 0.6 m (2 ft) of the surface will be filled with cement. The casing at a depth of 0.6 m below the land surface will be cut off and removed, and the hole will be backfilled to the surface.

2.3.10.2 Recovery plant

Construction and appearance

The proposed uranium recovery plant will be housed in an existing building located on the site. The building was originally constructed for use by research and development test operation performed by the applicant. The building is 52 m (170 ft) long by 12 m (38 ft) wide and 7 m (22 ft) high, except at the west end, which has a 12-m (39-ft) equipment bay. The building will be expanded to house tanks, generators, miscellaneous equipment, and a laboratory. The layout of the plant building and other existing and planned plant area facilities is given in Fig. 2.7.

In addition to the processing plant building, the 1.5-ha (3.6-acre) facility compound will contain quarters for the plant crew; areas for parking, equipment storage, and a sanitary-waste leach field; and storage tanks for process chemicals and solutions and plant fuels Berms will be established around the diesel fuel and process chemical and solution storage tanks.

Because the site is remote, electric utility service is not currently available. Therefore, plant electrical requirements will be met by onsite diesel power generators. Transmission lines will be extended from the facility compound to the individual mining units as required.

Uranium recovery process

The uranium recovery plant will use standard concentration and purification processes. From the results of the pilot test, the expected uranium concentration in the pregnant liquor will average about 82 ppm of U_3O_8 but will vary from as high as 300 ppm to lows of nearly zero. Ion exchange resins function acceptably under these conditions and will be used in the process. Recovery plants using resin ion exchange columns are organized into three sequential units: the leaching circuit, the elution/precipitation circuit, and product preparation area (Fig. 2.8). To simplify plant operation and eliminate atmospheric releases of uranium concentrates, the yellow cake will not be dried but will instead be shipped as a concentrated slurry. The leaching circuit includes the well field and the ore body, which lie outside the boundaries of the plant complex proper. The leaching circuit presents a large potential for environmental effects compared with the other plant circuits, which are isolated from the surroundings.

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

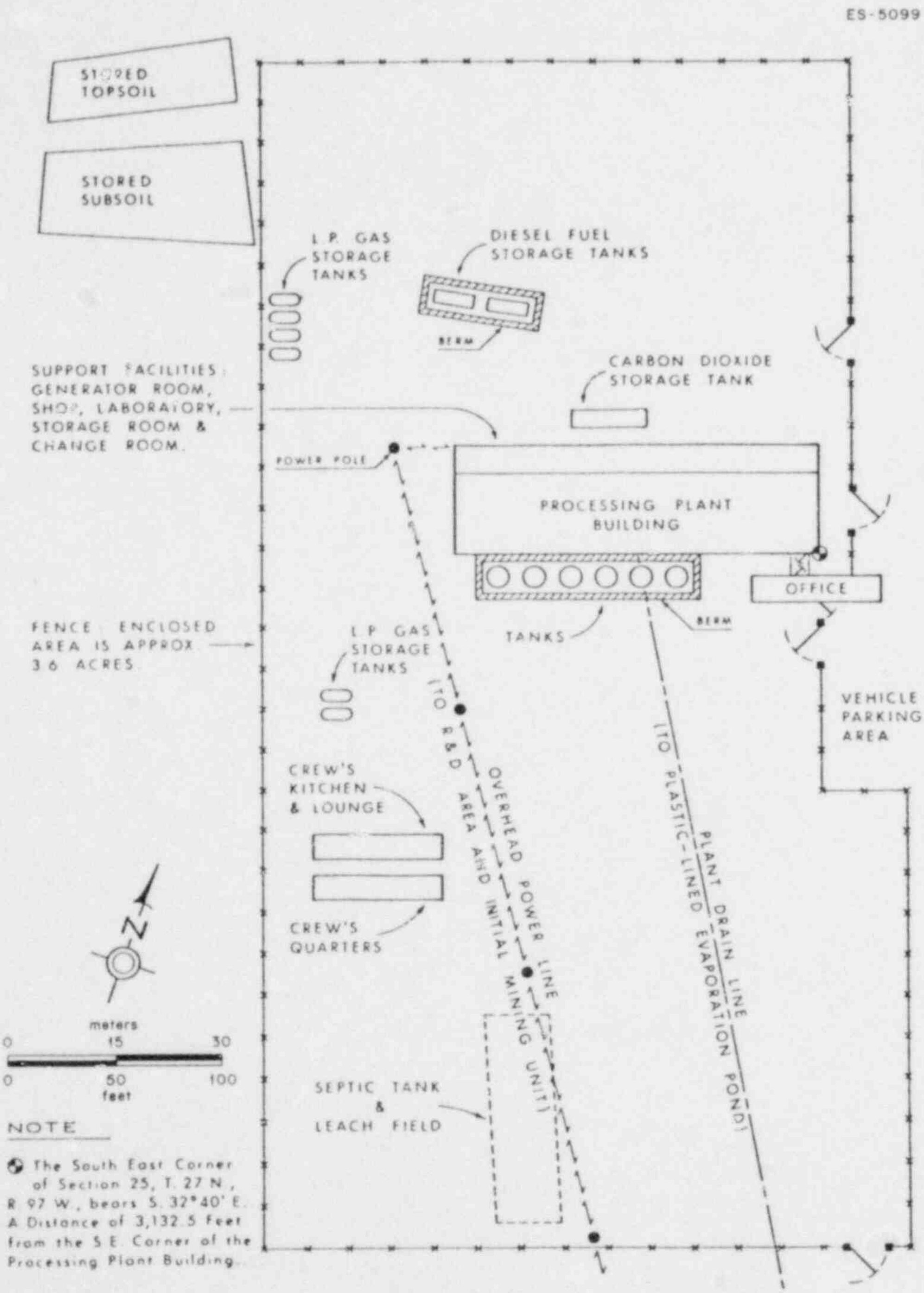

Fig. 2.7. Plant facilities layout. Source: ER, Fig. 3.3-1.

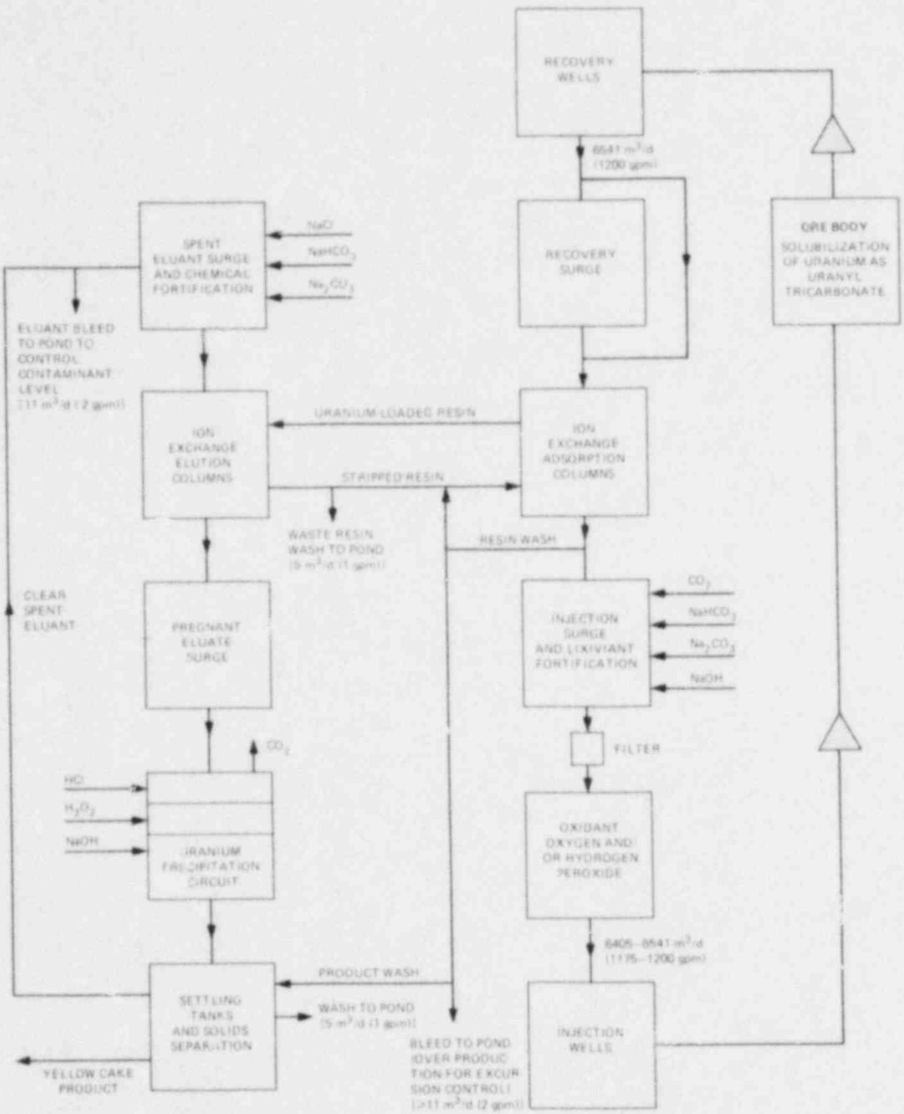

Fig. 2.8. Uranium recovery plant schematic. Source: ER, Fig. 3.3-2.

body. The Bison Basin Project will use a lixiviant consisting of sodium carbonate/bicarbonate (Na_2CO_3) and oxygen (or hydrogen peroxide, H_2O_2) in water. Although the lixiviant concentration has not been reported, the pilot test was operated with sodium bicarbonate concentrations apparently in the range of 1 to 3 g/liter. The commercial plant should operate in the same range. On injection into the ore zone, the dissolved oxygen reacts with the uranium minerals, oxidizing the uranium to its +6 oxidation state. The uranium complexes with carbonate to give a uranyl tricarbonate ion [$UO_2(CO_3)_3^{-4}$], which is soluble and easily recovered from the ore zone. As the ore minerals are disrupted by leaching, a portion of the radium content may also be dissolved. Depending on site conditions, contaminants such as As, Se, V, and Mo may also be oxidized and mobilized. Lesser quantities of Cu, Pb, Ba, F, Zn, Cd, and Hg may be mobilized (ref. 20, p. 61). However, the results of the pilot-scale test at this site do not show any major changes in trace element mobilization during leaching.[33]

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 production justifies continuation. For example, approximately 25 pore volumes of lixiviant were circulated through the pilot plant test cell before the uranium grade began to decline, signaling the exhaustion of the cell. At design capacity flow of 4548 liters/min (1200 gpm), approximately 200 injection and 100 production wells would be in operation. The lixiviant output of these wells would be collected and pumped to the central recovery plant in buried pipelines.

The uranium-bearing solution, now called pregnant lixiviant, is directed to the ion exchange columns or diverted to a surge tank for storage. As the solution passes through the columns, the ion exchange resin beads in the columns preferentially absorb the uranium (uranyl tricarbonate) from the solution and release the chloride ion back into the solution. The barren lixiviant leaving the column may contain less than 1 ppm uranium.

To control the spread of lixiviant from the ore zone, a leach circuit bleed of around 0.38 liters/s (6 gpm) is taken between the ion exchange columns and the injection surge tank. The bleed causes the well-field injection rate to fall below the production rate and generate a net flow of water towards the well field. Additional control is obtained by monitoring flow rates of individual injection and production wells.[34] A portion of the lixiviant bleed will be used for processing purposes in the recovery plant, but all of the bleed will ultimately be sent to the evaporation pond(s) for disposal.

The barren lixiviant entering the injection surge tank will be monitored for pH and bicarbonate levels. Carbon dioxide and/or sodium carbonate will be added as necessary to restore the lixiviant to its original strength. The solution is returned to the well field, where the oxidant (oxygen gas and/or hydrogen peroxide) is added just prior to reinjection of the lixiviant into the ore zone.

Elution circuit

The ion exchange resin will adsorb uranium from solution until it is exhausted or fully loaded with uranium. The elution circuit strips the uranium from the resin and prepares the resin for reuse in the adsorption circuit.

The Bison Basin Project will use moving bed ion exchange columns to allow continuous operation. The moving bed units will withdraw fully loaded resin from operation as freshly eluted resin is returned. The loaded resin is transported to the elution columns. Elution reverses the ion exchange reaction, forcing the uranium from the resin and replenishing the resin with chloride ion. Upon removal from the elution circuit, the eluted resin is rinsed and then returned to the ion exchange columns. The rinse solution is discharged to the evaporation pond.

The solution leaving the elution column contains uranium (as uranyl tricarbonate ion), sodium chloride, sodium carbonate/bicarbonate, and contaminants such as vanadium, molybdenum, and sulfate. The eluate is acidified with hydrochloric acid to destroy the tricarbonate complex and drive off carbon dioxide after which the uranium is precipitated by the addition of hydrogen peroxide and sodium hydroxide. The yellow cake product settles out of the solution and is withdrawn to the product preparation area.

A portion of the spent eluate will be discharged to the evaporation ponds to control the concentration of contaminants such as SO_4, Cl^-, V, and Mo in the circuit.[34] The estimated flow of this stream is 7.6 liters/min (2 gpm) (ER, p. 208).

The remaining spent eluate passes to the spent eluate surge and chemical fortification tank. Makeup water (from lixiviant bleed), sodium chloride, sodium carbonate, and bicarbonate will be added to bring the eluant to the desired strength (1.5 *M* NaCl, 0.5 *M* $NaHCO_3$).[19] The fresh eluant is then ready for recycle to the elution column.

Product preparation area

The yellow cake (precipitated uranium) 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 yellow cake drying will be eliminated.

The yellow cake product from the Bison Basin Project will be shipped as a slurry (50% U_3O_8 by weight) in specially designed and licensed trailers.[35] Therefore, the yellow cake drying equipment employed in conventional product preparation operations will not be used at the Bison Basin recovery plant. The yellow cake slurry will be shipped to the Kerr-McGee Nuclear corporation hexafluoride processing plant in Gore, Oklahoma.

2.3.10.3 Proposed aquifer restoration program

Ogle Petroleum, Inc., will restore the well-field aquifer as part of a continuing operation during and after mining. The company proposes to accomplish restoration through a combination of groundwater sweeping and clean water circulation. The first step in restoration will consist of the transfer of about one pore volume from the mining unit last mined to the mining unit to be mined next and the simultaneous transfer of an equivalent amount of water in the opposite direction (Fig. 2.5). After transfer of the first pore volume, cycling of the groundwater through the surface purification unit will begin with the purified water fraction being reinjected into the aquifer undergoing restoration and the reject stream (brine) being transported to evaporation ponds.

The restoration of the 0.37-ha (0.93-acre) pilot-scale tract required the recirculation of eight pore volumes of treated water through the leached zone.[23] Commercial-scale restoration should proceed under similar conditions.

The applicant expects that the reverse osmosis treatment unit will have a water-recovery rate of 80 to 90%.[33] The capacity of the commercial reverse osmosis unit has been tentatively set at 627 m^3/d (115 gpm) but may be increased as necessary to speed the restoration of the aquifer. Final capacity determination will be made after the commercial restoration criteria are approved by the NRC and the State. Assuming a treatment rate of 627 m^3/d (115 gpm) and comparing the mining flowrate [6.5×10^3 m^3/d (1200 gpm)] and the number of pore volumes circulated for leaching (approximately 25) and for restoration (approximately 8). the staff conservatively estimates that the restoration operations on a mining unit will continue 3.3 times longer than the leaching operation. As operating experience accumulates and optimal procedures are devised or the reverse osmosis capacity is increased, it is likely that the restoration process may take considerably less time than is presently estimated.

Clean water recirculation will continue until restoration sampling indicates that the water quality in the affected aquifer returns to its premining potential use. Baseline monitoring of groundwater at the site indicated that with the exception of sulfate, total dissolved solids, and radium, the ore zone aquifer meets drinking water quality (Table 3.22). To preserve potential water use, restoration criteria will be as close to baseline as reasonably achievable on a parameter by parameter basis. The final specific restoration criteria must be approved by both the Wyoming Department of Environmental Quality and the NRC (see 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 Bison Basin Project. Because of the generally small scale of the operation, the magnitude of effluent emissions and waste generation will also be small, thus minimizing the offsite impacts resulting from the operation (Sect. 4). The following sections summarize the atmospheric emissions, liquid wastes, solid wastes, and proposed methods of control and management for each.

Atmospheric emissions

The principal nonradioactive atmospheric emissions from the Bison Bason Project will be suspended particulates and pollutants in the exhaust from vehicles and diesel-powered generators. Vehicular emissions result from both onsite operations and commuter traffic over the unsurfaced road between the site and Sweetwater Station, a distance of approximately 45 km (28 miles). Dust emissions from wind erosion and operations on the site are expected to be about

68 t (75 tons) per year.[34] These emissions will be minimized through prompt reclamation of affected areas and establishment of vegetative cover on soil stockpiles. Dust releases resulting from project-related traffic are estimated to be 272 t (330 tons) per year. The exhaust emissions are summarized in Table 2.9.

Table 2.9. Vehicle- and equipment-related emissions for Bison Basin Project

Pollutant	Emissions from vehicle traffic [kg (lb)/year]	Emissions from equipment at site [kg (lb)/year]
Carbon monoxide	4,054 (8,937)	22,050 (48,611)
Hydrocarbons	547 (1,206)	3,518 (7,756)
Nitrogen oxides	698 (1,538)	88,634 (195,405)
Sulfur oxides	49 (109)	9,444 (20,820)
Particulates[a]	68 (151)	9,456 (20,847)

[a] Represents exhaust and tire-wear emissions only.

Source: Ogle Petroleum, Inc., "Responses to U.S. Nuclear Regulatory Commission Questions Dated November 26, 1979," Docket No. 40-8745, Dec. 7, 1979, Response No. 29.

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 surge tanks or the ion exchange columns. Based on the baseline concentration of 80,000 pCi of radon-222 per liter and a maximum flow of 83 liters/s (1315 gpm: 1200 gpm leach circuit flow and 115 gpm restoration flow), the radon release per plant operating year is estimated to be 209 Ci/year (ER, p. 222).

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 Bison Basin Project is presented in Fig. 2.9.

The processing plant bleed stream will have an estimated flow of 33 m^3/d (6 gpm). This figure includes resin wash water [5.5 m^3/d (1 gpm)], eluant bleed [11 m^3/d (2 gpm)], yellow cake wash water [5.5 m^3/d (1 gpm)], and an additional lixiviant bleed [11 m^3/d (2 gpm)]. Because all process water is drawn from the leaching circuit, the waste stream will bear essentially similar trace element loadings as does the lixiviant, except for contaminants that are concentrated by ion exchange into the eluant. The expected composition of the processing plant bleed is given in Table 2.10. Occasionally, additional liquid wastes will be generated by equipment wash down and plant housekeeping activities. This water will originate from the domestic water supply. The average flow from this source will be less than 5.5 m^3/d (1 gpm).

Restoration waste brine will be produced by the reverse osmosis unit. The estimated flow (ER, p. 212) is 93.2 m^3/d (17.1 gpm). The composition of the waste brine is listed in Table 2.10.

The periodic acid cleaning of wells will generate liquid wastes. Cleaning will be accomplished by the injection of 38 liters (10 gal) of concentrated hydrochloric acid to dissolve scale-forming constituents (Ca, Fe, Si, SO_4, CO_3, etc.). Air lifting to clear the well screens will follow, and the solution recovered during air lifting will be sent to the evaporation ponds. Because the interval between cleanings will be a month or more, this activity is not expected to increase significantly the waste flow to the evaporation pond.

The processing plant bleed, restoration waste brine, and well-cleaning wastes will be impounded in evaporation ponds to prevent liquid discharge to surface-water or shallow groundwater systems. The evaporation area required to accommodate the total wastewater production of 43.12 x 10^3 m^3

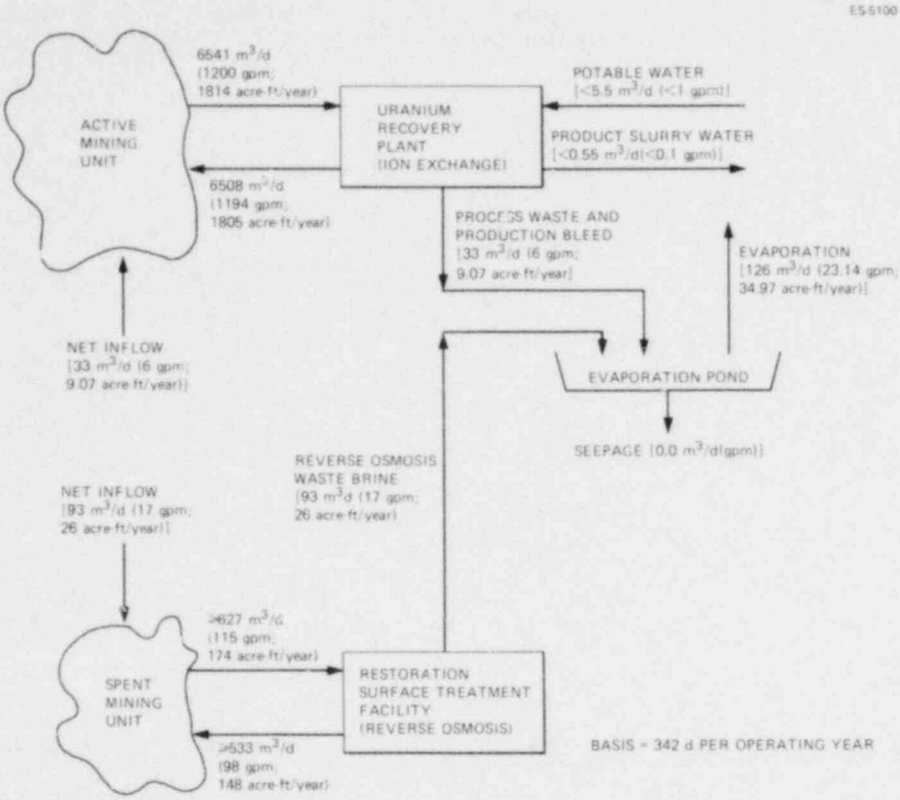

Fig. 2.9. Water balance for the Bison Basin Project.

(34.97 acre-ft) per year less the reservoir evaporation rate of 1.1 m (42 in.) per year is about 4 ha (10 acres). Additional evaporation ponds will be constructed adjacent to the existing evaporation pond (Fig. 2.10).

The engineering design and method of evaporation pond construction will be similar to that of the pond built for the research and development project (Fig. 2.11). The ponds will be lined with 20- to 30-mil chlorinated polyethylene liner reinforced with dacron or an equivalent. Each pond will have 0.6 m (2 ft) of freeboard. The ponds will not be located in or across drainages, and there will be no surface discharge from them.

The pond monitoring system will consist of leak detection systems and a set of monitor wells completed in the shallow aquifer underlying the ponds. The leak detection system will consist of a network of perforated pipe located beneath the liner in a sand and gravel filter bed. The perforated pipe will be connected to a standpipe located at the low point in the system. The standpipes from each pond will be checked every two weeks for the presence of liquid. If liquid is present, it will be analyzed to determine from its composition if liner failure has occurred. If failure is confirmed, the liquid in the pond will be pumped to adjacent ponds and the damaged liner section will be repaired. The details of leak detection will be approved by the staff and be a condition of the license.

The monitor wells will be completed in the unconfined 1.0- to 1.3-m-thick (3- to 4-ft) aquifer underlying the pond area at a depth of 16.2 to 16.5 m (53 to 54 ft). The wells will be located down gradient (with respect to the groundwater flow) from the ponds (Fig. 2.11). These wells will be sampled quarterly to detect seepage and contamination from the ponds. If contamination is found, the remedial actions outlined above will be utilized.

Table 2.10. Constituent concentrations of Bison Basin Project liquid waste streams from sample taken on July 6, 1979

All values are in mg/liter unless otherwise indicated

Constituent	Production plant bleed[a]	Restoration waste brine[b]
Flow rate, m^3/d (gpm)	33 (6)	93.43 (17.14)
pH, units	6.8	7
Specific conductivity, μmhos/cm	7400	9000
NH_4, as N	0.18	
NO_3, as N	170	
NO_2, as N	0.6	
HCO_3	891	400
CO_3	0	
Ca	189	75
Cl	1950	600
B	<1.0	
F	0.28	
Mg	57	
K	21	
Na	1648	1000
SO_4	470	4500
Al	1.29	
As	0.02	
Ba	<0.05	
Cd	<0.02	
Cr	<0.01	
Cu	0.06	
Fe	0.12	
Pb	<0.05	
Mn	10.08	
Hg	<0.001	
Ni	0.11	
Se	<0.01	
Zn	0.30	
Total dissolved solids	4966	
Mo	<0.05	
V	<0.05	
U	21.0	0–10
^{226}Ra, pCi/liter	240 ± 4.97	
^{230}Th, pCi/liter	2.38 ± 1.20	

[a]Data from Ogle Petroleum, Inc., Source Material License No. SUA-1336, Quarterly Report, Dec. 27, 1979, Docket No. 40-8693.

[b]Data from Ogle Petroleum, Inc., "Responses to U.S. Nuclear Regulatory Commission Questions Dated November 26, 1979," Docket No. 40-8745, Dec. 7, 1979, Response No. 32.

Sanitary wastes from the office and personnel facilities will be disposed of by a State-approved septic tank and leach field system, the location of which is shown in Fig. 2.9.

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 57 to 76 m^3 (75 to 100 yd^3) of these wastes will be generated during the first year of the project. Operation refuse will be generated at the rate of 15 to 23 m^3 (20 to 30 yd^3) per year during the mining and restoration phases of the project. Trash generated in the office facilities and personnel quarters and uncontaminated, worn process

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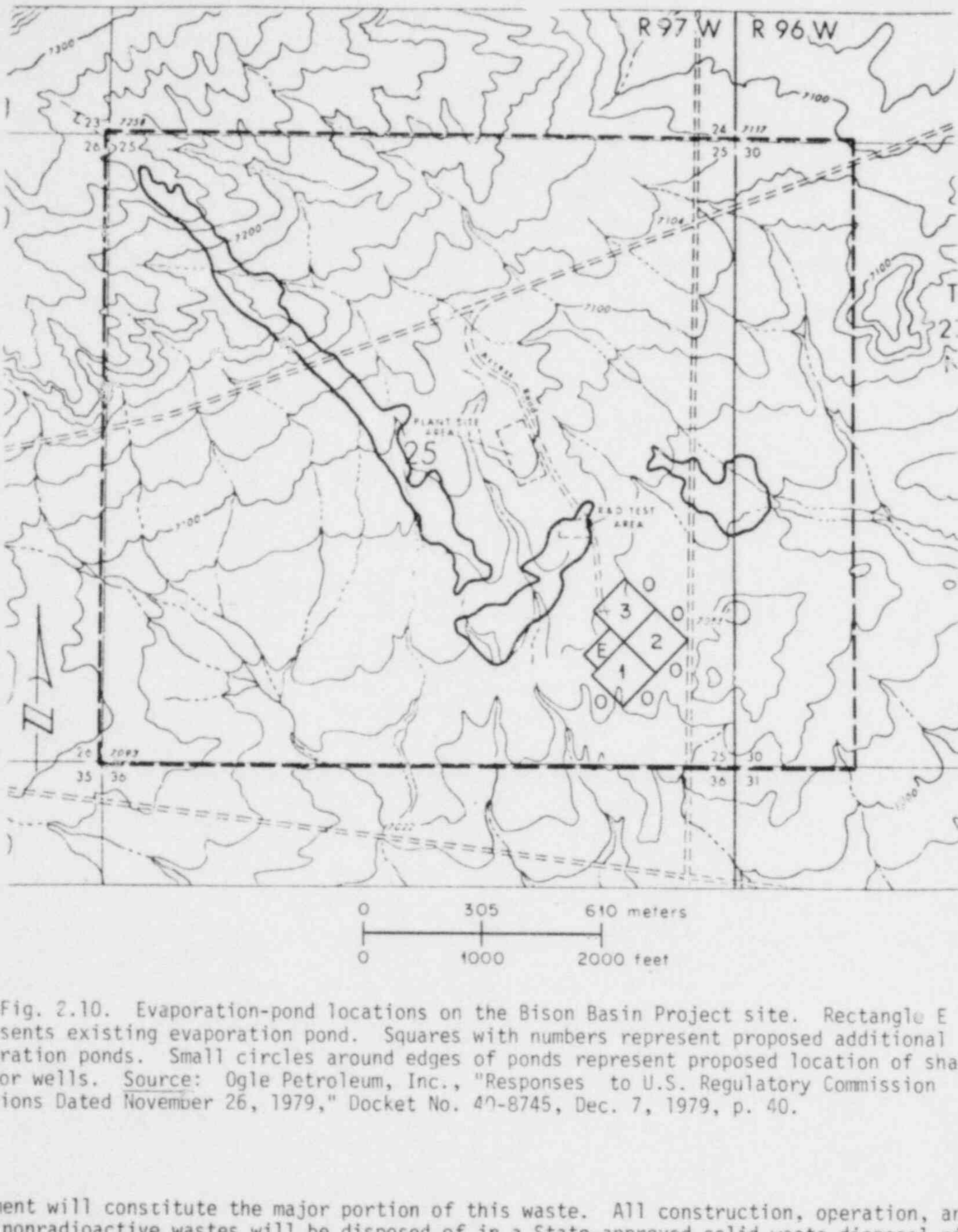

Fig. 2.10. Evaporation-pond locations on the Bison Basin Project site. Rectangle E represents existing evaporation pond. Squares with numbers represent proposed additional evaporation ponds. Small circles around edges of ponds represent proposed location of shallow monitor wells. Source: Ogle Petroleum, Inc., "Responses to U.S. Regulatory Commission Questions Dated November 26, 1979," Docket No. 40-8745, Dec. 7, 1979, p. 40.

equipment will constitute the major portion of this waste. All construction, operation, and other nonradioactive wastes will be disposed of in a State-approved solid waste disposal pit located within the permit area.

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 emplaced in the mud pits excavated in connection with well-drilling activities. Based on bore holes of 19.69-cm diam (7.75-in.) by 116-m depth (380-ft), the amount of drill cuttings per well will be 3.30 m^3 (4.32 yd^3). The construction of 990 wells will result in the production of nearly 3272 m^3 (4280 yd^3) of wastes. Less than 2.5% of the wastes would be radioactive materials (0.07% U_3O_8) from the ore zone. The

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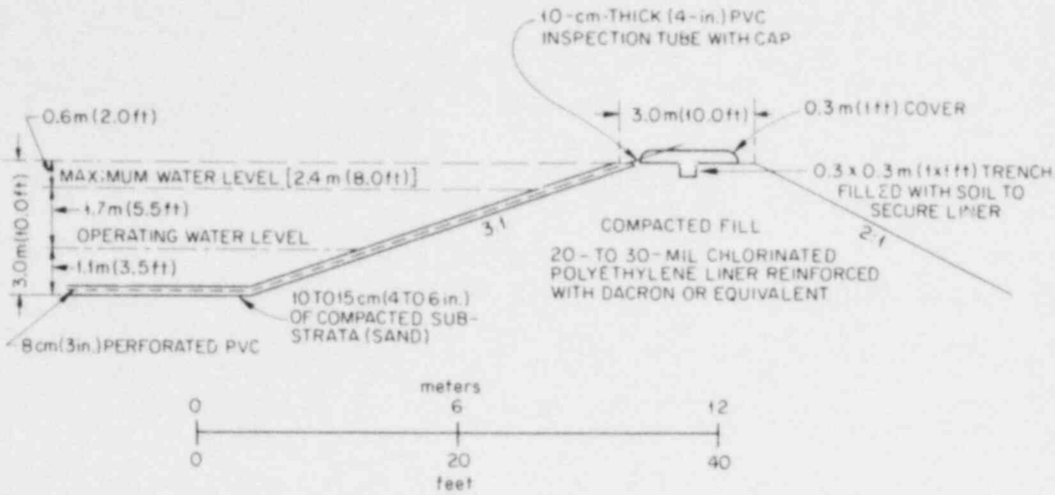

Fig. 2.11. Schematic of evaporation-pond design. Source: ER, Fig. 3.4-1.

subsequent backfilling and reclamation of the mud pits containing these wastes will ensure safe disposal.

Process solid wastes will include spent ion exchange resins, sediments removed from surge tanks and filters, and contaminated worn equipment. All of these low-level radioactive wastes will be placed in the evaporation ponds. The production rate of this waste is estimated to be 3 to 4.6 m^3 (4 to 6 yd^3) per year.[35]

The recovery plant bleed and the average restoration waste brine will have total dissolved solids contents of about 5000 mg/liter and 7000 mg/liter respectively. 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 2.9) will be present in the residue in a relatively leachable form. Based on the projected waste flowrates, soluble solid wastes will accumulate in the ponds at the rate of 279 t (308 tons) per year.[35]

Because of the chemical and radionuclide content of the wastes, environmental isolation is necessary. 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 to use onsite impoundments for final waste disposal.

After the liquid in the evaporation ponds has evaporated, the applicant proposes to bury the plastic liner and radioactive residue plus any other radioactive materials in a shallow pit to be excavated in the middle of each pond. The radioactive material will be covered by either 0.3 m (1 ft) of clay or a plastic liner and a minimum of 1.5 m (5 ft) of natural fill. The retaining dike formed by the material excavated during construction of the ponds will be pushed into the pond so that no depression remains to accumulate precipitation or runoff. This would not meet present criteria for disposal.

The NRC[22,32] and the States of Wyoming[22,32] and Texas[31] (where all previous commercial-scale uranium in situ leaching has taken place) have followed a policy of requiring the removal of in situ leaching radioactive solid wastes to a licensed low-level waste disposal site or a conventional uranium mill tailings pond. The merits of such offsite disposal are discussed in Sect. 2.3.6.1. The staff will require such disposal for solid wastes at the Bison Basin project.

2.3.10.5 Surface reclamation and decommissioning

In accordance with NRC and Wyoming Department of Environmental Quality regulations, Ogle Petroleum, Inc., plans to properly decommission the Bison Basin Project facilities and reclaim affected areas of the permit area to their original use, wildlife, and livestock grazing. A detailed decommissioning and reclamation plan will be submitted for NRC and Wyoming Department of Environmental Quality Land Quality Division approvals. The basic elements of the plan are described below.

Reclamation will occur in stages throughout the life of the project. Reclamation of each well field will commence soon after the completion of restoration monitoring. Production, injection, and monitor wells will be properly abandoned by filling the casing with mud from the bottom of the hole to within about 3.7 m (12 ft) of the land surface. The casing from 3.7 m below the surface to within approximately 0.6 m (2 ft) of the surface will be filled with cement. The casing at a depth of 0.6 m below the land surface will be cut off and removed, and the hole will be backfilled to the surface. All artificial features, such as covered mud pits and roads, will be graded to blend with natural land contours. Stockpiled topsoil will be replaced where needed and all affected areas properly prepared and seeded with an acceptable mix of plant species.

At completion of operations the processing plant and all appurtenant buildings, tanks, and equipment will be disassembled and trucked from the site. Items that are not salvageable, except radioactive materials, will be buried onsite in a pit at a location approved by the State of Wyoming. The floor of the pit will be above the groundwater table, and the buried material will be covered by a minimum of 1.5 m (5 ft) of mounded natural fill. Topsoil removed during excavation of the pit will be placed on top of the fill and seeded. Once the building and tank foundations have been removed, the stored topsoil will be redistributed over the disturbed areas.

Contrary to the applicant's proposal, all radioactive materials will be removed offsite in accordance with license conditions laid down by the NRC. A radiological survey and an environmental report will be prepared on the plant-decommissioning activity.

After grading, topsoil distribution, and soil preparation, the affected areas will be seeded in the same manner as were the well fields. However, the fence around the evaporation pond and recovery plant areas will not be removed until the completion of reclamation.

The applicant will secure bonding to ensure the availability of funds to complete restoration and reclamation. The staff recommends that the bond should be updated annually to account for current costs and project status factors.

2.3.11 Staff evaluation of the proposed operation and alternatives

The staff considers that the need for increased uranium production is demonstrated in Sect. 2.2 and that licensing action is in the public interest.

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.

Because the geological and hydraulic conditions at the site meet the criteria specified in Sect. 2.3.3.2, the staff concurs with the applicant's choice of in situ leaching to extract uranium at this site.

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.

The applicant's proposal for onsite disposal of evaporation pond waste would not meet present criteria. The staff will require these wastes to be removed to a licensed burial site.

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 AFFECTED ENVIRONMENT

3.1 CLIMATE

3.1.1 General influences

The climate of the site is dominated by the low- and high-pressure centers and frontal systems that migrate through the area during the year. The climate is semiarid, with a mean annual precipitation of 33 cm (13 in.).[1] More than one-third of the annual precipitation occurs during the months of April, May, and June in the form of wet snow and rain. Temperatures vary from summer highs near 38°C (100°F) to winter lows near -40°C (-40°F). The seasons are distinct with mild summers and harsh winters. Spring and fall are transitional seasons, with warm days and cold nights; snowfalls can be expected during both these seasons.[2]

3.1.2 Winds

The open, rolling topography surrounding the site allows generally free flow of winds through the area. Although wind data are available for Lander, Wyoming, about 64 km (40 miles) northwest of the site, the staff has determined that topographical effects cause them to be unrepresentative of the site. The Rock Springs, Wyoming, airport is located 97 km (60 miles) southwest of the site in similar topography. Apparent in the wind rose for the Rock Springs airport (Fig. 3.1) is the predominance of winds from the west, west-southwest, and southwest. Winds from these three components account for 47% of all hourly observations. The directional bias and intensity of the winds are most pronounced during the winter months. The average annual wind speed is 19 km/h (12 mph); however, the average speed from the three dominant components is 23 km/h (14 mph). Calm conditions [wind speeds less than 3 km/h (2 mph)] occur about 11% of the time annually with a minimum of 7% in the fall. Wind speeds of 48 to 64 km/h (30 to 40 mph) are common in the area, and speeds of 112 km/h (70 mph) or greater may accompany passing storms.

For dispersion calculations the staff has used meteorological data from Casper, Wyoming — about 187 km (116 miles) northeast of the site — which are considered by the staff to be applicable to the site and of better quality over a longer collection period than data from the Rock Springs airport.

The average annual wind speed for Casper is 21 km/h (13.1 mph), with about 45% of all hourly observation from the west, west-southwest, and southwest. Table 3.1 gives average wind speeds and directions for Casper.

3.1.3 Precipitation

Precipitation data from Lander, Wyoming, about 72 km (45 miles) north-northwest of the site, are believed by the staff to be most representative of the site, because of the distance to other National Weather Service precipitation-recording stations. The average annual precipitation in Lander is 34.8 cm (13.7 in.),[3] but relatively large variations in the monthly and seasonal totals occur (Table 3.2). The maximum annual precipitation recorded during the last 39 years was 52.5 cm (20.66 in.), which occurred in 1941.

Interpolation of maps of normal annual precipitation and annual average lake evaporation[4] indicate the average precipitation at the site to be between 30 and 41 cm (12 and 16 in.) per year and the average evaporation to be between 86 and 107 cm (34 and 42 in.) per year.

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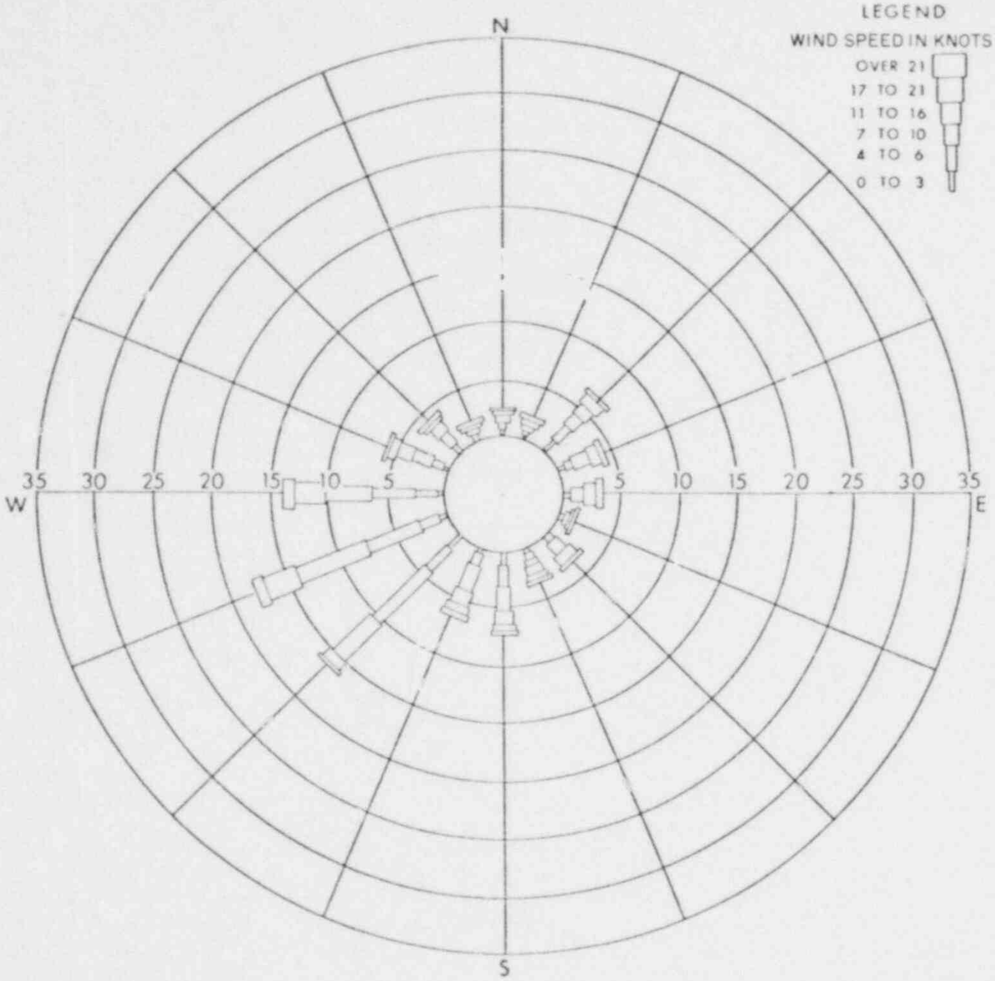


Fig. 3.1. Five-year (1950-1954) annual average wind rose for Rock Springs, Wyoming. Source: ER, Fig. 2.7-2.

3.1.4 Storms

Blizzard conditions are relatively common in the site area between October and May. A blizzard occurs when snowfall is associated with low temperatures and sustained winds greater than 48 km/h (30 mph). Although total snowfall amounts may be relatively small, strong winds cause extensive drifting and reduce daytime visibility to 0.4 km (0.25 mile) or less. Blizzard conditions lasting 1 d or longer may occur five or more times per year.

Hail and local flooding generally will occur in association with severe thunderstorms. Between late April and September, approximately 30 to 35 thunderstorms take place in the site area per year. Of these storms, two to four may be considered severe, with 1-d precipitation totaling more than 1.3 cm (0.5 in.) or winds gusting to greater than 80 km (50 mph). Hail will occur in association with these storms about three to five times per year. Tornado occurrence in the general area of the site is extremely rare.

3.2 AIR QUALITY

Sites in the vicinity of the proposed Ogle Petroleum mine at which air quality variables are measured include discrete-sampling stations at Riverton (80 km north), Boulder (120 km west-northwest), and Rock Springs (100 km southwest) and a remote continuous-sampling station

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

Direction	Speed (m/s)						
	0–1.5	1.6–3.2	3.3–5.1	5.2–8.2	8.3–10.8	>10.8	Total
N	0.4	1.5	1.4	0.8	0.3	0.1	4.5
NNE	0.4	1.9	2.2	2.1	0.6	0.1	7.3
NE	0.2	1.0	1.4	1.0	0.2	0.1	3.9
ENE	0.2	0.9	1.1	0.6	0.1	0.0	2.9
E	0.4	1.3	1.7	1.2	0.2	0.1	4.9
ESE	0.2	0.7	0.7	0.4	0.1	0.0	2.1
SE	0.2	0.6	0.5	0.2	0.0	0.0	1.5
SSE	0.2	0.7	0.4	0.1	0.0	0.0	1.4
S	0.2	0.7	0.4	0.1	0.0	0.0	1.7
SSW	0.2	0.9	1.8	4.5	4.3	2.4	14.1
SW	0.2	0.9	2.8	6.3	4.5	2.1	16.8
WSW	0.4	1.7	5.2	4.8	2.0	0.9	15.0
W	0.8	2.9	4.5	2.8	1.0	0.6	12.6
WNW	0.3	1.3	1.0	0.9	0.3	0.1	3.9
NW	0.2	1.1	1.0	0.5	0.2	0.0	3.0
NNW	0.4	1.8	1.3	0.6	0.2	0.1	4.5
All directions	4.9	19.9	27.4	27.1	14.1	6.6	

[a] A 2% calm has been distributed in the table.

Source: National Oceanic and Atmospheric Administration, *Monthly and Annual Wind Distribution by Pasquill Stability Classes for Casper, Wyoming, 1966–1975*, 1976.

Table 3.2. Mean and maximum monthly precipitation and snowfall for Lander, Wyoming

Month	Precipitation (cm)		Snowfall (cm)	
	Mean	Maximum	Mean	Maximum
January	1.2	4.2	17.2	67.3
February	1.6	5.5	33.2	111.2
March	3.0	7.6	40.1	125.7
April	6.0	13.8	38.8	167.6
May	6.5	15.3	17.5	86.1
June	4.9	17.4	10.6	46.7
July	1.5	5.3	0.0	0.0
August	1.1	4.5	0.0	0.0
September	2.6	11.8	2.0	59.9
October	3.1	9.1	14.7	101.3
November	2.2	5.2	30.4	82.5
December	1.1	[illegible].8	20.3	69.0

Source: National Oceanic and Atmospheric Administration, *Local Climatological Data, 1975, Lander, Wyoming*, 1976.

at Patrick Draw (70 km south). All sites provide data on total suspended particulates (TSP); SO_2 and NO_2 data are collected at Rock Springs and Patrick Draw; ozone is monitored at Patrick Draw.[5] There is no air quality monitoring on the project site.

Federal TSP standards are 75 μg/m³ for the annual geometric mean and 260 μg/m³ for the maximum 24-h concentration, which should occur no more than once per year. Wyoming TSP standards are 60 μg/m³ and 150 μg/m³ for the two respective time units. The highest TSP values occur in the summer and fall dry seasons, and lowest values occur during winter with snow cover.

Generally, TSP values in the study region are moderate. Only one station reported annual values in excess of State annual standards during 1978 (113 μg/m³ at Rock Springs, Fearn Station),[5] and none of the four stations exceeded Federal annual standards. One of the four locations reported maximum 24-h TSP values in excess of State and Federal standards. Rock Springs (Fearn Station) reported that 18 of 61 daily TSP values were in excess of the Wyoming standard, including one value in excess of the Federal standard. A second station at Rock Springs (Alder Station) reported that 4 of 60 samples exceeded the State 24-h standard. Annual average values range from a low of 9.4 μg/m³ at Boulder to 112.9 μg/m³ at Rock Springs (Fearn Station).

Federal SO_2 standards are 80 μg/m³ for the annual arithmetic mean and 365 μg/m³ for the maximum 24-h concentration, which should occur no more than once per year. Wyoming SO_2 standards are 60 μg/m³ and 260 μg/m³ for the two respective time units. Secondary standards are 0.02 parts per million (ppm) and 0.10 ppm for the two respective time units and 0.5 ppm maximum 3-h concentration, which should occur no more than once per year. No State or Federal SO_2 standards were exceeded at the two reporting stations during 1978.[5]

The Federal and State NO_2 standard is 100 μg/m³ for the annual arithmetic mean (0.05 ppm annual arithmetic mean), which was not exceeded at either reporting station during 1978. The State O_3 standard of 160 μg/m³ (0.08 ppm) was not exceeded at any reporting station during 1978.[5]

There are no Wyoming standards for CO or hydrocarbons. The Federal CO standard is 160 μg/m³ during a 3-h interval. The Federal hydrocarbon standards are 40,000 and 10,000 μg/m³ for 1-h and 8-h intervals respectively.

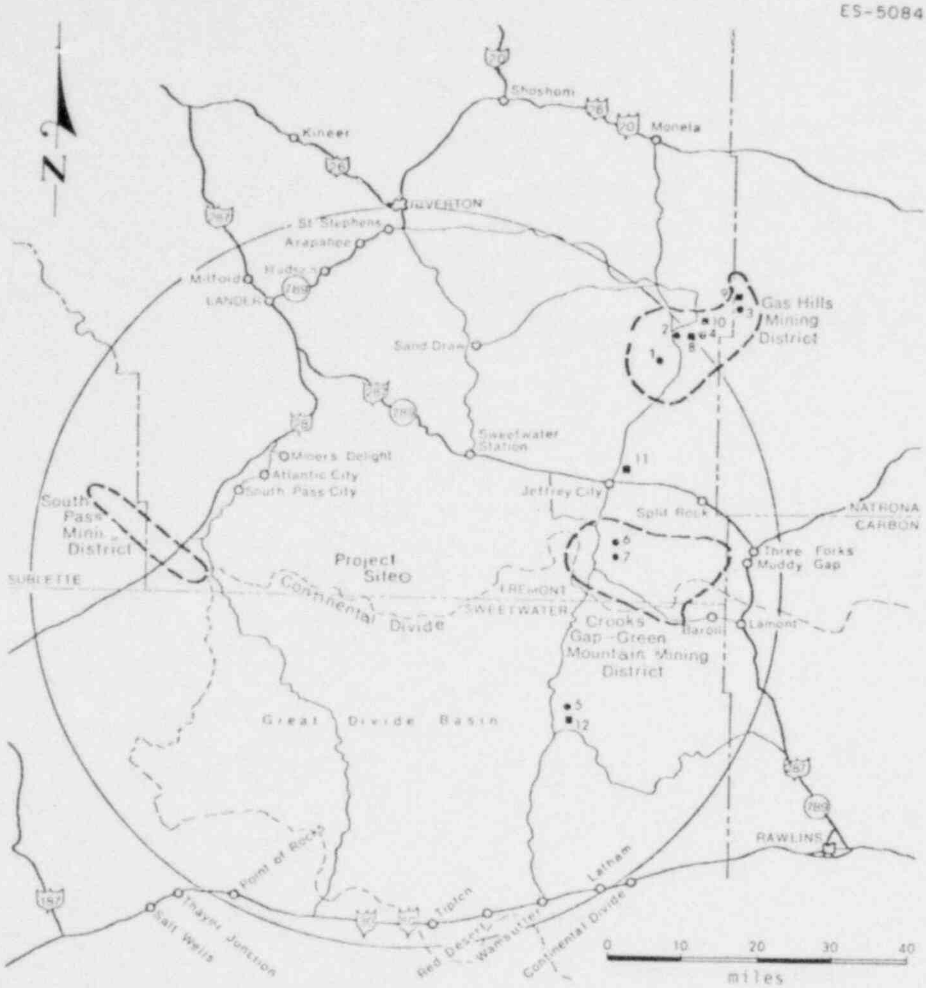
3.3 TOPOGRAPHY

The permit area is located in south-central Wyoming on the southeast flank of the Wind River uplift, about 6 km (4 miles) north of Cyclone Rim, which forms the topographic divide between the Great Divide Basin to the south and the drainage of West Alkali Creek immediately north. Streams in the area are ephemeral, running only for days or weeks at a time. Ephemeral lakes in closed drainage basins such as Grassy Lake on the east side of the site also occur. Grassy Lake contains water three to four months of the year.[6]

The project is situated on gently rolling terrain, with elevations normally between 2130 and 2200 m (6988 and 7218 ft) above sea level. The land slopes generally southeast at about 74 m/km in the immediate area of the proposed mining activities.

3.4 DEMOGRAPHY AND SOCIOECONOMIC PROFILE

The proposed Bison Basin project area is located in the southern portion of Fremont County, Wyoming, approximately — in air kilometers (miles) — 80 km (50 miles) south of Riverton, 48 km (30 miles) southwest of Jeffrey City, and about 72 km (45 miles) southeast of Lander (Fig. 3.2). The approximate highway distances from these urban areas to the project site are, respectively, Riverton, 133 km (83 miles); Lander, 96 km (60 miles); and Jeffrey City, 58 km (36 miles). If the unimproved section [about 32 km (20 miles)] of the road connecting Riverton to Sweetwater Station (county Highway 135, the unidentified roadway in Fig. 3.2) is upgraded to all-weather status, the highway distance from the site to Riverton would be reduced to about 96 km (60 miles) (George Hartman, Manager of Mining, Ogle Petroleum, Inc., personal communication, Nov. 1, 1979). Lander, though it is the county seat (population, ~7700), is about 20% smaller than Riverton (population, ~9200). Jeffrey City (population, ~2800) is unincorporated and is primarily a living area for employees of nearby mining and milling projects owned and operated by Western Nuclear, Inc. Therefore, practical considerations, such as the lack of utility-supplied electricity and water at the project site and the relative capabilities of the above communities to absorb in-migrants, indicate that the small number of project employees (~30) and their



LEGEND

● ACTIVE URANIUM MINES

1. FEDERAL-AMERICAN PARTNERS
   GAS HILLS MINE
2. UNION CARBIDE
   WEST GAS HILLS MINE
3. UNION CARBIDE
   EAST GAS HILLS MINES
4. PATHFINDER
   LUCKY Mc MINE
5. MINERALS EXPLORATION CO.
   SWEETWATER MINE
6. WESTERN NUCLEAR INC.
   CROOKS GAP MINES – CONGO, GOLDEN GOOSE II, SEISMIC, RESERVE
7. PATHFINDER
   BIG EAGLE MINE

■ ACTIVE URANIUM MILLS

8. FEDERAL-AMERICAN PARTNERS
9. UNION CARBIDE
10. PATHFINDER
11. WESTERN NUCLEAR INC.
12. MINERALS EXPLORATION (UNDER CONSTRUCTION)

Fig. 3.2. The Bison Basin Project site and the regional area. The circle represents the 80-air-kilometer (50-mile) radius from the site. Access to the site is by the Bison Basin Oil Field Road, which extends about 45 km (28 miles) southward from U.S. Highway 287 near Sweetwater Station. This road is not shown in the figure. Source: ER, Fig. 2.2.2.

families will locate in the Riverton and Lander areas. A few key or specialized personnel may occasionally commute from Ogle Petroleum's Casper office [highway distance, ∿233 km (145 miles)]. The socioeconomic descriptions and impact analyses have therefore focused on these communities and the surrounding regions in Fremont County.

3.4.1 Population

Historical population data for the State of Wyoming, Fremont County, and the urban areas of interest are summarized in Table 3.3. The site area is uninhabited: the nearest residence, that of an oil field caretaker, is about 11 air kilometers (7 miles) away. Sweetwater Station (population, ∿50 in the summer and ∿15 during the winter) is the nearest settlement, about 30 air kilometers (19 miles) and 45 highway kilometers (28 miles) north of the project site. Jeffrey City is the closest town. Significant population centers within an 80-km (50-mile) radius are indicated in Table 3.4.

Table 3.3. Historical population data for Wyoming, Fremont County, Lander, and Riverton

Variation between the two sets of values for 1977 reflect the dynamic economic conditions prevalent in the region around the proposed project site. This volatility increases the difficulty of reasonably forecasting population changes caused by increased mining and milling activities

	Total population				Population change (%)					
					Total			Annual		
	1970[a]	1977[a]	1977[b]	1978[b]	1970–1977[a]	1970–1977[b]	1970–1978[b]	1970–1977[a]	1970–1977[b]	1970–1978[b]
Wyoming	332,416			424,000			27.6			3.1
Fremont County	28,352	36,765	33,653		29.7	18.7		3.8	2.5	
Lander	7,125	[illegible]	7,667		16.5	7.6		2.2	1.0	
Riverton	7,995	10,150	9,234		27.0	15.5		3.5	2.1	

[a]Data from Fremont County Planning Commission, *Land Use Plan*, Nov. 9, 1978.

[b]Data from Catherine O'Brien, Population Dept., U.S. Bureau of the Census, Washington, D.C., Oct. 16, 1979, personal communication.

Table 3.4. Populations of significant townships within an 80-km (50-mile) radius of the proposed Bison Basin project[a]

Lander	Jeffrey City	Hudson	Riverton
7700	2800	506	9200

[a]July 1977 estimates.

Source: Catherine O'Brien, Population Dept., U.S. Bureau of the Census, Washington, D.C., Oct.16,1979, personal communication.

Table 3.5 summarizes population projections through 1990 for Fremont County, Lander, and Riverton. Because any significant influx or outflow of industry will impact population growth trends, forecasting population changes in areas with relatively small population bases — such as exists in the regions surrounding the proposed project site — has inherent pitfalls. For example, a major industry employing about 500 workers in the Lander area is iron mining. Air pollution control problems at an iron ore processing site near Salt Lake City, Utah, could conceivably lessen the demand for iron ore and result in either curtailment or shutdown of Lander's iron-mining operations. Should these events become a reality, a sizable decrease in employment would occur from secondary impacts, resulting in population out-migration. Conversely, sudden, significant population growth can occur with the startup of new industry. For example, because of increased energy resource expansion and development activities, the population of Jeffrey City grew from 1100 in early 1976 to 2800 in December 1977, a 155% increase (ER, p. 15).

Table 3.5. Projected populations for Fremont County, Lander, and Riverton

	Total population			Population change (%)	
				Total	Annual
	1980	1985	1990	1980–1990	1980–1990
Fremont County					
High[a]	39,650	47,950	56,250	42	4.2
Low[b]	40,600	45,640	47,860[c]	18[d]	2.3[d]
Lander urban area[a]	8,960	10,840	12,710	42	4.2
Lander (10-mile radius)[e]	3,260[f]	4,100[g]	4,950[h]	52[i]	5.2[i]
Riverton urban area[a]	10,940	12,230	15,520	42	4.2
Riverton urban area[j]	10,610	12,365		17[k]	3.4[k]
Riverton (10-mile radius)[e]	7,330[f]	9,200[g]	11,080[h]	51[i]	5.1[i]

[a]Data from Fremont County Planning Commission, *Land Use Plan*, Nov. 9, 1978.

[b]Data from State of Wyoming Department of Administration and Fiscal Control, Division of Research & Statistics, *Wyoming Population and Employment Forecast Report*, Cheyenne, June 1979.

[c]1988 forecast.

[d]Eight years, 1980–1988.

[e]Data from Fremont County Planning Department, February 1979. These population estimates are for the rural areas surrounding Lander and Riverton.

[f]1979 forecast.

[g]1984 forecast.

[h]1989 forecast.

[i]1979–1989.

[j]Data from William Peterson, Riverton City Administrator, "Population of Riverton" (unpublished paper), 1979.

[k]Five years: 1980–1985.

3.4.2 Housing

As is usual in low-population-density areas that are experiencing rapid development of energy resources, the housing of potential in-migrants is a critical issue in the Lander-Riverton area. The incremental housing needs for Fremont County shown in Table 3.6 were forecast by the staff and are based on population and housing statistics developed by the Fremont County Planning Commission.[7] About 5300 new housing units will be needed in Fremont County in 1990 to accommodate anticipated population increases. Because nearly 70% of the total county population lives within 16-km (10-mile) radii of Lander and Riverton, the majority of the new housing units will be required in those areas. Also, because Riverton has commercial airline service, has more inclusive retail services, and is geographically closer to energy resource development areas (such as the Gas Hills mining and milling district), housing development in the Riverton area will probably proceed at a greater rate than in the Lander area.

Table 3.6. Additional housing unit requirements projected for Fremont County in 1990[a]

	Housing types			
	Single family	Multifamily	Mobile home	Total needs
Urban				
Existing preferences[b]	2688	243	491	3422
Projected preferences[c]	1958	527	1058	3543
Rural				
Existing preferences[b]	1385	126	253	1764
Projected preferences[c]	1009	272	545	1826
Fremont County				
Existing preferences[b]				5186
Projected preferences[c]				5369

[a]These statistics are based on housing preferences, on housing usage data (e.g., average persons in housing units), and on predicted "probable" population expansions from 1980 to 1990. The population of Fremont County is expected to increase by about 16,597: 10,953 in urban areas and 5644 in rural areas. Sample calculations are illustrated on pp. 59 and 60 of the source listed below.

[b]Based on existing housing unit preference trends, that is, based on current usage patterns: 81% of the population of Fremont County lived in single-family dwellings, 6% in multifamily residences, and 13% in mobile homes.

[c]Based on projected housing unit type preference trends.

Source: Fremont County Planning Commission, *Land Use Plan*, Nov. 9, 1978.

Based on staff discussions with local officials, the status of and the barriers to housing development in the Riverton area are as follow.

1. A private firm is planning a 500-home development about 13 km (8 miles) north of Riverton. Because "strip" development will probably occur along the highway from Riverton to the proposed development and because the housing will be distantly located from Riverton — an established, incorporated city — county planners expect that a new elementary school and additional county school buses will be needed if the proposed residences are built (Ray Price, Assistant Fremont County Planner, personal communication, Nov. 1, 1979).

2. Considerable subdivision development activity has commenced in the immediate Riverton area during the past 18 months (mid-1978 to late 1979). Expectations are that 450 additional mobile homes and 1100 single and multifamily units will be constructed. Construction will proceed under city control and will be financed by a bond issue (William Peterson, Riverton City Administrator, personal communication, Nov. 1, 1979). The estimated cost of a new three-bedroom home [102 m^2 (1100 ft^2)], which includes an unfinished basement and one-car garage and which is located in an area of comparable homes, is about $58,000. The average monthly rent for a three-bedroom house varies from $300 to $425.[8]

3. Riverton has an immediate need for expanded sewage treatment facilities: the current plant is 20 years old and has a 5680-m^3/d (1.5×10^6 gpd) design capacity. It is currently operating at a peak load of 15,150 m^3/d (4.0×10^6 gpd) (William Peterson, Riverton City Administrator, personal communication, Nov. 1, 1979). The septic field systems being utilized for new residences are undesirable because of the relatively high water tables in the area.

3.4.3 Employment

Compared with national averages, unemployment rates in Wyoming and in Fremont County are very low.

1. The 2.3% unemployment rate recorded by Wyoming in September 1979 was the lowest in the nation — the seasonally adjusted national rate was 5.8%. The August 1979 unemployment rate of 2.4% (latest estimate available for comparison purposes) was the lowest in the nation for the fifth consecutive month.

2. The unemployment rate for Fremont County declined from 4.2% in September 1978 to 2.7% in September 1979. Fremont County's labor force increased at a 5.4% rate (16,479 to 17,372) over the same time period, indicating that the county provided employment for a sizable increase in the labor force while almost halving its unemployment rate.[9]

An overview of Wyoming's uranium mining employment is presented in Table 3.7. Uranium mining employment in Fremont County dramatically increased — nearly 40% per year — from 1975 to 1978. Employment forecasts by major industrial classifications for Fremont County (1980 and 1981) are summarized in Table 3.8.

Table 3.7. Uranium mining employment in Wyoming

	Annual average			1978		
	1975	1976	1977	First quarter	Second quarter	Third quarter
Carbon County	429	490	698	718	1013	1067
Converse County		449	629	722	743	747
Fremont County	892	1134	1636	1830	1968	2192
Natrona County	282	337	250	564	579	593
Wyoming	1604	2410	3213	3837	4306	4602

Source: John Moklar, Chief of Research and Analysis, Wyoming Employment Security Commission, Casper, June 1979, personal communication.

Table 3.8. Forecasts of employment by industrial classifications for Fremont County

	Percentage of work force	Number of persons employed	
		1980	1981
Agriculture	6	1,042	1,042
Mining	24	4,118	4,204
Construction	4	713	736
Manufacturing	3	472	472
Transportation	5	823	859
Trade	19	3,235	3,367
Finance	2	342	353
Service	13	2,242	2,300
Government	19	3,177	3,207
Others	5	941	941
County total	100	17,107	17,481
State total		222,969	229,440

Source: St[illegible] Wyoming Department of Administration and Fiscal Control, Division of Research and Statistics, *Wyoming Population and Employment Forecast Report*, Cheyenne, June 1979.

3.4.4 Economics

3.4.4.1 Regional economic base

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 come from outside the region's boundaries. The definition of an appropriate region is therefore very important in economic base analyses. For this study, Fremont County was chosen as the basic region. This is a judgmental decision of the staff and is based on the belief that the vast majority of the socioeconomic impacts related to the proposed project will occur in Fremont County — mostly in the Lander and Riverton areas.

The land area devoted to mining, crop production, and pasture compose only a very small fraction of the total land area in Fremont County. The vast majority of the county's acreage is classified as rangeland, with vegetation being limited to arid, high, desert types. Grazing is the primary use for these nonirrigated rangelands. Over half of this land is Federally owned and managed by either the Bureau of Land Management or the U.S. Forest Service.[10]

The mineral extraction industry and agriculture are by far the most important basic industries in Fremont County. Manufacturing activities, though increasing steadily in recent years, are very limited;[8] over 65% of the manufacturing firms employ fewer than eight people. Producers of lumber and wood products are the major manufacturing employers.

This section will focus on the two basic economic activities, mining and agriculture.

Mining

The importance of and the extraction of mineral resources — oil, natural gas, iron, and uranium — in Fremont County have substantially increased in recent years. Oil production has decreased, but natural gas, iron, and uranium extraction activities have increased.[7] Uranium mining and milling are expected to continue to increase as new mines in the Copper Mountain, Gas Hills, Green Mountain, and Red Desert regions either begin or expand production. It is estimated that uranium deposits with varying ore grades underlie at least 91,000 ha (220,000 acres) of surface area in Fremont County.[7] Major uranium mining and milling activities within an 80-km (50-mile) radius of the proposed project site are listed in Table 3.9. Oil reserves are estimated to be about 60 x 10^6 bbl, and it is anticipated that oil production will continue to decline slowly; natural gas production is expected to increase.[7] Iron production from an open-pit taconite mine near Atlantic City is expected to continue at or near current production levels for several years.[7]

Coal is no longer being mined in Fremont County. Although there are about 665 x 10^6 t (733 x 10^6 tons) of subbituminous grade coal in the county, most of it is not strippable; therefore, coal mining will probably not make a significant contribution to the county's economy in the near future (ER, p. 26).

Agriculture

Historically, agriculture has been a major component of the economy of Fremont County. In 1974, about 36,000 ha (89,000 acres) were utilized for crop production [out of about 87,000 ha (216,000 acres) of irrigated cropland and pasture]. The three leading crops, which accounted for about 92% of total production, were alfalfa, wild hay, and barley.[11] The 1975 livestock totals were about 117,000 cattle and 48,000 sheep.[12] Total agricultural sales for 1974 amounted to $20,079,000, about 5.6% of Wyoming's total agricultural sales of $361 million for that year. The amount of land used for agricultural production, yield per acre, quantity of crops grown, and the value of agricultural crops has been steadily increasing. Although the number of farms and ranches has been declining, their average size has been increasing.[7]

3.4.4.2 Income

Wyoming's per capita income for 1978 was $9096, a 22.3% increase over the 1977 per capita income of $7434. For 1978, Wyoming ranked second in the nation in per capita income (Alaska was first); in 1977, Wyoming ranked thirteenth.[13] Table 3.10 shows an eight-year trend for the State's per capita income and the effective buying power for that income. The growth rate in per capita

Table 3.9. Major nuclear fuel cycle facilities within an 80-km (50-mile) radius of the proposed Bison Basin Project

Facility	Company	Location	Approximate air distance from Bison Basin Project [km (miles)]
Gas Hills Mine and Mill	Federal-American partners	Gas Hills	80 (50)
East and West Gas Hills mines and Gas Hills Mill	Union Carbide Corporation	Gas Hills	80 (50)
Lucky Mc and Big Eagle mines and Lucky Mc Mill	Pathfinder Mines Corporation	Gas Hills	80 (50)
Sweetwater Mine and Mill (mill under construction)	Minerals Exploration Company	Red Desert region, northeastern Sweetwater County	48 (30)
Split Rock Mill	Western Nuclear, Inc.	Jeffrey City	56 (35)
Crooks Gap mines (Golden, Goose II, Congo, Seismic, Reserve)	Western Nuclear, Inc.	Crooks Gap district	48 (30)

Sources:

1. ER, Table 2.2-2.

2. U. S. Nuclear Regulatory Commission, *Draft Environmental Statement Related to the Minerals Exploration Company's Sweetwater Uranium Project, Sweetwater County, Wyoming,* Docket No. 40-8584, December 1977.

Table 3.10. Wyoming per capita personal income and effective buying power, 1970–1978

	Income ($)	Buying power[a] ($)
1970	3672	2981
1975	5942	4805
1976	6723	5242
1977	7434	5940
1978	9096	

[a] In essence, effective buying power is a measure of consumer purchasing power, that is, the worth of money determined by what it can buy at a given time in comparison with what it can buy at a specified previous time.

Sources:

1. Casper Area Chamber of Commerce, *Area Development Statistics,* Casper, Wyo., March 1979.

2. Employment Security Commission of Wyoming, Research and Analysis Section, vol. 16, no. 5, Casper, *Wyoming Labor Force Trends,* May 1979.

income from 1975 through 1978 was 17.7% per year. Buying power increased 11.8% per year from 1975 through 1977 and 14.2% per year from 1970 through 1977.

Table 3.11 gives recently reported weekly earnings in several industrial categories for the United States, Wyoming, and Fremont County. As can be seen from the table, mining is a relatively high-paying industry.

3.4.4.3 Finance and taxes

There are three banks and one savings and loan company in the Riverton area, with assets of $110 million and $117 million respectively. A second savings and loan company is nearing completion.

Assessed valuations and mill levy rates for Lander, Riverton, and Fremont County from 1969 to 1979 are summarized in Table 3.12. The 1978 revenues were $16.5 million for Fremont County, $7.5 million for Riverton, and $5.6 million for Lander.

3.4.4.4 Community services and public facilities

As in most relatively lightly populated regions where development of mineral resources is expanding rapidly, the two largest cities of Fremont County, Lander and Riverton, are experiencing, and will continue to experience, some difficulties in meeting community service requirements. It is difficult to forecast accurately needs for additional facilities. Although anticipation of a large industrial development may indicate need for expanded facilities and staff, the unanticipated phasing out of another source of employment may relax facility requirements.

Education

Fremont County School District No. 1 includes Lander, the county seat; District No. 25 includes Riverton. Table 3.13 summarizes statistics for these districts. Central Wyoming Junior College, with an enrollment of about 1800, is located in Riverton.

Medical

In the Riverton area are 19 physicians and surgeons, 11 dentists, and 4 optometrists. Memorial Hospital, located in Riverton, has 54 beds and an occupancy rate of 63%. Also located in the Riverton area are the Vision Clinic, Wind River Medical Clinic, Fremont Mental Health Clinic, and the Fremont Manor Nursing Home, which has 90 beds and 100% occupancy. The Bishop Randall Hospital in Lander has 56 beds and an occupancy rate of 84%. Lander has 39 physicians, a considerably larger number than would be expected in a community of that size. This large number of physicians chiefly results from a concentration of specialists in the Lander Medical Clinic, which has a clientele from a wide area. The region has attracted physicians who enjoy the outdoor activities, such as ranching, skiing, and horseback riding, which are available in the area (Dr. Mary Irvine, State Training School, Lander, Wyoming, personal communication, Dec. 5, 1979). There are also six dentists in the Lander area.

Fire and police protection

The Riverton police force numbers 29; the force is believed to need additional staffing and vehicles (William Peterson, Riverton City Administrator, Nov. 1, 1979). Areas outside the city limits are protected by the county sheriff's office, which has a staff of nine. Riverton's 47-member volunteer fire department serves an area within a 29-km (12-mile) radius. The Riverton fire underwriters' rating is 7. Lander has a volunteer fire department with a membership of 30.

Table 3.11. Average weekly earnings ($) by industry

	United States (Sept. 1979)	Wyoming (Sept. 1979)	Fremont County (Oct.–Dec. 1978)
Manufacturing	273	245	227
Mining	375	393	410
Construction	360	396	272
Transportation and public utilities	337	357	279
Trade	167	171	155
Finance, insurance, and real estate	194		204
Services	178		184

Source: Employment Security Commission of Wyoming, Research and Analysis Section, *Wyoming Labor Force Trends*, and *State and County Summary of Covered Employment and Total Payroll by Industry, Fourth Quarter 1978*, Casper, May 1979.

Table 3.12. Assessed valuations[a] and mill levies[b]

Area	Assessed valuation (millions of current dollars)											Mill levy (1979)
	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	
District 1, including Lander	37.6	36.9	39.1	38.4	39.4	41.7	45.5	50.0	58.3	66.2	68.0	65.6
Lander only	8.7	8.6	8.6	8.7	8.8	9.4	9.4	10.5	10.9	11.8	12.7	76.7
District 25, including Riverton	29.6	29.6	31.3	33.2	39.4	37.3	37.8	40.9	51.5	65.5	64.1	79.9
Riverton only	9.7	10.7	10.9	11.0	11.1	11.8	12.0	13.9	14.5	15.8	17.5	88.8
Total county	107.9	108.1	114.5	115.2	122.1	125.1	136.9	145.3	175.3	220.2	230.1	

[a]Assessed valuation is 25% of estimated 1967 cost.

[b]The mill levies are equivalent to tax rates in dollars per $1000 of assessed valuation.

Source: Loraine Ocenas, County Assessor, Fremont County Tax Assessor's Office, Nov. 1, 1979, personal communication.

Table 3.13. School district statistics

	District 25[a] (includes Riverton)	District 1[b] (includes Lander)
High schools	1	1
Junior high schools	1	1
Elementary schools	5	3
Pupil to teacher ratio	27:1	17:1
Annual expenditure per pupil, $	1572	2261
Enrollments		
High school	1698	789
Junior high school	749	319
Elementary school	769	1210

[a]Data from Riverton Area Chamber of Commerce, *Riverton, a City of Quality Living, Profile 1979* and Weldon Shelby, Curriculum Coordinator, School District 25, Nov. 1, 1979, personal communication.

[b]Data from Cathy Guschewsky, Secretary to the Superintendent, Fremont County School District 1, Dec. 3, 1979, written communication.

Water supplies

The City of Lander is currently expanding its water treatment facilities. Its supply comes from two reservoirs in the Wind River Mountains plus the Middle Fork of the Popo Agie River. The treatment process includes filtration and chlorination. Storage capacity is approximately the daily peak usage of 15,150 m^3/d (4×10^6 gpd). The source capacity is 26,500 m^3/d (7×10^6 gpd). Riverton's water supply is taken from wells. A new water treatment facility capable of treating water from the Wind River when well capacities are inadequate is under construction.

Sewage treatment

Lander's sewage treatment facility adequately meets Wyoming Department of Environmental Quality standards. The facility includes a lagoon-oxidation system with a des'gn capacity believed adequate for a population of 10,000. Riverton's plant is designed f 5680 m^3/d (1.5×10^6 gpd) and is handling a peak demand of 15,150 m^3/d (4×10^6 gpd). S c tank systems are being used for new housing; this is not a satisfactory method becau of the high water table levels in the area (Raymond Price, Assistant Fremont County Planner, personal communication, Nov. 1, 1979).

Municipal solid waste

Both cities dispose of municipal solid wastes in landfills. Riverton will require additional space for this usage in about two years. The Bureau of Land Management has, in the past, been cooperative in supplying land for this purpose (William Peterson, Riverton City Administrator, personal communication, Nov. 1, 1979).

Transportation

Riverton is served by the Riverton Regional Airport, which has a 2.6-km (8600-ft) asphalt runway. Commercial service is provided by Frontier Airlines, which operates three daily flights. U.S. Highway 26, State Highway 789, and County Road 135 are the major traffic arteries to Riverton. Railroad service is provided by the Chicago and Northwestern Railroad, and five carriers provide motor freight service. The main roads to Lander are U.S. Highway 287 and County Road 789. No rail service exists. Two motor freight carriers offer scheduled service.

Utilities

Electricity is supplied to Riverton by the Pacific Power and Light Company, natural gas by Northern Utilities Gas Company, and telephone service by Mountain Bell. Rural electricity is supplied by the Riverton Valley Electric Association. These same utilities provide service to Lander.

Recreation

Riverton has only 40% of the recommended open-space recreational acres for a community of its size; however, because many residents are primarily involved in individual outdoor activities such as skiing, hunting, and fishing, this statistic is not very meaningful. Recreational areas in Fremont, Sweetwater, and Carbon counties and their distances from the proposed Bison Basin site are shown in Table 3.14. No parks or recreational facilities exist in the general area of the proposed site. Antelope hunting actively occurs in the general region, which includes extremely large areas of browse for that type of game.

Table 3.14. Recreational facilities in Fremont, Sweetwater, and Carbon counties

	County	Air kilometers to Bison Basin site
Flaming Gorge National Recreation Area	Sweetwater	77.4
Pathfinder National Wildlife Refuge	Carbon	64.8
Boysen Reservoir State Park	Fremont	63.0
Seminoe State Park	Carbon	72.0
Big Sandy State Park	Fremont	54.0
Sinks Canyon State Park	Fremont	39.6
South Pass Mining Area	Fremont	27.0
Platte River Crossing Historic Monument	Carbon	77.4

Source: ER, p. 29.

3.5 LAND USE

3.5.1 Land resources

The project site and all surrounding land is used as nonirrigated grazing land. The closest irrigated farmland is along the Sweetwater River near Sweetwater Station, 30 km northeast of the project site. The lack of rainfall (Sect. 3.1.3) and groundwater (Sect. 3.6.2), the short growing season (Sect. 3.1.1), and the poor soils (Sect. 3.8) all appear to preclude not only more intensive agricultural uses but also urban developments.

The grazing capacity of the site is about 4 ha per animal unit month (A.U.M.) (10 acres/A.U.M.) [3.74-4.54 ha/A.U.M. (9.25-11.23 acres/A.U.M.)].[16] The range is utilized only during summer months. Game species are discussed in Sect. 3.9.1. Mineral resources are discussed in Sect. 3.7.2.

3.5.2 Historical, archaeological, and scenic values

3.5.2.1 Historical and cultural places

Several historic trails passed through Fremont County along the general alignment of the Sweetwater River, 52 km (28 miles) north of the proposed project site. These include the Robert Stuart Trail (1812), the Bonneville Trail (1821), the Oregon Trail (1843-1845), the Mormon Trail (1847), and the California Trail (1849-1851). A number of markers can be seen between Split Rock on the east and South Pass on the west.

Seven sites in Fremont County, three sites in Sweetwater County, and nine sites in Carbon County are listed in the "National Register of Historic Places." The closest of these sites to the proposed project site are South Pass, where several historic trails crossed the Continental Divide, and South Pass City, a late nineteenth-century gold-mining town, located 40 km (25 miles) west and 40 km (25 miles) west-northwest of the site respectively.

The applicant established contact with Jan Wilson, Acting Director of the Wyoming Recreation Commission, and Ned Frost, Chief of the Historical Division of the Wyoming Recreation Commission. They indicated that "no cultural properties enrolled in the "National Register of Historic Places" are located within the area of your concern," and that within that area "there are no historic properties listed in the *Wyoming Inventory of Historic Sites* (which might qualify for future enrollment in that Register)" (Jan Wilson, Acting Director of the Wyoming Recreation Commission and Ned Frost, Chief of the Historical Division of the Wyoming Recreation Commission, personal communication, Nov. 2, 1979). Thus, neither the National Register of Historic Places nor its supplements through December 1979 nor other official sources list any areas of cultural or historic interest close to the proposed site.

3.5.2.2 Archaeological resources

An archaeological reconnaissance survey was conducted by George M. Zeimens, Associate State Archaeologist, in November 1977. The area survey included the access road and all land in the project area that will be disturbed by the proposed in situ mining operation. Zeimens recommended archaeological clearance for the project, with the stipulation that the Office of the Wyoming State Archaeologist be notified immediately if any buried cultural materials are found during construction or mining activities.

An archaeological site is located in the center of Section 30, T27N, R96W. However, no land disturbance will occur at this site because it is outside the project area. No paleontological sites will be affected.

3.5.2.3 Scenic values

The lands of the proposed project site, and all lands within view from the site and from the Bison Basin Oil Field Road, are entirely devoid of trees and are rolling, without any particularly distinctive or interesting landform. The predominant mood is established by very low, grayish-tan desert scrub that extends without relief in every direction.

The site is within visible range of the northern rim of the Great Divide Basin. The plant structures, however, lie below the topographic divide between West Alkali Creek and Sulphur Creek and are nearly indistinguishable at a distance.

3.6 WATER

3.6.1 Surface water

The Bison Basin Project site [3.4 km^2 (1.3 sq miles)] is located within the West Alkali Creek drainage basin [440 km^2 (170 sq miles)] in an upland area near the topographic divide with the Sulphur Creek drainage basin (Fig. 3.3). Both streams are part of the Sweetwater River drainage network. West Alkali and East Alkali creeks meet to form Alkali Creek about 18 km (11 miles) downstream from the site, and the confluence of Alkali Creek and the Sweetwater River is about 25 km (16 miles) from the site. West Alkali Creek is intermittent with a well-defined, active channel carrying runoff generated by snowmelt and spring and summer thunderstorms. It flows for about two to three months each year and appears to be a "losing" stream (one with the groundwater table below the streambed and net losses of water to the unconfined groundwater aquifer). At its closest point the project site is 1.6 km (1.0 mile) from and 25 m (18 ft) above West Alkali Creek. Ephemeral streams, some with poorly defined channels, carry runoff from the site. Runoff from approximately 55% of the site drains into Grassy Lake, a shallow but completely enclosed depression that is 1.3 km (0.8 mile) from the site and is flooded for about three to four months each year. The bottom of Grassy Lake is clayey, and groundwater outflows from it are thought to be minimal. Runoff from the remainder of the site (northeast section) drains into one of two small unnamed playas, one of which has an outflow to West Alkali Creek about 3 km (1.9 miles) downstream from the site.

Water quality information for West Alkali Creek is from one "grab" sample collected by the applicant on May 18, 1979, at stations upstream and downstream of the project site runoff and 4.2 km (2.6 miles) apart. Dominant water quality features are very high pH and TDS, with Na^+ dominant among the cations and HCO_3^- and CO_3^{2-} among the anions. Alkali Creek is not suitable as a public water supply since concentrations of TDS, As, Fe, and Mn, as well as pH, exceed standards; however, it is likely used at times by wildlife and livestock as a water supply (Table 3.15). Water quality data are unavailable for Grassy Lake; however, water quality in Grassy Lake should be similar to that of West Alkali Creek following major spring runoff events. During late spring and summer, Grassy Lake constituents become increasingly more concentrated because of evaporation and are diluted slightly after thunderstorms.

Alkali Creek and Sweetwater River, perennial downstream watercourses, are currently classified as Class II waters by the Wyoming Department of Environmental Quality because, according to the Wyoming Game and Fish Department, they support a trout fishery. Upstream of its confluence with Alkali Creek, the Sweetwater River is classified as a Class I water; no further water quality degradation by point sources is permitted.

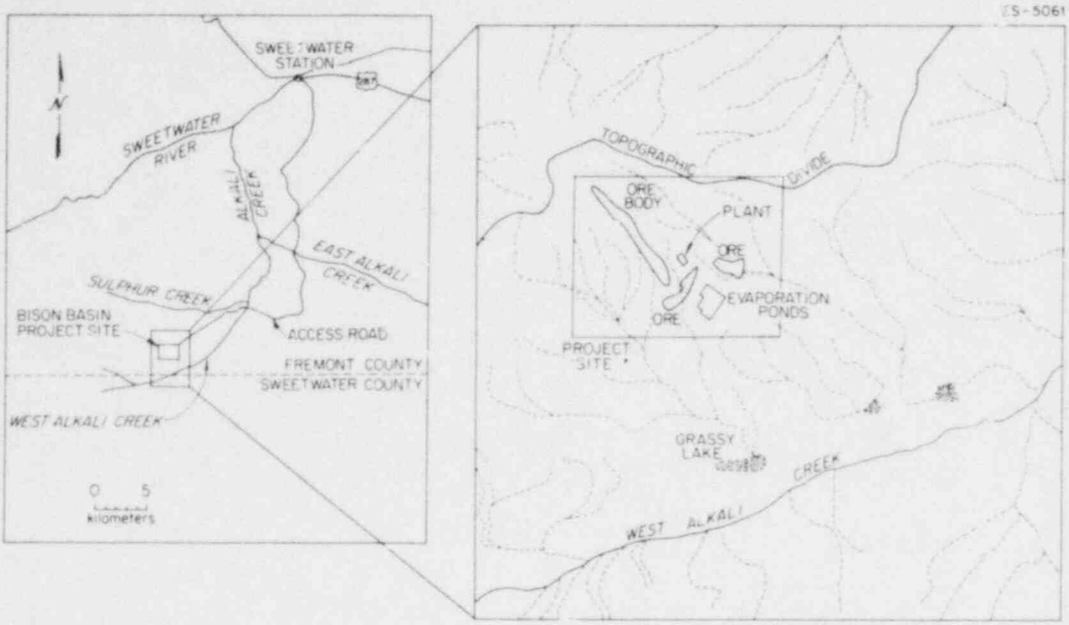


Fig. 3.3. Drainage patterns and their relationship to the proposed project site. Dashed lines indicate ephemeral washes. Source: ER, Figs. 2.1-2 and 2.1-3.

3.6.2 Groundwater

3.6.2.1 Regional flow system

The regional groundwater hydrologic system in this part of Wyoming has not been clearly defined because of sparseness of data-yielding wells. The surface land use of limited livestock grazing has not placed a demand on the use of groundwater supplies. Welder and McGreevy (1966) in their discussion of the groundwater in the adjoining Great Divide Basin, south of the project area, indicate that both unconfined (water table) and confined aquifer systems are present. Further, they state that "the unconfined aquifers are generally permeable 'blanket' type deposits of Quaternary or Tertiary age, and the confined aquifers are confined by impermeable rocks." The conclusion of their report indicates that "this part of the State is underlain by many water-bearing sandstone units that differ greatly in distribution, thickness, grain size, sorting, cementation, and clay or silt content. Single widespread aquifers having uniform characteristics are probably not present."[15] These observations are also thought to be applicable to the groundwater systems present in the Bison Basin area.

3.6.2.2 Site-specific groundwater and aquifer characteristics

Locally, the shallow aquifer groundwater system extending down to and including the mineralized sandstone unit proposed for solution mining is controlled by the McKay Lake-Daley Lake syncline (see Figs. 3.4 and 3.5). This synclinal structure creates a closed groundwater basin, with subsurface waters in the project area moving at a slow rate to the southeast, essentially downward toward the axis.

The first groundwater encountered during drilling in the project area is at a depth of 15 to 20 m (50 to 65 ft) below the land surface and is normally under water table conditions. The next deepest water-saturated zone of significance is the basal "B" sands, a 0- to 3-m-thick (10-ft) lenticular sandstone interval located in the Laney member of the Green River formation at the bottom of the "B" unit (see Fig. 3.6). This aquifer has mudstone aquicludes above and below which produce confined conditions. The upper aquifer monitor well for the research and development well field [well 303-6-M3 discussed later (Fig. 3.14)] is completed in the "B" sands.

Table 3.15. Water quality in West Alkali Creek at stations upstream and downstream of all potential drainage from the site, May 18, 1979

All values are in mg/liter unless otherwise indicated

Constituent	West Alkali Creek[a]		Drinking water standard[b–d]	Wyoming Department of Environmental Quality wildlife and livestock criteria[e,f]
	Upstream	Downstream		
pH, units	9.5	9.3	6.5–8.5	6–9
Total dissolved solids	640	724	500	5000
Specific conductivity, μmhos/cm	900	1165		
Cl	58	90	250	2000
CO_3	168	156		
HCO_3	110	268		
NO_2	<0.01	<0.01		
NO_3	2.4	3.0	10.0	
NH_3	<0.1	<0.1		
SO_4	60	90	250	3000
Na	198	288		2000
K	18	25		
Ca	13	14		1000
Mg	2	6		500
Al	1.5	2.15		
As	0.04	0.06	0.05	0.2
B	<1.0	<1.0		0.5
Ba	<0.05	<0.05	1.0	
Cd	<0.002	<0.002	0.01	0.05
Cr	<0.01	<0.01	0.05	1.0
Cu	0.14	0.08	1.0	0–5
F	0.71	0.81	0.7–1.2	2.0
Fe	1.90	3.12	0.3	
Hg	0.001	<0.001	0.002	0.1
Mn	0.11	0.37	0.05	
Mo	<0.05	<0.05		
Ni	<0.04	<0.04		
Pb	<0.05	<0.05	0.05	0.1
Se	<0.01	<0.01	0.01	0.05
U	0.030	0.038		
V	<0.05	<0.05		
Zn	0.37	0.17	5.0	25
^{226}Ra, pCi/liter	1.35	0.06	5.0	
^{230}Th, pCi/liter	10.0	0.0	10	

[a]Data from ER, Sect. 2.12, pp. 191–192.

[b]U. S. Environmental Protection Agency, *Quality Criteria for Water*, Report EPA-440/9-76-023, July 1976.

[c]"Proposed National Secondary Drinking Water Standards," *Fed. Regist.* 42(62): 17143–17147 (1977).

[d]U. S. Public Health Service, *Drinking Water Standards*, PHS Publication 956, 1962.

[e]Wyoming Department of Environmental Quality, Land Quality Division, *Guideline No. 4* (rev.), Nov. 9, 1976, pp. 3-43.

[f]J. E. McKee and H. W. Wolf, eds., *Water Quality Criteria*, 2d ed., The Resources Agency of California, State Water Quality Control Board, Publication No. 3-A, 1963.

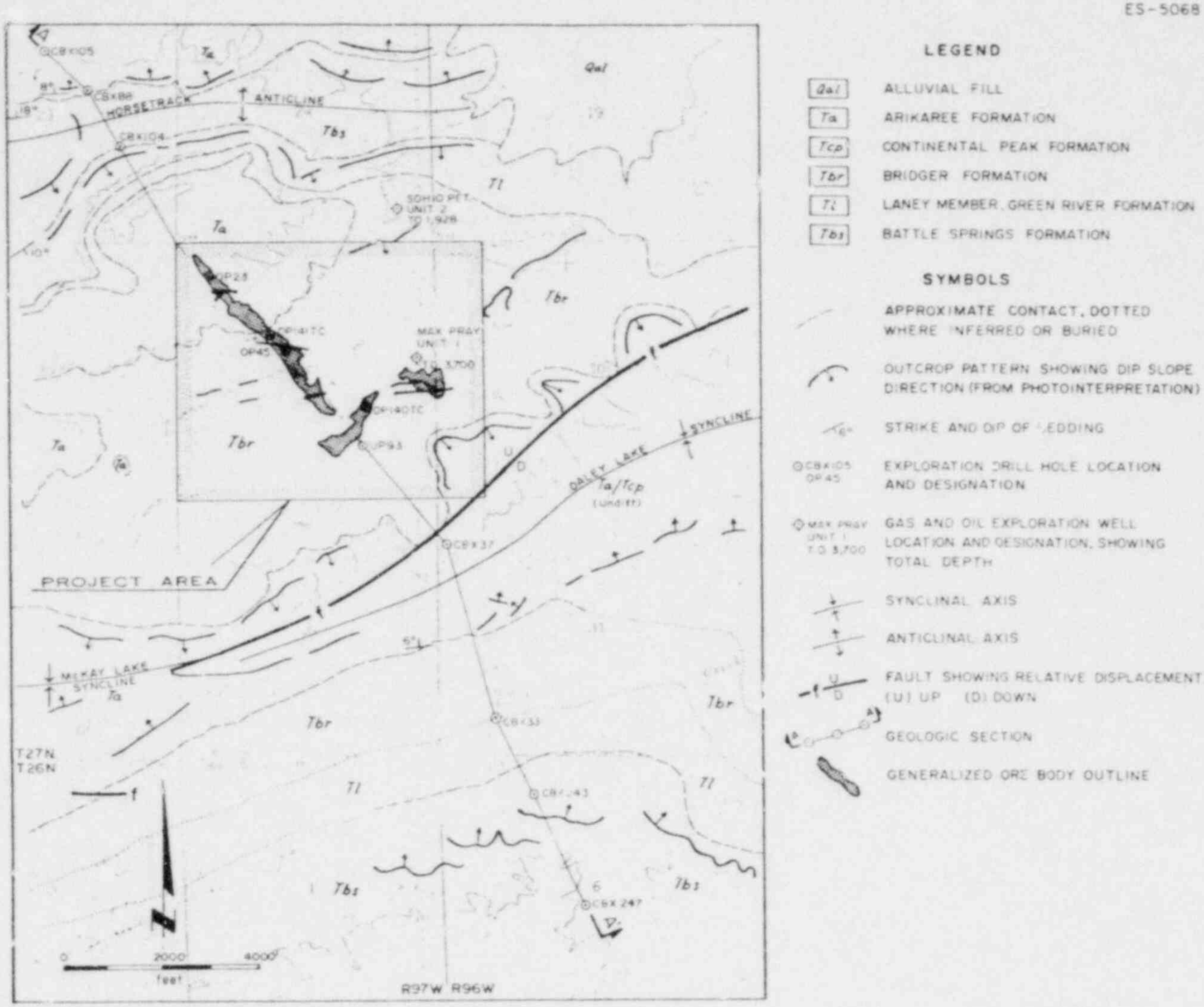


Fig. 3.4. Location of McKay Lake-Daley Lake syncline with respect to project area. Source: ER, Fig. 2.4-1.

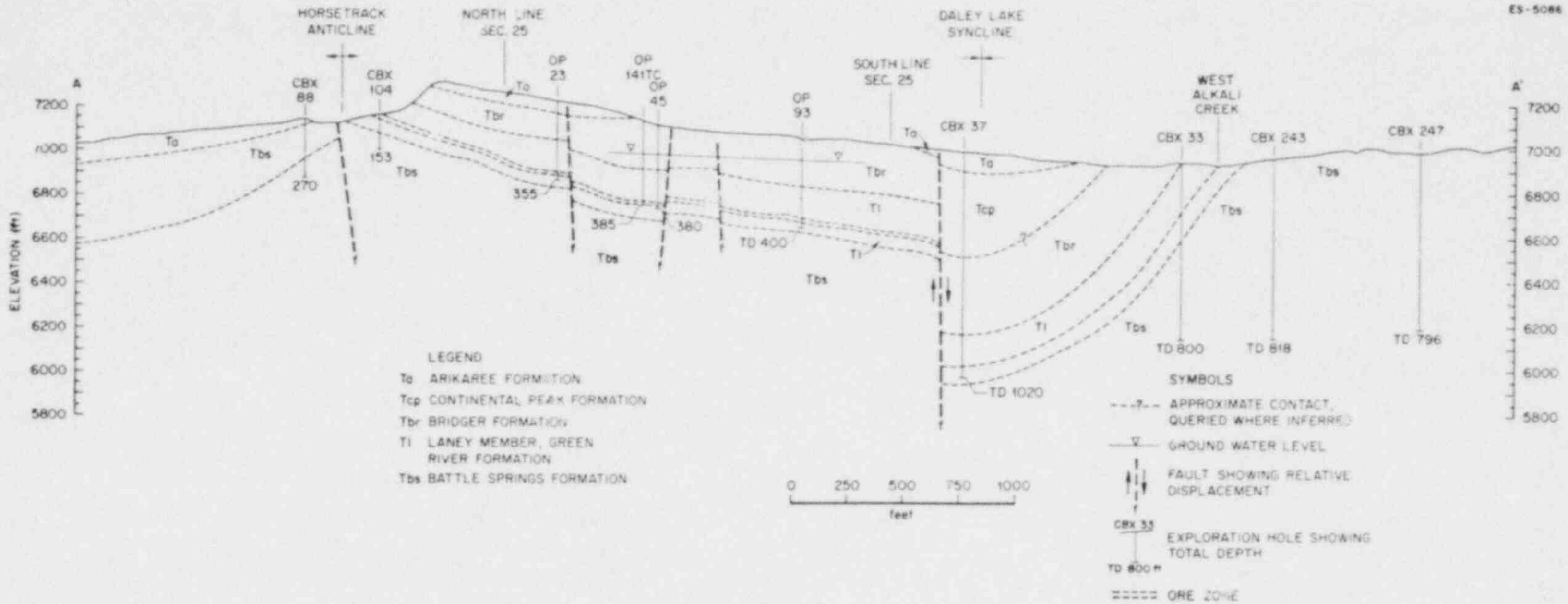


Fig. 3.5. Sample geologic section of project area. Source: ER, Fig. 2.4-2.

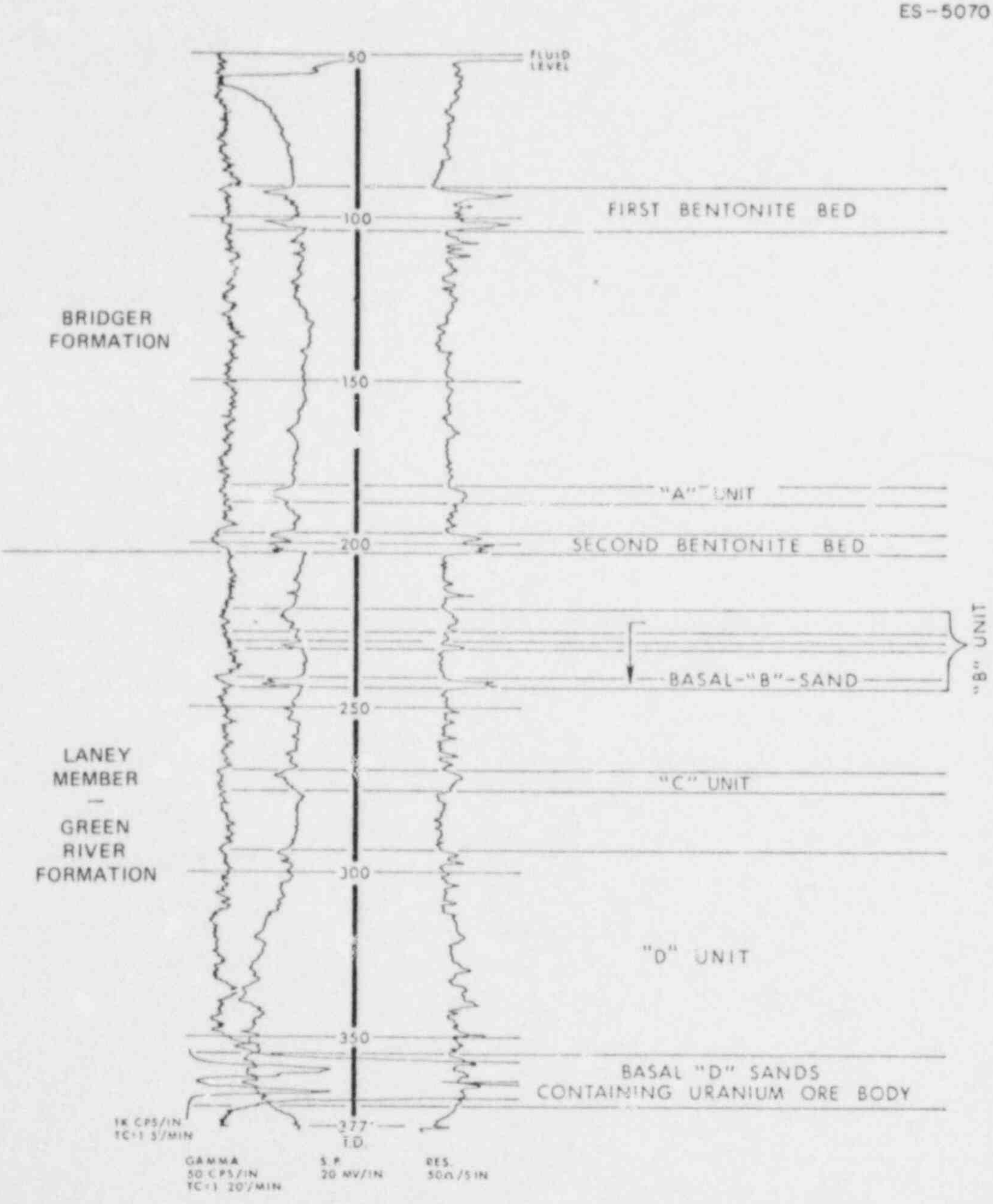


Fig. 3.6. Log from hole OP-45 (taken as representative); see Fig. 3.7. Source: ER, Fig. 2.4-12.

The water in this well has a static head of 57 m (186 ft) above the top of the aquifer. The upper aquifer monitor wells for the commercial operation will also be completed in the basal "B" sands.

The next older sandstone unit with sufficient thickness and areal extent to be considered an aquifer is referred to as the basal "D" sands located in the Laney member at the bottom of the "D" unit (Fig. 3.6). This is the host rock for the uranium deposit that Ogle Petroleum, Inc., proposes to mine. The "D" sands consist of an approximate 4.5-m (15-ft) interval, which varies in depth from outcrop around the Horsetrack anticline to a dipping below the surface to an average distance of 114 m (375 ft) in the project area and deepening to over 290 m (950 ft) at the axis of the Daley Lake syncline. This sandstone aquifer is overlain and underlain by persistent mudstone aquicludes. Geologic and hydrologic data obtained to date from the "D" sands indicate that there is no communication either with the overlying "B" sands or the underlying Battle Springs formation aquifers (Sect. 3.6.2.3). Exploratory drilling has indicated that as much as 31 m (95 ft) of mudstone underlies the ore body. Two sandy intervals underlying the ore body sands have also been encountered. However, they are very sinuous and laterally discontinuous, vary greatly in thickness over short intervals, and probably represent abandoned stream channels. Detailed hydrologic information on the Battle Springs formation has not been gathered as Ogle Petroleum does not plan to mine in this underlying formation; however, it has been established that no aquifer is present for at least 79 m (260 ft) below the ore zone.

The hydrologic properties of the "D" sands (production zone aquifer) in the project area were established from the results of three separate aquifer tests conducted in both the north and the south portions of the elongated 16-ha (40-acre) ore body. The locations of the aquifer tests are shown in Fig. 3.7. Details pertaining to these aquifer tests may be found in Appendix B.

Information from three separate pump tests indicates that the average transmissivity ranges from 1.4 to 2.4 m^2/d (117 to 198 gpd/ft) and that the average hydraulic conductivity ranges from 0.24 to 0.41 m/d (5.8 to 10.0 gpd/ft^2). These values of hydraulic conductivity are relatively low, classifying the aquifer as poor.[16] The data also indicate that leach chemicals will be confined to the production zone aquifer because no significant vertical leakage was detected during the pump tests.

3.6.2.3 Hydraulic communication

The static head of the "B" aquifer is approximately 15 m (48 ft) higher than the static head of the "D" aquifer. To test for hydraulic communication between the "B" and "D" sands, immediately prior to pumping of Well 303-6-P22 for Aquifer Test 3, the water levels for all wells used in the test were measured (Fig. 3.8). The water level in Well 303-6-M3 completed in the "B" aquifer was 19.0 m (62.33 ft) below the land surface. The water level in the wells completed in the "D" aquifer (303-6-P21, 303-6-P8, 303-6-P30, 303-6-P31, 303-6-P32, and 303-6-P10) immediately surrounding the "B" aquifer well (303-6-M3) ranged from 33.5 to 34.3 m (109.90 to 112.51 ft) below the land surface. At the conclusion of this test, the following drawdowns were noted:

Well number	Maximum drawdown	Aquifer
303-6-M1	4.2 m (13.8 ft)	"D" sands
303-6-M2	4.4 m (14.3 ft)	"D" sands
303-6-M3	0.0 m (0.0 ft)	"B" sands
303-6-M4	5.2 m (17.1 ft)	"D" sands
303-6-M5	4.8 m (15.8 ft)	"D" sands
303-6-M6	5.0 m (16.5 ft)	"D" sands

From this test it was concluded that hydraulic communication between the "B" and "D" aquifers does not exist in the first mine unit; staff expects this condition to apply to the other mine units.

As is indicated in Sect. 3.7.1, several normal faults, with small but variable displacements, transect the 16 ha- (40-acre) ore body. The locations of these faults are plotted on Fig. 3.9. Data from Aquifer Test 3 also indicated that there was hydraulic communication across the fault located immediately north of the initial (first) mining unit.

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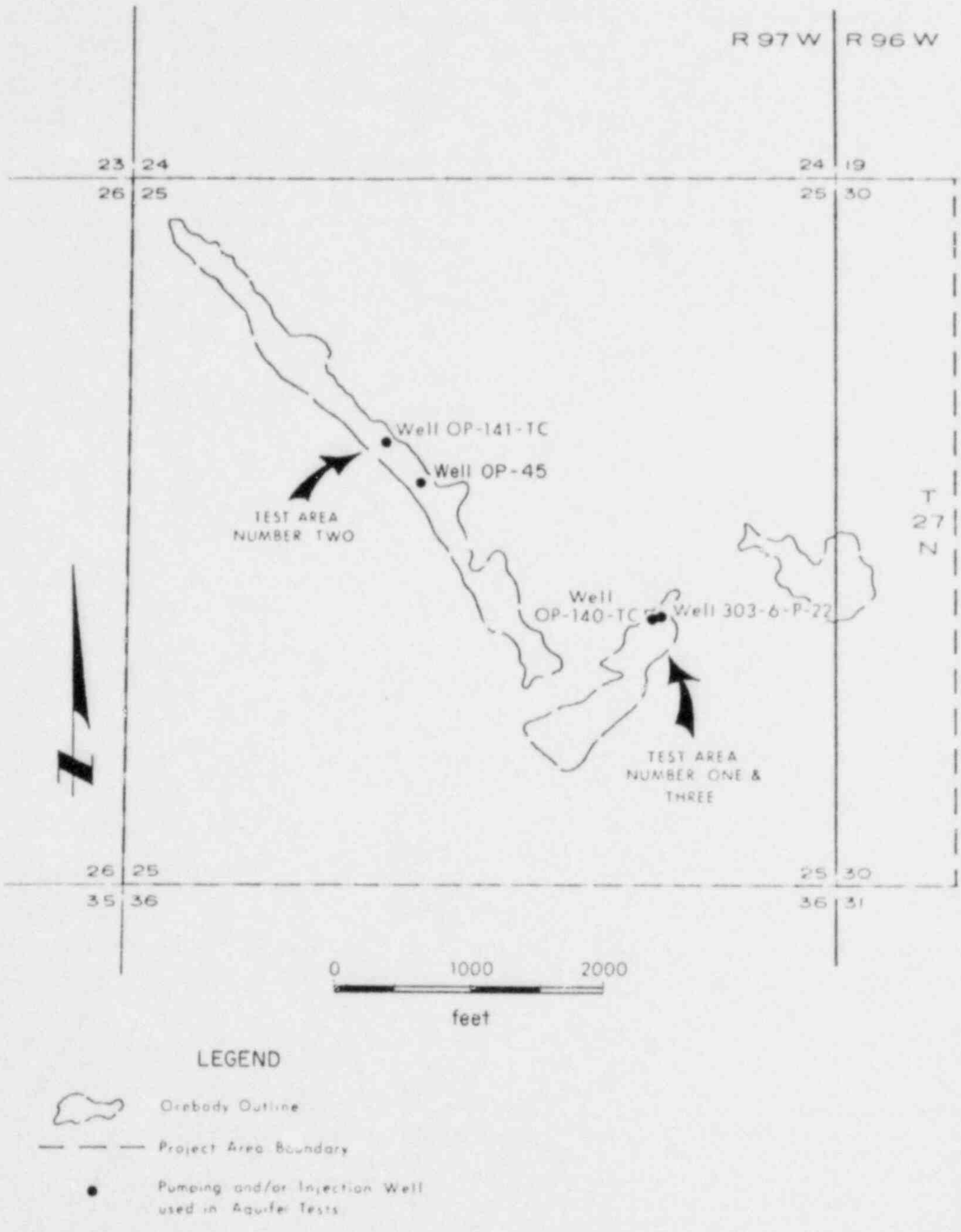

Fig. 3.7. Location map of aquifer tests. Source: ER, Fig. 2.6-1.

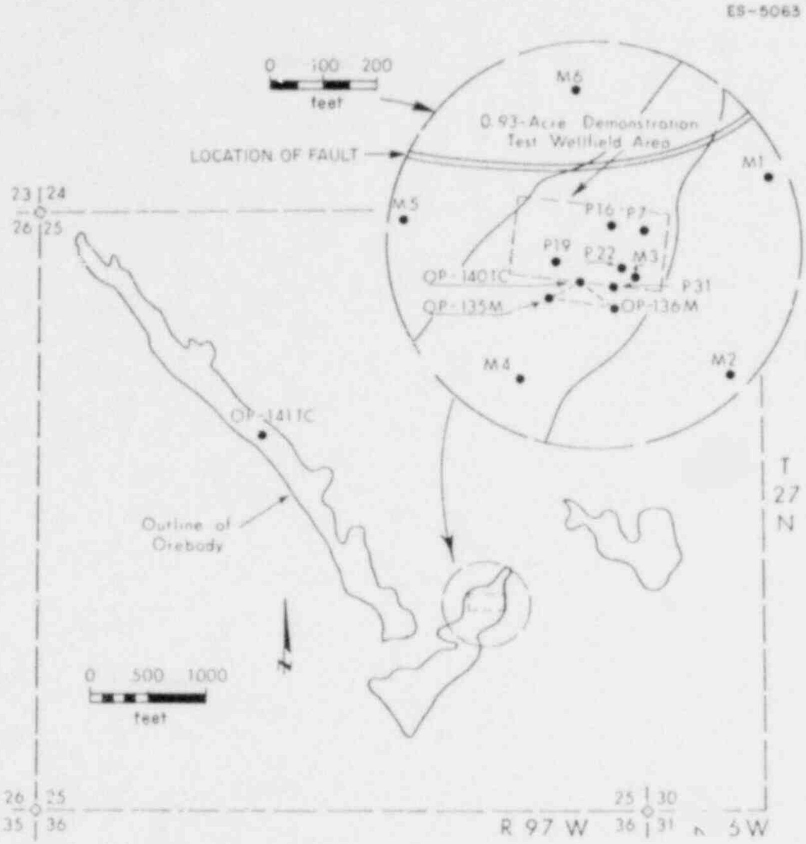

Fig. 3.8. Location of wells used in Aquifer Test 3. All wells are completed in the ore body aquifer ("D" sands) except M3, which is in the "B" sands. Source: ER, Fig. 2.10-1.

from the data above, at the conclusion of Aquifer Test 3, the drawdown in well 303-6-M6 located across a fault from the pumped well (303-6-P22) was 5.0 m (16.5 ft), indicating that horizontal hydraulic communication exists across the fault.

The hydrologic influence of faults and leakage through confining layers in each mining unit will be investigated before the production and injection wells are installed and leaching agents are injected to confirm the continuity of confining characteristics. The requirement for gathering of further, confirmatory information shall be a license condition. If hydraulic difficulties occur near a fault, the well field will be operated so that the wells nearest the fault will be used only for recovery of solution. Regardless of tests results, the aquifer above the ore zone will be specifically monitored near the faults. This type of operation is illustrated in Fig. 3.10. The staff recommends that monitor wells (see Sect. 4.4.2.5) be placed for timely detection of any fault interconnection between aquifers.

3.6.2.4 Potentiometric surface

The static potentiometric elevations in Wells OP-94, OP-95, and OP-136 (see Figs. 3.11 and 3.12) and Wells OP-41 and OP-132 (see Figs. 3.12 and 3.13) were monitored periodically between June and September 1977. The results in terms of potentiometric level are shown in Table 3.16.

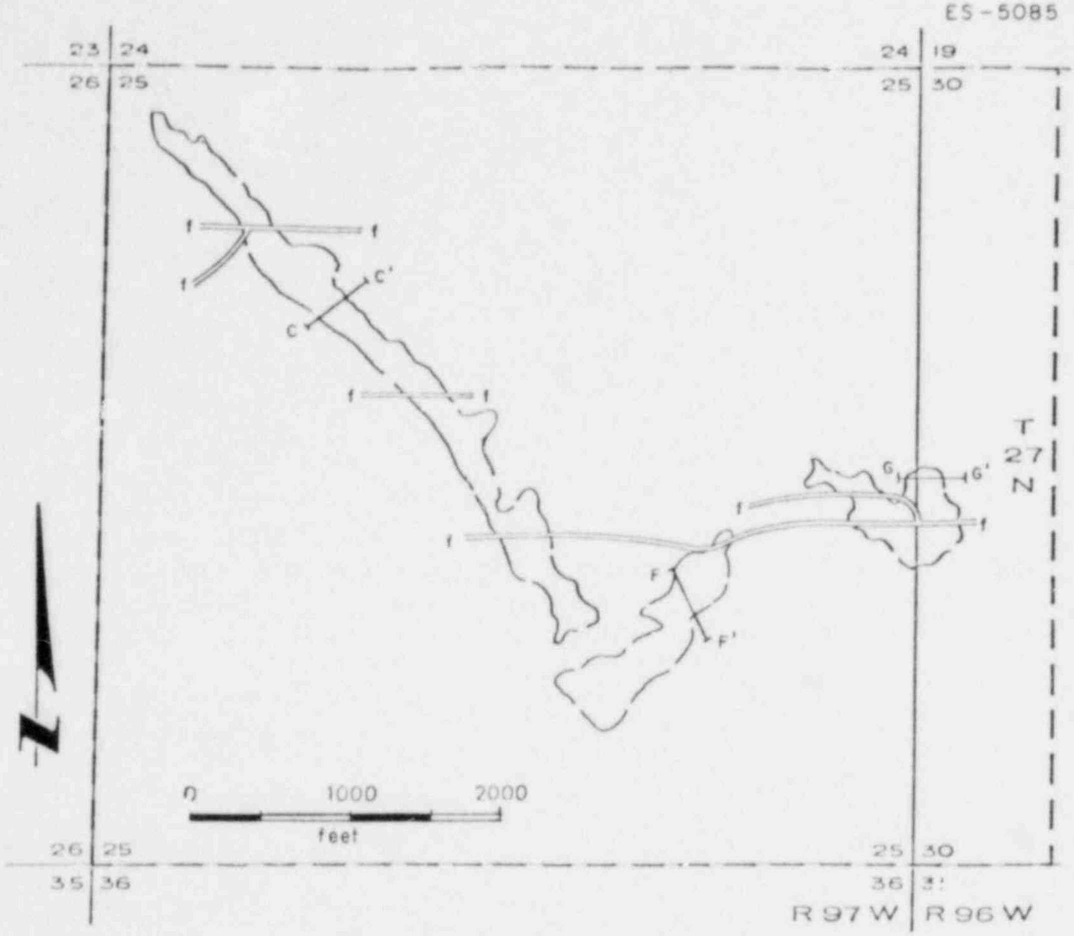

Fig. 3.9. Location of faults (f) transecting the ore body. Geologic section of C-C' will be presented in Fig. 3.16, F-F' in Fig. 3.17, and G-G' in Fig. 3.18. Source: ER, Fig. 2.4-3.

Assuming that hydraulic communication exists across the other faults, Fig. 3.12 presents the potentiometric contour map of the production zone aquifer based on data from the previously mentioned wells. The contour map indicates that the groundwater in the production zone aquifer is moving southeast under a hydraulic gradient of about 0.002 m per meter (0.009 ft per foot), producing a groundwater velocity of approximately 2.7 m (9 ft) per year.

3.6.2.5 Site-specific groundwater quality

All sampling for baseline groundwater quality values were made in connection with feasibility push-pull tests conducted in June 1977 and with baseline monitoring in late 1978, preceding commencement of the 0.1 m^3/min (25 gpm) demonstration project.

Baseline ore host aquifer ("D" sands) water quality was determined on samples from four wells within the mineralized zone, preceding the push-pull feasibility tests conducted in June 1977. These wells were the following: OP-135, OP-136, OP-140-TC, and OP-141-TC. Locations are shown in Figs. 3.11 and 3.13, and results are given in Table 3.17.

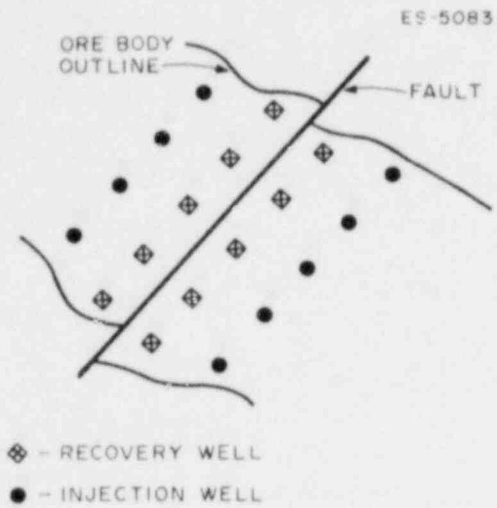

Fig. 3.10. Proposed layout of well fields adjacent to faults. Source: Responses to NRC, 1979.

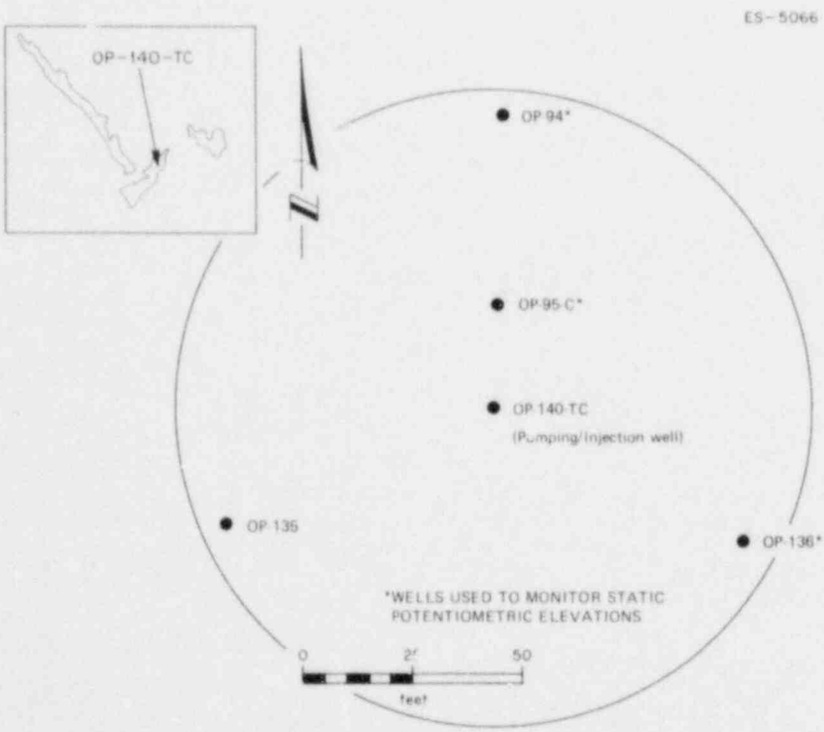

Fig. 3.11. Location of monitor wells to measure static potentiometric elevations. All wells are completed in the ore body aquifer ("D" sands). Source: ER, Fig. 2.6-2.

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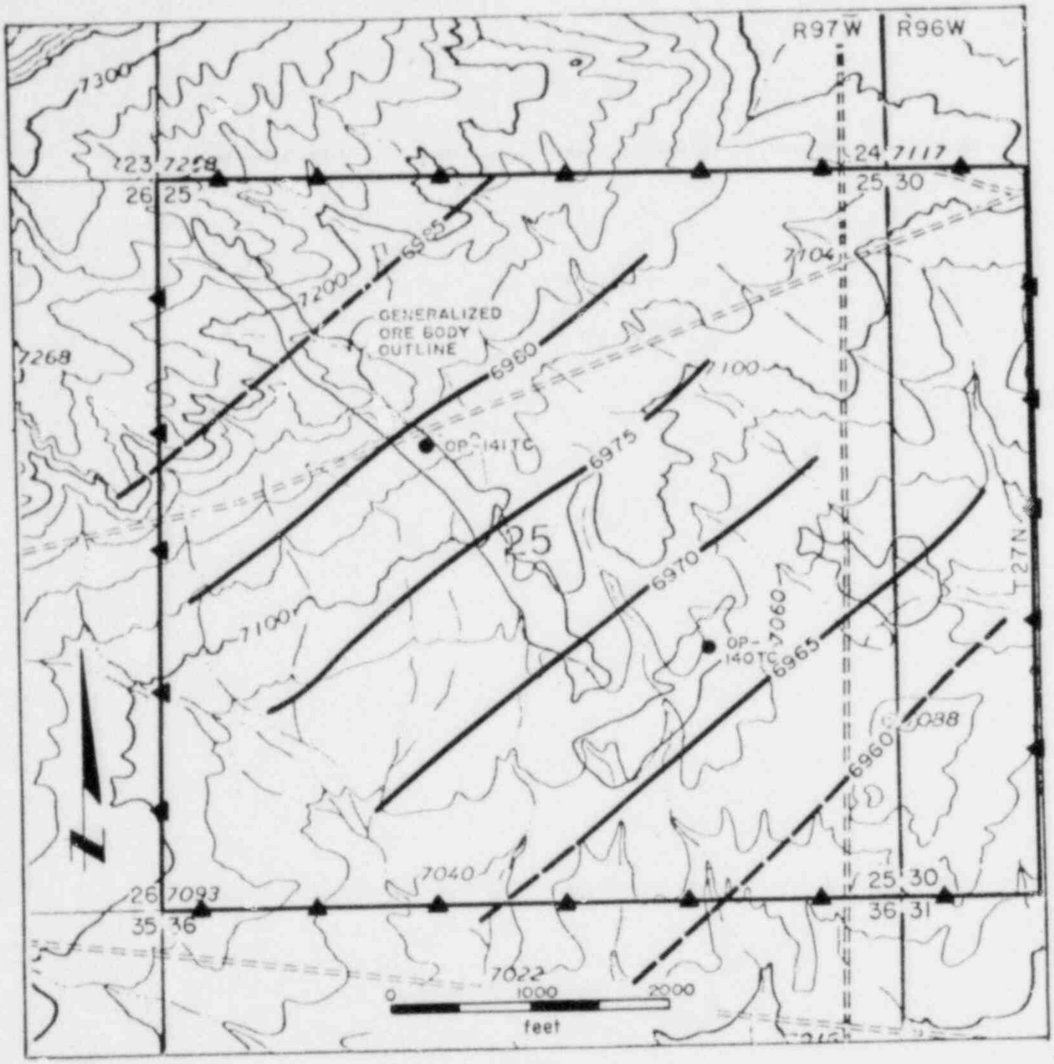

LEGEND

— 6970 — POTENTIOMETRIC CONTOUR, DASHED WHERE INFERRED. ALTITUDE TO WHICH WATER WILL RISE IN WELLS IN THE ORE SAND AQUIFER.

● OP-141TC CONTROL WELL LOCATION AND DESIGNATION

—▲— PROJECT AREA BOUNDARY

Fig. 3.12. Potentiometric contour map of the ore zone aquifer. Source: ER, Fig. 2.6-46.

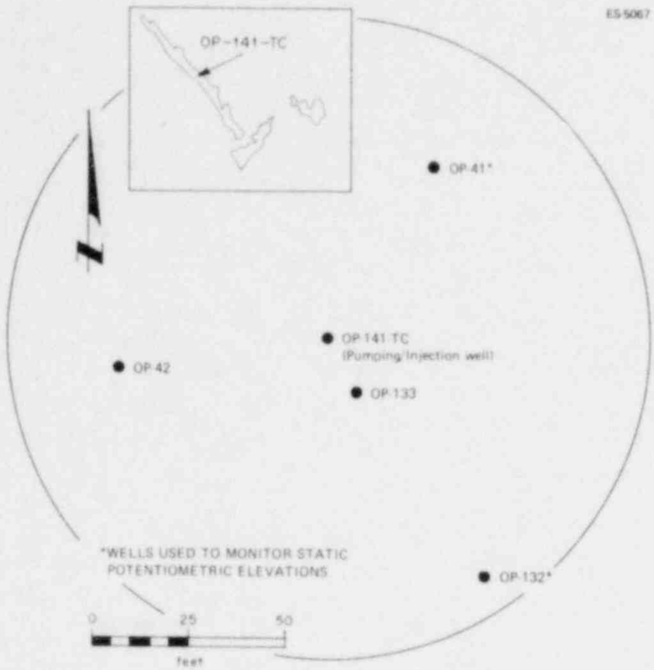

Fig. 3.13. Location of monitor wells used to measure static potentiometric elevations. All wells are completed in the ore body aquifer ("D" sands). Source: ER, Fig. 2.6-15.

Table 3.16. Mean potentiometric surface elevations of wells on Bison Basin site[a]

Well No.	Collar elevation [m (ft) above mean sea level]	Perforation interval [m (ft) below land surface]	Mean potentiometric surface elevation [m (ft) above mean sea level]
OP-94	2156.42 (7074.88)	116–122 (380–400)	2123.68 (6967.45)
OP-95C	2156.73 (7075.87)	119–123 (389–404)	2124.03 (6968.61)
OP-135	2155.68 (7072.44)	116–122 (380–400)	2123.46 (6966.74)
OP-136	2155.56 (7072.04)	116–122 (380–400)	2123.69 (6967.48)
OP-41	2172.39 (7127.26)	110–116 (360–380)	2126.92 (6978.09)
OP-42	2172.10 (7129.09)	110–116 (360–380)	2127.11 (6978.71)
OP-132	2171.18 (7123.29)	110–116 (360–380)	2127.42 (6979.62)

[a] All wells are completed in the ore body aquifer ("D" sands).
Source: ER, Table 2.6-4.

Preceding the 0.1 m^3/min (25 gpm) demonstration operation, baseline ore host aquifer ("D" sands) water quality was determined in late 1978 on samplings from ten wells: 303-6-M1, 303-6-M2, 303-6-M4, 303-6-M5, 303-6-M6, 303-6-P7, 303-6-P16, 303-6-P19, 303-6-P22, and 303-6-P31. Also, water quality determinations were made on samples from well 303-6-M3 in the upper "B" zone. Locations of the above wells are shown in Fig. 3.14, and results of the water analysis are given in Tables 3.18 and 3.19. Table 3.18 is a statistical summary of baseline water quality for five wells completed in the ore body aquifer ("D" sands) and which will undergo restoration. Table 3.19 gives the same information for the five monitor wells completed in the "D" sands.

Table 3.17. Baseline water quality, Bison Basin, Wyoming

All values are in mg/liter unless otherwise indicated; all wells are completed in the ore body aquifer ("D" sands)

Constituent	Well No.					
	OP-140 TC		OP-141 TC		OP-135	OP-136
	Sample date and hour					
	6-1-77 (11:30 a.m.)	6-7-77 (5:00 p.m.)	6-16-77 (2:21 p.m.)	6-16-77 (4:00 p.m.)	6-2-77 (2:00 p.m.)	6-1-77 (6:45 p.m.)
pH	8.92[a]	8.80	8.23	8.09		
Temperature, °C		12.5	12.0	11.6		
Standard oxidation-reduction potential, mV	400[a]	184	92	92		
Specific conductance, μmhos/cm at 25°C	2300	1850	2450	2400		
Total dissolved solids	1370	1330	1790	1780	1380	1390
Hardness[b]	98.9	101.1	194.8	193.9	101.8	96.8
Al	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
As	−0.04	−0.04	−0.04	−0.04	−0.04	−0.04
B	0.27	0.26	0.32	0.38	0.28	0.26
Ca	27.7	28.9	54.0	54.0	27.7	26.2
Cd	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01
Cl	25	29	11	9	24	26
Cr	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01
Cu	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01
F	1.01	1.02	0.68	0.66	1.07	1.04
Fe, total	−0.04	−0.04	−0.04	−0.04	−0.04	−0.04
Fe, dissolved	−0.04	−0.04	−0.04	−0.04	−0.04	−0.04
Hg	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001
K	5.3	6.1	6.7	6.4	5.0	4.9
Mg	7.0	6.8	14.2	14.0	7.7	7.4
Mn	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01
Mo	−0.04	−0.04	−0.04	−0.04	−0.04	−0.04
Na	440	445	495	487	452	455
Ni	−0.04	−0.04	−0.04	−0.04	−0.04	−0.04
P	−0.1	−0.1	0.1	0.1	0.1	−0.1
Pb	−0.04	−0.04	−0.04	−0.04	−0.04	−0.04
^{226}Ra, pCi/liter	230	210	260	280		
Se	−0.02	−0.02	−0.02	−0.02	−0.02	−0.02
Sr	0.77	0.82	1.27	1.27	0.74	0.72
U_3O_8[c]	0.01	0.02	0.04	0.04	−0.01	−0.01
V	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
Zn	−0.01	−0.01	0.02	0.01	−0.01	−0.01
Bicarbonate	90[a]	110	180	190		
Carbonate	20[a]	20	−10	−10		
Sulfate	825	725	1100	1090	825	725
Ammonia[d]	0.4	0.1	−0.1	0.2		
Nitrate[e]	0.2	−0.2	−0.2	−0.2	−0.2	−0.2

[a] Values were taken several days after sample collection and are less reliable than the other reported values.

[b] Hardness in mg/liter, expressed as equivalent $CaCO_3$.

[c] Total uranium, expressed as equivalent U_3O_8.

[d] Total ammonia, expressed as N equivalent.

[e] Total nitrate, expressed as N equivalent.

Source: Rocky Mountain Geochemical Corporation, Salt Lake City, Utah. Data tabulated by D. B. Roberts, Sept. 7, 1977.

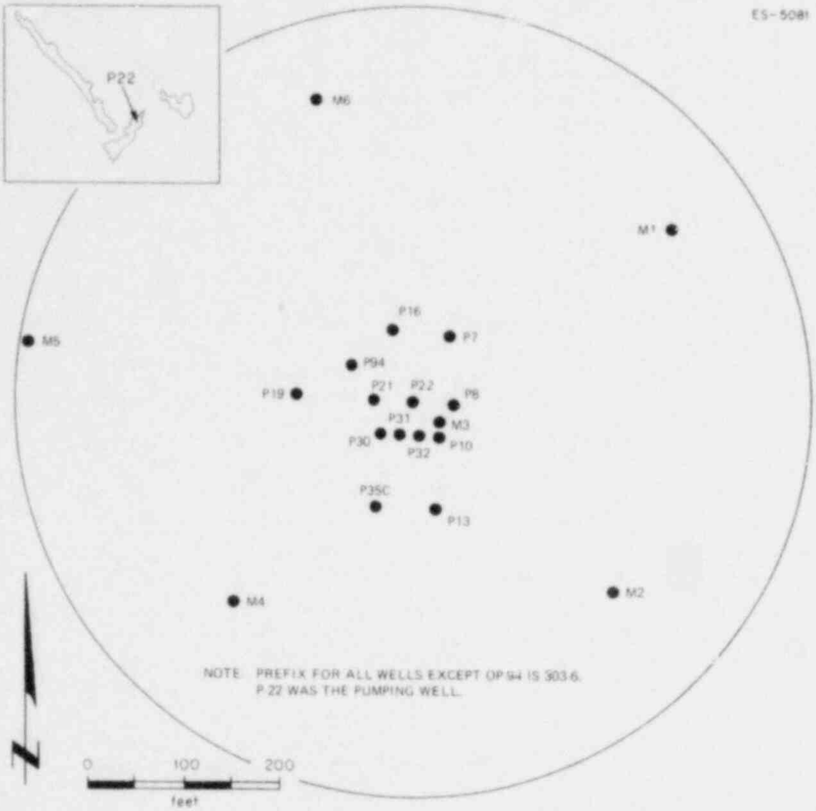

Fig. 3.14. Location map of wells pumped for baseline ore host aquifer water quality determinations made in late 1978. All wells are completed in the ore body aquifer ("D" sands) except M3, which is in the "B" sands. Source: ER, Fig. 2.6-30.

Table 3.20 gives a statistical summary of water quality for monitor well 303-6-M3, completed in the "B" sands (Fig. 3.14). Each of the 11 wells referred to above was pumped and sampled four times during the period from mid-August 1978 to late October 1978. Samples taken during the first two pumpings were analyzed for 34 parameters, and samples taken during the second two pumpings were analyzed for 21 parameters. The parameters evaluated are indicated in Table 3.21. Table 3.22 gives a comparison between concentrations of critical groundwater species and EPA drinking water standards ("maximum contaminant levels"). Target restoration values are also listed.

The baseline water in the ore zone aquifer ("D" sands) does not qualify as safe drinking water because of its high radium-226, sulfate, and total dissolved solids (TDS) levels. Additionally, the baseline water fails to meet the secondary water standards because of its high TDS concentration. The high sodium concentration in the water in the production zone makes the water unsuitable for irrigation. Nevertheless, the position of the NRC is that water constituents will be restored after mining to as close to baseline as possible. For this project some improvement in many constituents may be expected (Fig. 4.2).

3.6.2.6 Water use

According to records in the State Engineer's office, there are only three water wells in the four townships that include and surround the project area. Information pertaining to these three wells is listed below:

Table 3.18. Statistical summary of test area baseline water quality[a]

All values are in mg/liter unless otherwise indicated; all wells are completed in the ore body aquifer ("D" sands)

Constituent	Number of data points (N)	Concentration range	Concentration mean ($\bar{X}$)	Concentration standard deviation ($\sigma n-1$)
pH, units	20	8.8–11.4	9.73	0.82
Total dissolved solids	20	1336–1812	1493	120.7
Specific conductivity, μmhos/cm at 25°C	20	1740–2125	1853	134.8
Al	10	*b*	*b*	*b*
NH_4, as N	20	0.07–2.9	0.71	1.01
NO_3, as N	20	0.01–0.39	0.13	0.13
NO_2, as N	20	*c*	*c*	*c*
As	10	*c*	*c*	*c*
Ba	10	*b*	*b*	*b*
HCO_3	20	0–110	62.6	41.6
B	10	*d*	*d*	*d*
Cd	10	*e*	*e*	*e*
Ca	20	12–62	32.8	12.1
CO_3	20	18–48	30.3	7.9
Cl	20	28–52	34.2	5.3
Cr	10	*c*	*c*	*c*
Cu	10	*c*	*c*	*c*
F	10	0.7–1.2	0.98	0.17
Fe, total	20	0.01–0.13	0.025	0.032
Pb	20	*b*	*b*	*b*
Mg	20	0–8	3.45	2.24
Mn	10	*c*	*c*	*c*
Hg	10	*f*	*f*	*f*
Ni	10	*b*	*b*	*b*
K	20	7–16	9.8	2.4
Se	20	*c*	*c*	*c*
Na	20	320–493	443	37.9
SO_4	20	770–1100	901	88
U	20	0.001–0.011	0.0018	0.0024
V	10	*b*	*b*	*b*
Zn	20	*c*	*c*	*c*
^{226}Ra, pCi/liter	20	2.2–419.3	76.63	134.96
^{230}Th, pCi/liter	20	0–14.6	3.68	3.97

[a]Tabulated statistical values are based on data obtained from the sampling of five restoration sampling wells in the Demonstration Test area (wells 303-6-7C, 303-6-P16, 303-6-P19, 303-6-P22C, and 303-6-P31C).

[b]Data are below detection limit of 0.05.

[c]Data are below detection limit of 0.01.

[d]Data are below detection limit of 1.0.

[e]Data are below detection limit of 0.002.

[f]Data are below detection limit of 0.001.

Table 3.19. Statistical summary of monitor wells baseline water quality[a]

All values are in mg/liter unless otherwise indicated

Constituent	Number of data points (N)	Concentration range	Concentration mean ($\bar{X}$)	Concentration standard deviation ($\sigma n-1$)
pH, units	20	8.5–10.7	9.40	0.64
Total dissolved solids	20	1270–1554	1375.4	63.04
Specific conductivity, µmhos/cm at 25°C	20	1675–1925	1804.2	77.95
Al	10	*b*	*b*	*b*
NH_4, as N	20	0.01–10.1	0.88	2.33
NO_3, as N	20	0.01–7.80[c]	0.56	1.71
NO_2, as N	20	*d*	*d*	*d*
As	10	*d*	*d*	*d*
Ba	10	*b*	*b*	*b*
HCO_3	20	0–134	79.6	41.78
B	10	*e*	*e*	*e*
Cd	10	*f*	*f*	*f*
Ca	20	10–34	22.45	8.20
CO_3	20	12–48	30.90	9.73
Cl	20	28–70	38.42	10.62
Cr	10	*d*	*d*	*d*
Cu	10	*d*	*d*	*d*
F	10	0.06–1.30	0.93	0.35
Fe, total	20	0.01–0.06[c]		
Pb	20	*b*	*b*	*b*
Mg	20	2–6	3.85	1.18
Mn	10	*f*	*f*	*f*
Hg	10	*g*	*g*	*g*
Mo	10	*b*	*b*	*b*
Ni	10	*h*	*h*	*h*
K	20	7–16	[illegible]0.25	2.10
Se	20	*d*	*d*	*d*
Na	2[illegible]	421–481	436.90	15.11
SO_4	20	590–950	807.50	70.25
U	20	0.001–0.016[c]		
V	10	*b*	*b*	*b*
Zn	20	*d*	*d*	*d*
^{226}Ra, pCi/liter	2[illegible]	0.74–16[illegible] 1	24.23	43.49
^{230}Th, pCi/liter	20	0.0[illegible]–[illegible]3.9	8.2[illegible]	16.31

[a] Tabulated statistical values are based on data obtained from the sampling of five monitor wells completed in the "D" sands for the Demonstration Test project (wells 303-6-M1, 303-6-M2, 303-6-M4, 303-6-M5, and 303-6-M6).

[b] Data are below detection limit of 0.05.

[c] Constituent was not detected at level indicated.

[d] Data are below detection limit of 0.01.

[e] Data are below detection limit of 1.0.

[f] Data are below detection limit of 0.002.

[g] Data are below detection limit of 0.001.

[h] Data are below detection limit of 0.0[illegible]

Table 3.20. Statistical summary of water quality for monitor well 303-6-M3 in "B" sands

All values are in mg/liter unless otherwise indicated

Constituent	Number of data points (*N*)	Concentration range	Concentration mean ($\bar{X}$)	Concentration standard deviation (σ_{n-1})
pH, units	4	8.2–8.6	8.4	0.17
Total dissolved solids	4	1792–1958	1866	68.96
Specific conductivity, μmhos/cm at 25°C	4	2125–2275	2225	70.71
Al	2	*a*	*a*	*a*
NH_4, (as N)	4	0.14–4.0	1.11	1.93
NO_3, (as N)	4	0.01–0.47[b]		
NO_2, (as N)	4	*c*	*c*	*c*
As	2	*c*	*c*	*c*
Ba	2	*a*	*a*	*a*
HCO_3	4	98–98	98	0.00
B	2	*d*	*d*	*d*
Cd	2	*e*	*e*	*e*
Ca	4	57–67	60.25	4.72
CO_3	4	12–12	12	0.00
Cl	4	18–18	18	0.00
Cr	2	*c*	*c*	*c*
Cu	2	*c*	*c*	*c*
F	2	0.09–0.78	0.44	0.49
Fe, total	4	0.01–0.02[b]		
Pb	4	*a*	*a*	*a*
Mg	4	12–25	16.50	5.92
Mn	2	*c*	*c*	*c*
Hg	2	*f*	*f*	*f*
Mo	2	*a*	*a*	*a*
Ni	2	*g*	*g*	*g*
K	4	9–12	10.75	1.26
Se	4	*c*	*c*	*c*
Na	4	495–583	531.75	36.94
SO_4	4	1150–1310	1208.75	76.20
U	4	*f*	*f*	*f*
V	2	*a*	*a*	*a*
Zn	4	*c*	*c*	*c*
^{226}Ra, pCi/liter	4	0.43–4.3	1.44	1.91
^{230}Th, pCi/liter	4	0.3–19.5	5.78	9.21

[a] Data are below detection limit of 0.05.
[b] Constituent was not detected at level indicated.
[c] Data are below detection limit of 0.01.
[d] Data are below detection limit of 1.0.
[e] Data are below detection limit of 0.002.
[f] Data are below detection limit of 0.001.
[g] Data are below detection limit of 0.04.

Table 3.21. Groundwater constituents evaluated in four pumpings from mid-August 1978 to late October 1978[a]

All wells are completed in the ore body aquifer ("D" sands) except M3, which is in the "B" sands

Constituent	During first two samplings	During second two samplings
pH	X	X
Total dissolved solids	X	X
Specific conductivity	X	X
Al	X	
NH_4, as N	X	X
NO_3, as N	X	X
NO_2, as N	X	X
As	X	
Ba	X	
HCO_3	X	X
B	X	
Cd	X	
Ca	X	X
CO_3	X	X
Cl	X	X
Cr	X	
Cu	X	
F	X	
Fe, total	X	X
Pb	X	X
Mg	X	X
Hg	X	
Mo	X	
Ni	X	
K	X	X
Se	X	X
Na	X	X
SO_4	X	X
U	X	
V	X	
Zn	X	X
^{226}Ra	X	X
^{230}Th	X	X

[a]Wells sampled were 303-6-M1, 303-6-M2, 303-6-M4, 303-6-M5, 303-6-M6, 303-6-P7, 303-6-P16, 303-6-P19, 303-6-P22, 303-6-P31, and 303-6-M3.

Location	Name of well	Owner
27N-96W, Section 28	Cyclone No. 1	Union Carbide Corp.
26N-97W, Section 32	Osborne No. 1	Olson Sisters Corp.
26N-97W, Section 36	Olson No. 1	Olson Sisters Corp. and State of Wyoming

The Union Carbide well is located approximately 5 km (3 miles) east of the project area and is occasionally used by exploration drill crews. The total depth of this well is given as 88 m (290 ft), the depth to water is given as 32 m (105 ft), the yield is given as 109 m^3/d (20 gpm), and there is no indication as to the geologic formation being tapped. The other two wells, located more than 13 km (8 miles) south of the project area in the Great Divide Basin, are used for stock watering. State Engineer's records indicate that the Osborne No. 1 well is 59 m (192 ft) deep [19 m (65 ft) to water] and has a yield of 109 m^3/d (20 gpm), and that Olson No. 1 is a flowing well, 3 m (10 ft) deep, with a yield of 27 to 55 m^3/d (5 to 10 gpm).

Table 3.22. Target restoration values

All values are in mg/liter unless otherwise indicated

Parameter	Baseline range[a]	Livestock criteria[b]	Domestic criteria[b]	Target restoration values[c]
pH, pH units	8.09–11.4	6.5–8.5	6.5–8.5	6.5–Baseline
Total dissolved solids	1330–1812	5000	500	Baseline
Ammonia, as N	0.07–2.9		0.5	Baseline
Nitrate, as N	0.01–0.39	10.0	10.0	10.0[d]
Nitrite, as N	−0.01[e]	1.0	1.0	1.0
Bicarbonate	0–190			500[f]
Carbonate	10–48			(total carbonate)
Chloride	9–52	2000	250	250
Fluoride	0.66–1.2		1.4	Baseline
Sulfate	725–1100	3000	250	Baseline
Ca	12–62			500[f]
B	0.26–0.38	5.0	0.75	Baseline
Mg	0–8			250[f]
K	4.9–16			Baseline
Na	320–495			Baseline
Al	−0.1	5.0		Baseline
As	−0.4	0.2	0.05	Baseline
Ba	−0.05		1.0	1.0
Cd	−0.02	0.05	0.01	Baseline
Cr	−0.01	0.05	0.05	Baseline
Cu	−0.01	0.50	1.0	Baseline
Fe	0.01–0.13		0.30	Baseline
Pb	−0.05	0.10	0.05	Baseline
Mn	−0.01		0.05	Baseline
Hg	−0.001	0.00005	0.002	Baseline
Ni	−0.05			Baseline
Se	−0.02	0.05	0.01	Baseline
Zn	−0.01	25	5	5.0
Mo	−0.05			Baseline
V	−0.1	0.10		Baseline
U	0.001–0.04	5.0[g]	5.0[g]	5.0[g]
^{226}Ra, pCi/liter	2.2–419.3	5.0[h]	5.0[h]	Baseline

[a] Based on existing data collected from nine wells completed in the mineralized portion of the ore zone aquifer (wells OP-140-TC, OP-141-TC, OP-135, OP-136, 303-6-P 7, 303-6-P 16, 303-6-P 19, 303-6-P 22, and 303-6-P 31).

[b] Criteria are based on water quality standards presented in Appendix A of *Staff Analyses of Comments* (Wyoming Department of Environmental Quality, Jan. 14, 1980, Table I). A blank space signifies that no criteria have been established.

[c] Baseline is defined for each parameter for a given mining unit as the highest value obtained from the three rounds of baseline sampling (four rounds if there is significant variation) collected from the restoration sampling wells within the mining unit. Because of its extreme variation from well to well, ^{226}Ra is the one exception to the definition of baseline as described above. Baseline for ^{226}Ra will be on a well-by-well basis; therefore, ^{226}Ra baseline is defined for each restoration sampling well as the highest ^{226}Ra value obtained from the three rounds of baseline sampling (four rounds if there is significant variation). The Wyoming Department of Environmental Quality reserves the option to go to a restoration-sampling-well-by-restoration-sampling-well basis for all parameters if there is significant water quality variation among the restoration sampling wells within a mining unit. To achieve restoration of a mining unit, the average of the postrestoration values for each parameter (except ^{226}Ra) obtained from the restoration sampling wells during a sample round must be equal to or less than the target restoration value given in this table. Radium-226 restoration is on a restoration-sampling-well-by-restoration-sampling-well basis.

[d] An underlined number means that the restoration value is higher than the expected background concentration.

[e] The minus sign signifies that the parameter was not detected at the level indicated.

[f] Criteria are based on a publication of the U.S. Department of Commerce, *Monitoring Groundwater Quality Monitoring Methodology*, National Technical Information Service, PB-256 0681, June 1976, p. 142.

[g] All uranium data presented in this application are uranium as U_3O_8. Livestock and domestic criteria given in this table for uranium and the restoration value of 5.0 mg/liter of uranium are on the basis of uranium as U. The conversion factor for converting uranium as U_3O_8 to uranium as U is 0.848.

[h] Criteria are for the combined total of ^{226}Ra and ^{228}Ra.

The nearest public water supply is located at Jeffrey City, which is approximately 48 km (30 miles) by air northeast of the project area. The water supply source consists of a number of wells located in and around Jeffrey City.

The nearest producing oil well is approximately 13 km (8 miles) away in the Bison Basin Oil Field. There are two abandoned exploration oil wells within the vicinity of the project area. These wells have been sealed in accordance with State and Federal standards. The locations and other particulars on the two wells are as follows:

	Sohio Unit 2	Max Pray Unit 1
Location (both in T27N, R97W)	SE1/4/SE1/4, Section 24	SE1/4/NE1/4, Section 25
Surface elevation	2156 m (7072 ft) (ground)	2146 m (7040 ft) (derrick floor)
Total depth	588 m (1928 ft)	1128 m (3700 ft)
Date plugged and abandoned	September 1959	June 1959

3.7 GEOLOGY, MINERAL RESOURCES, AND SEISMICITY

3.7.1 Geology

3.7.1.1 Regional geology

The project site is located in south-central Wyoming on the southeast flank of the Wind River uplift and about 6 km (4 miles) north of Cyclone Rim, the topographic divide between the Great Divide Basin and the drainage of West Alkali Creek. This divide is also part of the continental divide (Fig. 3.2). The immediate area in which the project is located is known as the Bison Basin area or, alternatively, the Cyclone Basin area.

The geologic setting of basin and range is common throughout Wyoming. The basins usually contain Tertiary rocks of Eocene or Paleocene age, and the ranges have Precambrian granite or metasedimentary cores. The northern rim of the Great Divide Basin and the Sweetwater uplift are unusual in that rocks of Tertiary Oligocene, Miocene, and Pliocene ages are present. This variety of rocks is generally attributed to the late faulting that occurred in the area. The downthrust blocks along these faults contain the preserved late-Tertiary formations.

The Tertiary sedimentary formations in this region have continental origins. The topographic highs or mountain range cores provided most of the source material for the Paleocene and Eocene formations. The materials included the coarse clastics and feldspar-quartz sands for formations with alluvial fans and fluvial depositional environments, and the finer siltstone and mudstone materials are found in rocks with lacustrine environments. The formations of later Tertiary age in the Oligocene, Miocene, and Pliocene are basically derived from reworking older formations and from extensive volcanics that occurred to the northwest in the Idaho and Yellowstone areas.

3.7.1.2 Paleotectonic history

Prior to the Laramide orogeny, the area had experienced many periods of marine deposition followed by erosion. Sometime during the Cretaceous period, however, a moderate but increasing downtrend began in southern Wyoming basins and continued through the Laramide orogeny.

The Laramide orogeny, starting with normal faulting and mountain building, with subsequent erosion, was the beginning of continental disposition in the basins the result of which was formations such as the Fort Union formation.

This period of quiet was followed by thrust faulting in late Paleocene time. All of the mountain ranges in southwestern Wyoming — Uinta, Wind River, and others — were in existence at the beginning of the Eocene epoch as were the Rock Springs uplift and other anticlinal bulges now buried under younger Tertiary sediments.

Downwarping of the floor of the Great Divide Basin as well as that of the surrounding Wind River, Green River, and Washakie basins continued intermittently throughout the Eocene. These basins were responsible for catching the detrital material from the mountain ranges. The sedimentation resulted in such formations as the Wasatch-Battle Springs member, Green River-Laney member, Bridger formation, and the Uinta formation, which is not present at the project area.

Some uplift of the marginal mountain areas and other minor deformations, such as faulting and gentle warping, occurred during the early Eocene, between the end of the Eocene and Miocene, and again after the Miocene. These late deformational activities were accompanied with deposition from remaining mountain highs and from volcanic tuffs or ash falls from activity to the northwest.

3.7.1.3 Site geology

As stated previously, the uranium ore body to be mined by in situ leaching is in a sandstone unit of the Laney member of the Green River formation of Lower Eocene age. Figure 3.15 contains the complete stratigraphic column for the project area and includes sedimentary rock units of the Paleozoic, Mesozoic, and Cenozoic eras.[17] Bedrock formations exposed on the project site and the immediate vicinity are shown in Fig. 3.4. A plan view of the ore trend is given in Fig. 3.9, and typical cross sections through the ore body are presented in Figs. 3.16, 3.17, and 3.18.

The area of interest was mapped by the U.S. Geological Survey in 1966[15] and 1974.[17] This work provides the basic structural and stratigraphic framework, which has been modified for the purposes of the Bison Basin Project by detailed geologic data from the surface and subsurface exploration of Ogle Petroleum.

The dominant middle-upper Tertiary Age structural features are the McKay Lake-Daley Lake synclinal basins, bounded on the north by the Horsetrack anticline and on the south by the Mesa anticline.[17] The project area is located on the north side of the McKay Lake-Daley Lake syncline basin (Figs. 3.4 and 3.5).

Because the uranium ore zones to be mined by in situ leaching are restricted to the basal sands of the Laney member of the Green River formation of Eocene age, only the lithologic descriptions of the Battle Springs formation (Lower Eocene) and younger formations are described. Units will be described from youngest to oldest. Almost all the submitted geologic information from the site comes from the first mine unit (Fig. 2.4). Although the staff considers this information to be representative of the entire site, the applicant will be required to supply additional information to confirm the continuity of the geology at the other mine units before these units are mined.

Arikaree formation (Lower Miocene)

These conglomerates are 0 to 46 m thick (0 to 150 ft) near the base of the unit, made up of cobbles and boulders derived from Precambrian metagraywacke and granite, and loosely cemented in light gray, feldspathic, tufaceous sandstone. A lack of conformity exists at the base of the unit. Groundwater is not present in this formation at the project site.

Bridger formation (Upper Eocene)

The Bridger formation is composed of siltstones, sandy mudstones, gray, yellowish-gray, and greenish-gray to light olive. Some dolomite and hard, cherty, algal limestone lenses are present. Lenticular beds [0.3 to 0.6 m thick (1 to 2 ft)] of oolitic limestones occur locally in the upper part of the formation. Two persistent sandy bentonite beds occur within the project area; these beds show a distinctive pattern on the resistivity curve of the electric logs in exploratory drill holes (Fig. 3.6).

This unit occurs in the project area within the south flank of the Horsetrack anticline in Section 25, T27N, R97W, and extends eastward into Section 30, T27N, R96W. The unit, thinning northward, is approximately 30 to 91 m thick (100 to 300 ft) in the project area. The lower contact is conformable over the Laney member of the Green River formation.

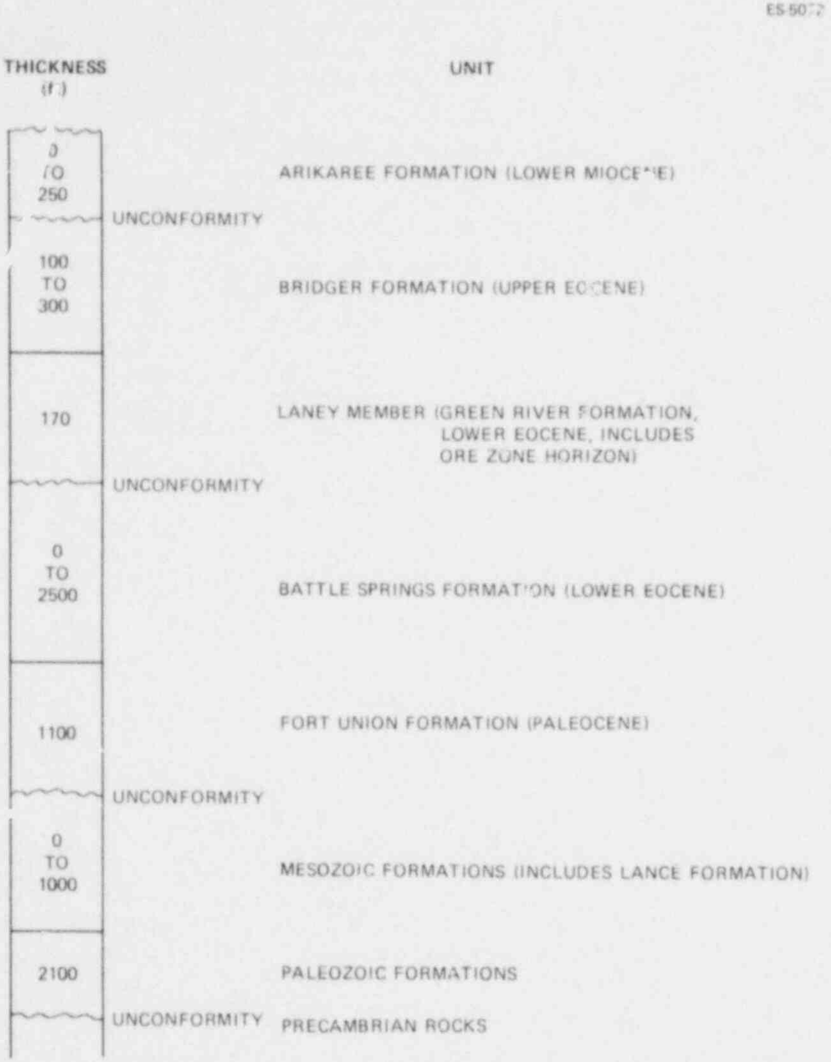

Fig. 3.15. Stratigraphic column for the project area. Source: ER, Fig. 2.4-11.

To conform with the stratigraphic nomenclature and mapping of Denson and Pipiringos,[17] the base of the Bridger formation is defined in this area as the base of the second bentonite bed observed in the subsurface electric logs (Fig. 3.6).

Groundwater has been encountered in this unit during drilling at a depth from 15 to 20 m (50 to 65 ft) below the land surface. It occurs in a 1- to 1.3-m (3- to 4-ft) sand unit and appears to be under unconfined conditions (see Sect. 3.6.2.2).

Laney member (Green River formation - Lower Eocene)

The Laney member is composed of siltstone and mudstone with interbedded fine- to coarse-grained (locally conglomeratic) sandstones, numerous hard, cherty, algal limestone lenses, and a basal mudstone unit. Thickness in the project area is 76 to 79 m (250 to 260 ft).

A detailed lithologic description of these geologic structures (Fig. 3.6) follows:

ES-5082

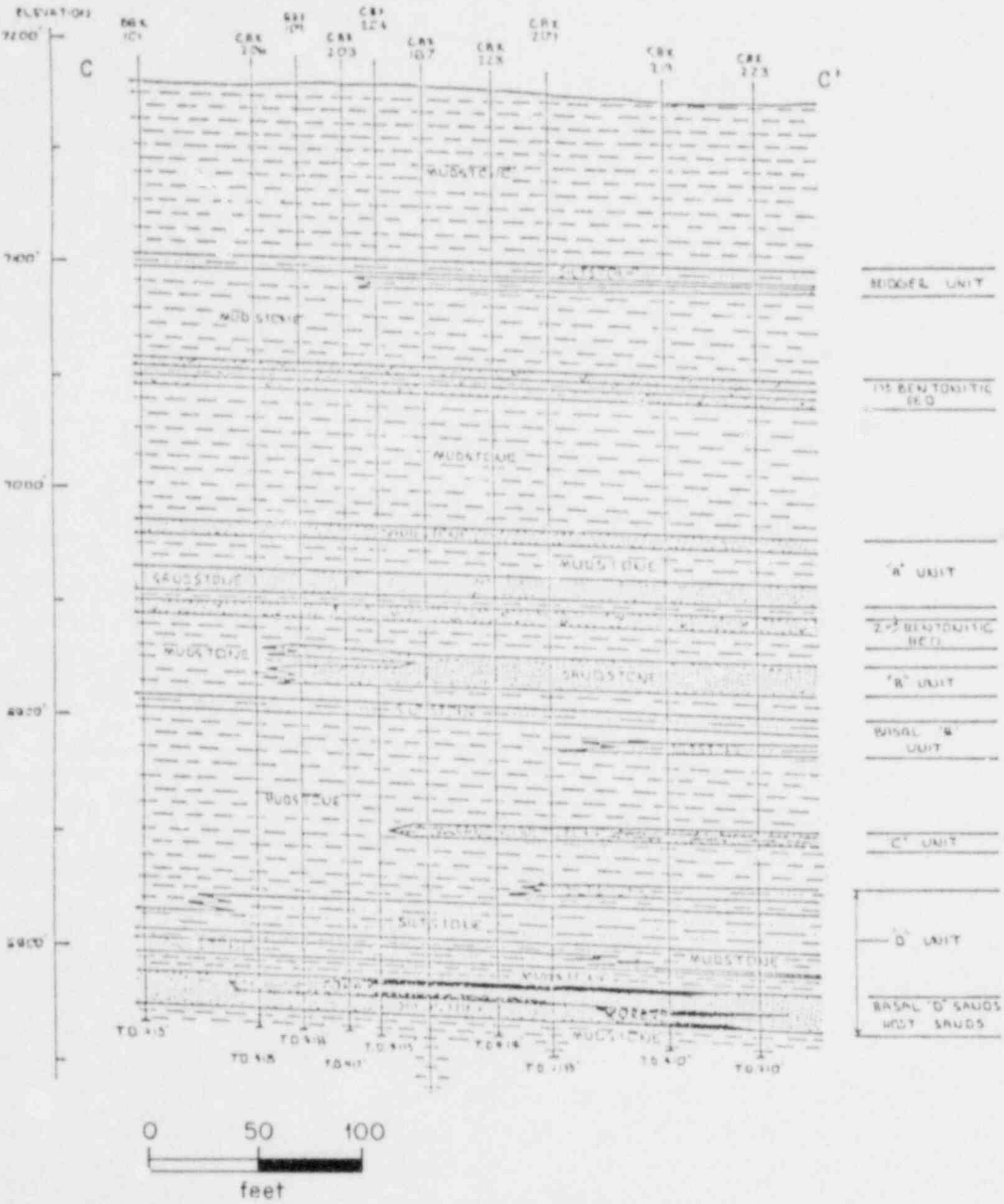

Fig. 3.16. Geologic section C-C' of ore body. (Refer to Fig. 3.9.)
Source: ER, Fig. 2.4-5.

ES-5069

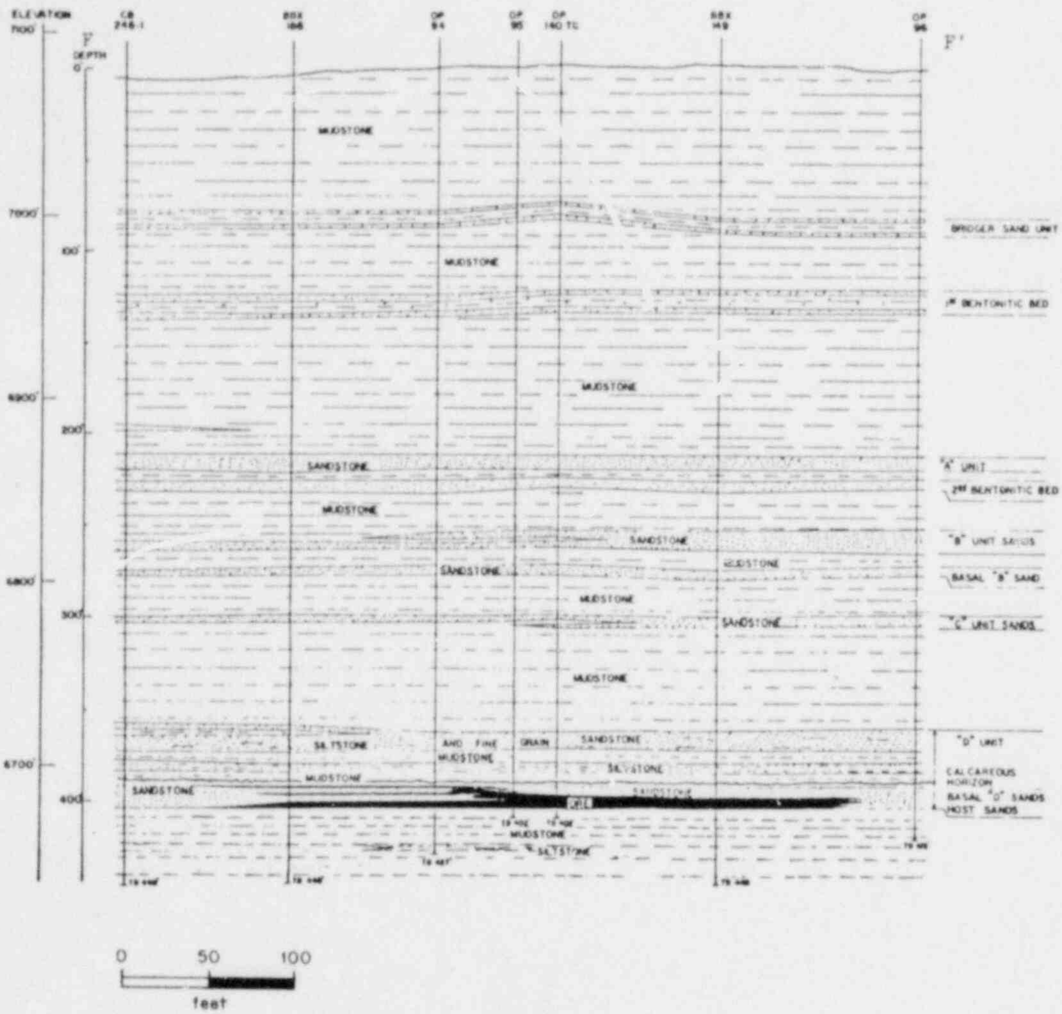

Fig. 3.17. Geologic section F-F of ore body. (Refer to Fig. 3.9.)
Source: ER, Fig. 2.4-8.

ES-5071

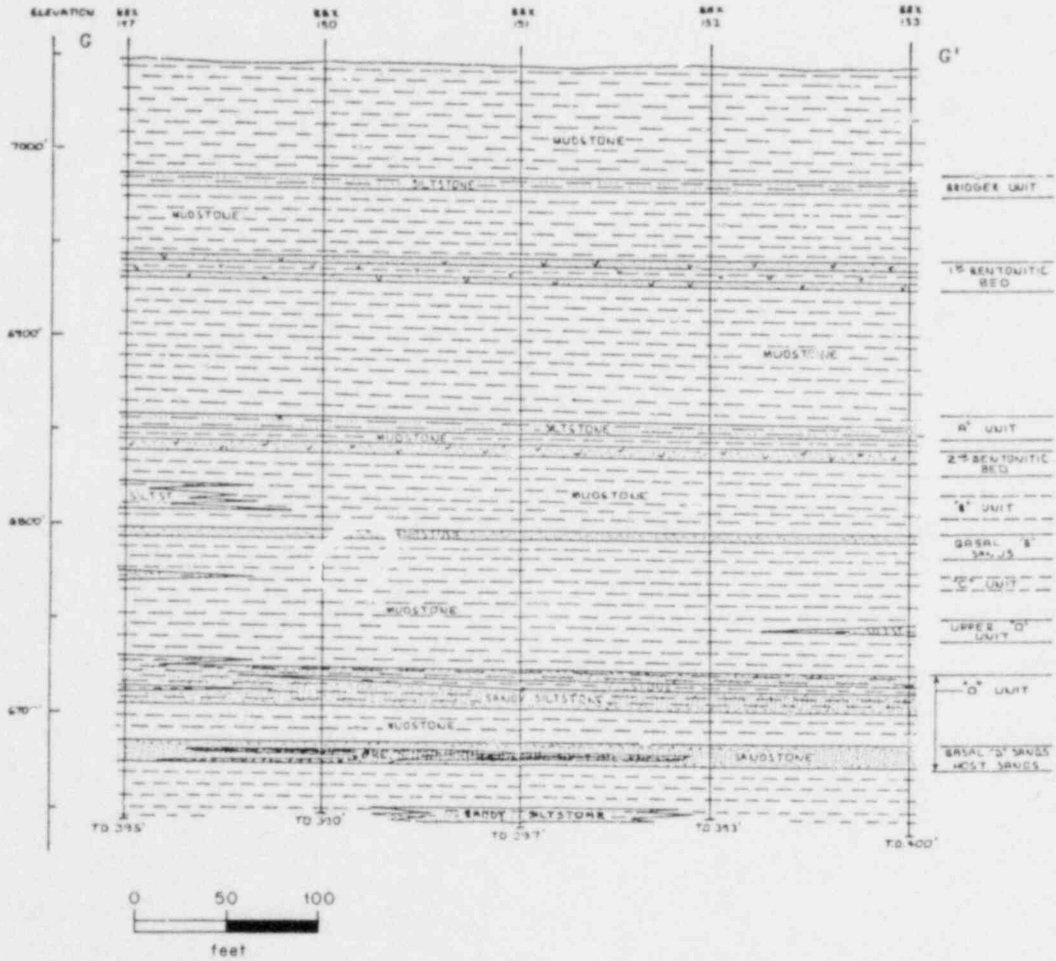

Fig. 3.18. Geologic section G-G' of ore body. (Refer to Fig. 3.9.)
Source: ER, Fig. 2.4-9.

Average thickness	Description
4.5 m (15 ft)	Top of the unit gray to pale olive mudstone, with local limestone lenses [less than 0.1-m (0.5-ft) thick].
7.6 m (25 ft)	Interbedded mudstones, siltstones and sandstones, designated "B" unit in Fig. 3.6. Basal "B" sandstone is a fine- to coarse-grained sand with subangular quartz (40 to 50%), feldspars (10 to 20%), other rock fragments (30 to 50%). There is fair to good porosity, a potential aquifer.
15 m (50 ft)	Mudstones with interbedded silty to very fine-grained sandstones. The sandstones — designated "C" unit in Fig. 3.6 — are light gray to olive gray and are found with limestone beds 0.03- to 0.09-m (0.1- to 0.3-ft) thick. There is no apparent porosity in the sandstone beds.
24 m (80 ft)	Mudstones, siltstones, and interbedded sandstones. Designated "D" unit in Fig. 3.6. Basal sandstone is the host rock of uranium ores and is well developed. Thickness varies from about 2.4 to 6.7 m (8 to 22 ft). The sandstone is usually fine- to coarse-grained and has poor to fair sorting. It is composed of quartz (30 to 40%), feldspars (15 to 20%), calcareous fragments (5%), pyrite, and other rock mineral grains. Organic matter is sparse (1%), and porosities are high. The basal ore sand has been tested as a low-yield aquifer, 55 to 82 m^3/d (10 to 15 gpm).
30 m (85 ft)	Mudstone, olive gray, good sorting, hard.

Battle Springs formation (Lower Eocene)

The Battle Springs formation, of Eocene Age, represents a large alluvial fan complex. It consists of alternating, coarse-grained, arkosic sandstones, mudstones, and siltstones. It is characterized by frequent lateral facies changes. In the Great Divide Basin, to the south and southwest, the formation grades into and intertongues with the Wasatch and Green River formations. Only partial sections of this formation have been penetrated in exploratory holes drilled in the project area.

3.7.1.4 Geologic structure

Several normal faults, forming horst and graben block features, have been delineated by exploratory drilling (Fig. 3.9). These faults generally run east to west. Displacements are small and variable [maximum displacement 15 m (50 ft)]. Displacements along the faults reveal no apparent surface expression and appear to be larger at greater depth, becoming smaller upward.

3.7.2 Mineral resources

Fremont County contains important mineral resources of uranium, oil, natural gas, and iron ore.

3.7.2.1 Uranium

Major uranium fields were discovered in 1953 in the Gas Hills area of eastern Fremont County and the Crooks Gap area to the south. Nearly all of the mining in the Gas Hills area is by the open pit method, whereas both open pit and underground mining exists in the Crooks Gap area. Uranium deposits, which underlie at least 89,000 ha (220,000 acres), are estimated to total at least 27×10^6 kg (60×10^6 lb) in the Gas Hills and Crooks Gap districts.

The Great Divide Basin of Sweetwater County has extensive low-grade uranium deposits that have recently become more economical as high-grade deposits have been depleted elsewhere. There have been announcements of new mine and mill operations in this area. The Shirley Basin area of Carbon County is reporting increased activity in uranium development.

3.7.2.2 Oil and natural gas

In Fremont County, crude oil reserves are estimated at 9.7×10^6 m^3 (61×10^6 bbl), and gas reserves are estimated at 14×10^9 to 28×10^9 m^3 (5×10^{11} to 10×10^{11} ft^3).

Oil production is expected to decline slowly in the future, while natural gas production is expected to double or triple in the years ahead.

Sweetwater County has abundant deposits of undeveloped oil shale. Like oil shale, gas and oil reservoirs have been identified in many geologic formations in the County; but, to date, commercial production has been limited to about a dozen different fields.[18]

3.7.2.3 Iron ore

Primarily from an open pit magnetite mine near Atlantic City, iron production in Fremont County averages about 3600 t (4000 tons) of iron pellets per day. The reserves in this formation are approximately 109×10^6 t (120×10^6 tons), and major production is expected to continue at the present levels for at least 20 years.

3.7.2.4 Coal

Coal is no longer actively mined in Fremont County. It is estimated that there are 665×10^6 t (733×10^6 tons) of subbituminous grade coal in the county. Because most of it cannot be strip-mined, it is expected that significant amounts will not be produced in the near future.

3.7.3 Seismicity

The area of Central Wyoming where the Bison Basin Project is located lies in a seismically relatively quiet region of the United States (Fig. 3.19). Few earthquakes capable of producing damage have originated in this region. Only one earthquake of Intensity V has occurred within a 100-km (62-mile) radius of the Bison Basin Project. This was the November 23, 1934, earthquake near Lander, which caused slight damage and frightened some people in that town. It was also felt as a somewhat lesser shock in South Pass about 40 km (25 miles) west of the site of the Bison Basin Project.[19]

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 normal faulting. Part of this seismic belt extends along the Wyoming-Idaho border, more than 200 km (124 miles) west of the Bison Basin Project, and would be the most probable source of earthquakes affecting the project area.

A recent probabilistic acceleration map of the contiguous United States[20] 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.

3.8 SOILS

Soils in the permit area were mapped by photointerpretive techniques, field reconnaissance, and profile descriptions. Soil samples obtained from auger holes drilled at representative locations indicate that there are three soil types and rock outcrops in the area. The ER Supplement contains descriptions and classifications of the typical soil profiles of each identified soil.

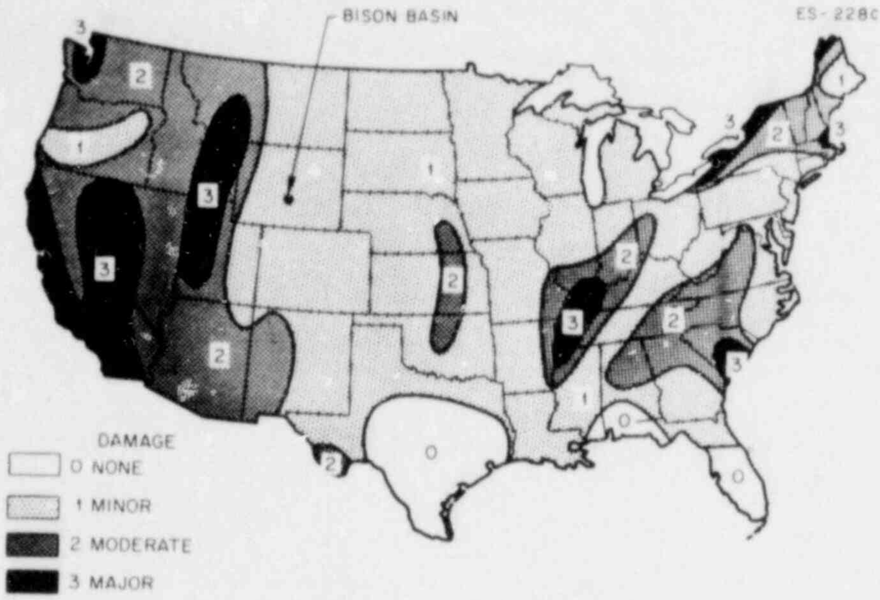

Fig. 3.19. Seismic risk map of the United States. Source: S. T. Algermissen, *United States Earthquakes*, U.S. Government Printing Office, Washington, D.C., 1968, Fig. 2.4.

The soils of the Bison Basin Project region are residual and are classified within the Torriorthents-Haplargids-Rock Outcrop association, according to the *General Soil Map of Wyoming*.[21] In the immediate vicinity of the permit area, 90% of the soils covering the project area are rocky, coarse, silty, or sandy loams. The soils are generally calcareous and mildly alkaline. As discussed in Sect. 4.2, this type of soil is usually adequate for successful reclamation. About 10% of the area is underlain by rock outcrops or by a thin (about 0.1-m thick) sandy loam developed over conglomerate rock. Though this soil has a high sodium and calcium content, it is still adequate for reclamation.

3.9 BIOTA

3.9.1 Terrestrial biota

The site and surrounding area, which are dominated by bluebunch wheatgrass (*Agropyron spicatum*) and big sagebrush (*Artemisia tridentata*), are classified as potential sagebrush steppe.[22] The species composition and population densities of plant and animal communities are severely restricted by the lack of growing season moisture and by low winter temperatures.

3.9.1.1 Plant communities

Dominant plant communities are comprised of only a few species of simple vertical structure. Abrupt changes in species distribution, plant density, and ground cover are typical because of the interaction of high water stress with changing slope gradients, exposure, and soil characteristics. The applicant defined and mapped nine distinctive plant communities that occur on the project site (ER, Sect. 2.8.1, Fig. 2.8-1).

Approximately two-thirds of the 304-ha project area is dominated by big sagebrush communities [moderate and sparse big sagebrush, 41%; big sagebrush with greasewood (*Sarcobatus vermiculatus*) and/or rabbit brush (*Chrysothamnus nauseosus*), 5%; big sagebrush with cushion plants (*Phlox* sp., *Arenaria* sp., *Hymenoxys* sp.), 20%]. Cushion plant communities without big sagebrush constitute another one-third of the project area vegetation [cushion plants, 26%; cushion plants with saltbush (*Atriplex nuttallii*), 4%; cushion plants with grassland, 2%]. Barren land with sparse vegetation cover, saline meadows, and saltbush shrub communities each comprise less than 2% of the project area. Information describing the community structure, density, and species composition is available in the ER, Sect. 2.8.1.

The project facilities are to be sited upon cushion plant and big sagebrush communities. The cushion plant communities occur on upland benches and terraces. Dominant plants [phlox (*Phlox* sp.), sandwort (*Arenaria* sp.), and actinea (*Hymenoxys* sp.)] provide up to 20% cover. Wheatgrass (*Agropyron* sp.) is common with occasional needlegrass (*Stipa* sp.) and blue grama (*Bouteloua gracilis*). The community exists on the driest portions of the project area and shows strong evidence of wind erosion (ER, Sect. 2.8.1).

Big sagebrush shrubland occurs on drier upland swales and gentle slopes. Vegetation averages 0.25 m in height. Cushion plants, wheatgrass, and needlegrass form the understory, with occasional Nuttall's saltbush. Species diversity is low; even when understory plants are included, vegetative cover rarely reaches 30%.

3.9.1.2 Important plant species

According to the U.S. Department of the Interior, no Federally listed endangered or threatened plant species occur in the region (H. E. Stiles, Acting Regional Director, U.S. Fish and Wildlife Service, U.S. Department of the Interior, Denver, Colo., letter to H. J. Miller, Section Leader, Division of Waste Management, U.S. Nuclear Regulatory Commission, Nov. 23, 1979). In addition, no plants are listed as "protected."

Big sagebrush is important to browsing species; wheatgrass, grama, and needlegrass are important to grazers.

3.9.1.3 Animal communities

Low wildlife density and diversity characterize animal communities in the vicinity of the project. Animal species are limited by the low density, stature, and diversity of the vegetation; by the competition for food with domestic livestock; and by the wide variance in water availability and temperature.

3.9.1.4 Important animal species

Ten Federally listed endangered and threatened wildlife species occur in Wyoming,[23] but only the bald eagle and black-footed ferret are likely to be present in the project area, according to the U.S. Department of the Interior (H. E. Stiles, letter to H. J. Miller, Nov. 23, 1979).

The bald eagle could be a migrant in the area or could utilize the project site for hunting. However, because the closest potential nest-site areas are 8 km away,[23] the project site is unlikely to contain habitat necessary for survival of bald eagles.

The black-footed ferret is strictly dependent upon prairie dogs for food. Its decline is attributed to twentieth-century programs to eradicate prairie dogs from rangeland.[24] Of 105 prairie dog sightings in Wyoming, 102 occurred in sagebrush–prairie habitat similar to that at the project site. In addition, white-tailed prairie dog burrows were observed at the site at approximately one per every 1 to 2 ha in many upland locations (ER, p. 153).

Presence of the black-footed ferret at the project site appears to be highly unlikely, however, because concentrations (towns) of prairie dogs necessary to feed a ferret family year-round were not observed;[23] because black-tailed prairie dogs, which more frequently form densely populated villages, were not observed;[23] because black-footed ferrets are not recorded from the area by the Wyoming Game and Fish Department;[24] and because activities required to construct current site facilities would have driven away any animals that are sensitive to man's presence. The NRC staff observed no prairie dog burrows or villages at proposed facility locations.

Economically important wildlife at the site include antelope, sage grouse, rabbits, and coyotes. Antelope utilize the site area for summer range and as a migratory route for one of the few remaining migratory antelope herds. The herd summers near Pickett Creek and winters near Rawlins (ER, Sect. 2.8.2). Mule deer have not been observed in the project area, although areas as close as 1 to 2 km are classified as mule deer year-long range (ER, Sect. 2.8.2).

Sage grouse winter and nest in drainage bottoms of the area. The nearest known strutting ground is approximately 16 km northeast of the project site. The site region in general is one of Wyoming's better sage grouse hunting areas (ER, Sect. 2.8.2). White-tailed jackrabbit, desert cottontail, and Nuttall's cottontail rabbit, in addition to coyote, also occur on the site (ER, Sect. 2.8.2, and refs. 23 and 25).

3.9.2 Aquatic ecology

No baseline data on aquatic biota are available on or near the project site. The ephemeral washes draining the site are likely to support only a very few, if any, forms of aquatic life. Grassy Lake, although intermittent, has a hydroperiod long enough to support algae, bacteria, and invertebrate populations during its aquatic phase. Colonization after lake refill by spring runoff is probably rapid and occurs by means of aeolian transport, by "hatching" of drought-resistant spores and cysts, and possibly by emergence from the moist lake bottom. Life cycles of many aquatic species are synchronized with seasonal hydrologic changes in these intermittent aquatic ecosystems.[26] Diversity and productivity may be high at first as nutrient and energy resources are exploited but will likely decrease as lake salinity increases (because of evaporation) and more saline-tolerant species dominate. Although some amphibians such as the spadefoot toad (*Scaphiopus* sp.)[27] may live along the shores of Grassy Lake, no aquatic vertebrates are likely to inhabit the lake. As the lake becomes increasingly more saline and eventually dries in late spring or summer, many algal and animal species produce eggs, spores, or cysts which are resistant to dessication and which initiate recolonization and repopulation of the lake when the hydroperiod repeats itself the following spring.

West Alkali Creek is intermittent and, according to observations by the staff and discussions with Wyoming Game and Fish Department staff, does not appear to have permanent pools upstream of its confluence with Sulphur Creek [about 10 km (6 miles) downstream from the project site]. Aquatic ecology of temporary pools in West Alkali Creek will be similar, though smaller in scale, to that of Grassy Lake. Permanent pools in other small streams in the area support fish, notably creek chubs (*Semotilus atromaculatus*), lake chubs (*Hybopsis plumbea*), fathead chubs (*Hybopsis gracilis*), white suckers (*Catostomas commersoni*), mountain suckers (*Pantosteus jordani*), fathead minnows (*Pimephales promelas*), longnose dace (*Rhinichthys cataractae*), and bigmouth shiners (*Notropis dorsalis*), and the attendant trophic structure, which supports fish.[28] Downstream, Alkali Creek and the Sweetwater River support naturally spawning brook (*Salvelinus fontinalis*), brown (*Salmo trutta*), and rainbow trout (*Salmo gairdneri*), and these streams have been classified as important trout fisheries by the Wyoming Game and Fish Department.

Hynes has noted that intermittent streams frequently support surprisingly diverse aquatic communities, especially if there are permanent pools.[29] Even intermittent desert streams may develop rich invertebrate faunas and a diverse algal flora.[26] Intermittent streams without permanent pools may be recolonized from downstream or, in the case of some species, from in situ resting stages, and, when flowing, temporarily support high rates of primary and secondary productivity. These streams may be important nursery areas for fish. With these considerations, West Alkali Creek may temporarily support a relatively rich aquatic flora and fauna, including fish (but probably not trout), and may be very important to downstream secondary productivity due to exported organic matter and migrating individuals.

3.9.2.1 Important aquatic species

Aquatic habitats on or near the site are not suitable for the humpback chub (*Gila cypha*) or the Kendall Warm Springs dace (*Rhinichthys osculus thermalis*), the only nationally recognized endangered species of fish reported for Wyoming.[30] Staff at the Wyoming Game and Fish Department know of no endangered or threatened species of fish in this area of Wyoming.

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4. ENVIRONMENTAL CONSEQUENCES

4.1 INTRODUCTION

The discussion of other energy alternatives (Sect. 1) concludes that no other alternative is a direct replacement for uranium recovery at this site. Including the present proposal, the alternatives, if uranium ore on the site is mined and refined, are then considered in detail. This section draws upon that material to consider and compare both the environmental impacts of the present proposal and the possible alternatives. This section forms the scientific and analytic basis for the judgments made in Sect. 2. The following descriptions provide information necessary to evaluate the consequences.

4.2 AMENABILITY OF THE ORE DEPOSIT TO IN SITU LEACHING

Amenability of the Bison Basin ore body to in situ solution mining was first demonstrated by two push-pull tests conducted in mid-1977 in two wells (OP-140-TC and OP-141-TC). The locations of these wells are shown in Fig. 3.7.

A more extensive and detailed demonstration has been completed. Under Source Material License No. SUA-1336, solution mining operations began on May 1, 1979, with respect to a 136-m^3/d (25-gpm) research and development operation on a 0.37-ha (0.93-acre) tract. The location and well-field configuration of the research and development tract are shown in Fig. 4.1, which shows that the research and development mining unit consists of a row of four injection wells separated from each other by a distance of 6 m (20 ft) and a parallel row of three recovery wells separated from each other by 12 m (40 ft), with 11 m (36 ft) between the injection row and the recovery row. A fourth well (P-19) is located outside the unit, 24 m (80 ft) to the west. This well plus wells P-7, P-16, P-22, and P-31 were used as restoration sampling wells.

Four guard wells (two injection wells and two recovery wells) are located 22 m (72 ft) north and south of the mining unit. Their purpose was to provide early warning of a lixiviant excursion and, if necessary, to induce a hydraulic gradient to return, and to confine the leachate to the well pattern area.

Five monitor wells in the production zone aquifer ("D" sands) surround the mining unit. They are located about 61 m (200 ft) from the boundaries of the 0.37-ha (0.93-acre) tract. In addition, a well (M-3) was completed in the upper aquifer to monitor vertical excursions.

The lixiviant used in the nominal 136-m^3/d (25-gpm) operation was sodium carbonate and sodium bicarbonate; oxygen (and occasionally hydrogen peroxide) was used as the oxidant. The previous push-pull tests in wells OP-140-TC and OP-141-TC used ammonium carbonate and ammonium bicarbonate as the lixiviant agent and hydrogen peroxide as the oxidant. Leaching was completed on July 31, 1979.

During the three-month mining period, about 126 kg (1600 lb) of uranium (as U_3O_8) was recovered from the ore zone. The average uranium concentration was 82 mg/liter, and the average flow rate was 105.7 m^3/d (19.4 gpm). About 25 aquifer pore volumes were circulated through the production zone before the uranium concentration fell to uneconomic recovery levels.

The staff believes that these results clearly demonstrate that the unit one ore body is amenable to in situ leaching and that injected fluids will be confined to the ore body. The staff does believe that the favorable characteristics of the unit one ore body apply to the rest of the proposed mine area; however, it will be a license condition that the applicant submit confirmatory information on other units prior to developing them.

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.

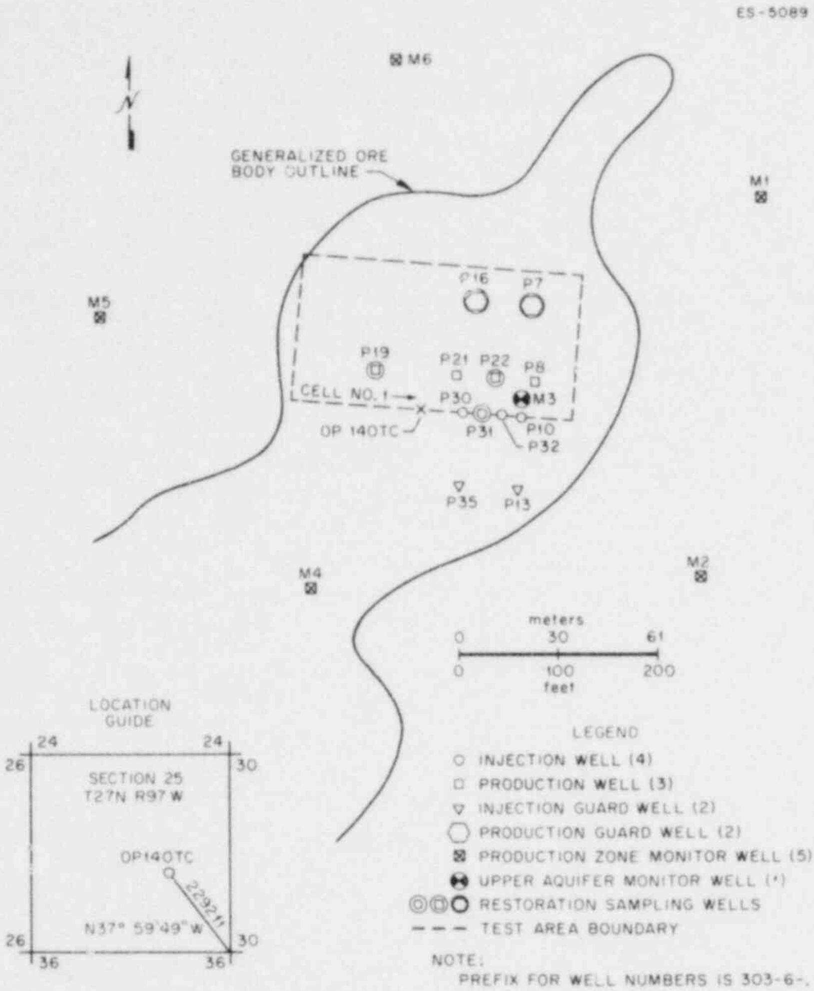

Fig. 4.1. Well-field layout. All wells are completed in the ore body aquifer ("D" sands) except M3, which is in the "B" sands. Source: ER, Fig. 3.1-1.

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 its 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 currently in the developmental stage, test results to date indicate that satisfactory levels of restoration can be achieved.

Restoration criteria

The consumptive use of water, the disposition of solid wastes, and additional costs must be optimized against groundwater condition if solution mining is to be a viable technique for recovery of uranium resources. In line with this, the staff 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 aquifer. The zones are defined as follows:

1. Mining zone — the area within the mineralized (ore deposit) portion of the aquifer. The perimeter of this zone is defined as one well spacing [about 15.2 m (50 ft)] either beyond the outer injection wells or the limit of the ore deposit to be mined. At the Bison Basin site, groundwater (as determined from the highest concentrations in wells) within this zone naturally contains concentrations of radium-226 that exceed drinking-water standards (419 vs 5 pCi/liter). The quality of the groundwater is such that the water is unfit for either domestic or livestock consumption. Groundwater within this zone will be affected by 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. Trend wells may be placed within this zone. At the Bison Basin site, groundwater quality in this zone (excluding wells placed in mineralized areas) is generally suitable for livestock use. However, 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 or better when such constituents exceed applicable standards, that is, for drinking water or for the use of wildlife and livestock (Table 3.22). Where the premining quality of the groundwater meets either drinking water or livestock watering standards, the appropriate established State or Federal criteria will be used to establish maximum permissible chemical concentrations for restoration purposes.[1] If there are no applicable criteria, a level should be selected for restoration that is consistent with public health and safety.

The target restoration values agreed to by the Wyoming Department of Environmental Quality and the applicant are given in Table 3.22. The number of restoration wells proposed by the applicant averages about one for every two acres of ore body. The staff concurs with the restoration target values and the density of restoration wells.

4.3.2 Applicant's restoration test

Starting August 5, 1979, approximately one nominal pore volume was pumped from the pilot well field to the evaporation pond. This operation, completed on August 9, 1979, represented the lixiviant that would be transferred to a new well field during commercial operation. From August 10 through September 14, 1979, fluids from the recovery wells were routed to a reverse osmosis (RO) unit. The clean water from the RO unit was reinjected into the pilot well field, and the concentrated brine from the RO unit was discharged to the evaporation pond, as would be the case for commercial-scale well-field restoration.

The results for the major ionic constituents from production well P-22 are shown in Fig. 4.2. The restoration test demonstrated that staff objectives for restoration could be realized. Bicarbonate and chloride exceed baseline as shown in Fig. 4.2 because neither is at levels unacceptable for any water use. (For public drinking water, the chloride maximum is 250 mg/liter, and no standard exists or is needed for bicarbonate.)

Conductivity, a reasonable measure for total ionic content, was restored to baseline after a nominal five pore volumes of RO treatment.

None of the minor constituents or trace elements exceeded drinking water standards after restoration.

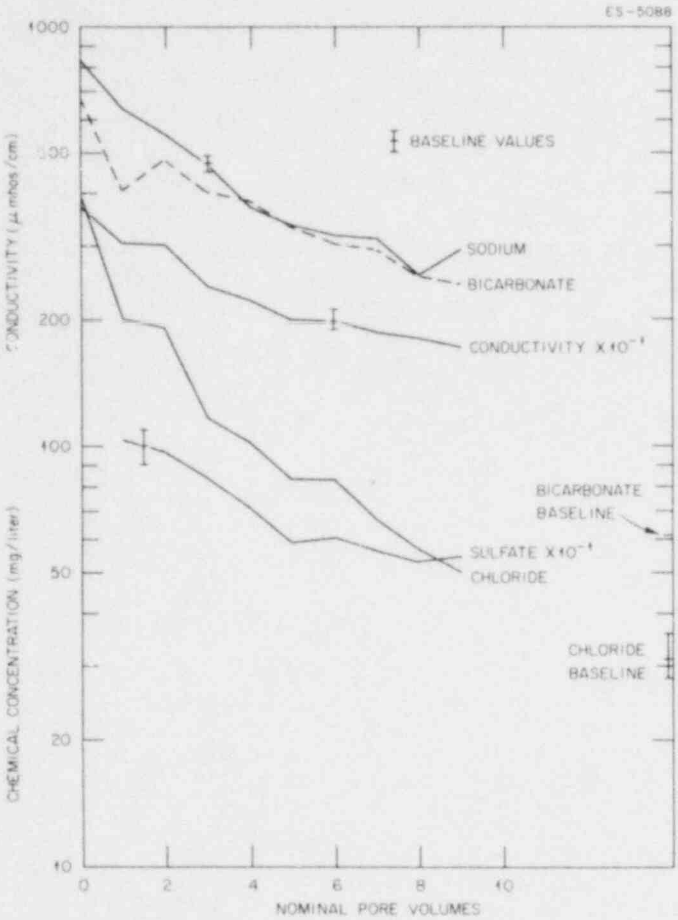

Fig. 4.2. Major ionic constituents from production well P-22.

Monitoring through March 18, 1980, showed either no increase or an insignificant increase for the constituents in monitored wells (Fig. 4.1). Radium-226 exceeded applicable standards both before and during mining.

The applicant calculated the nominal pore volumes of 437 m^3 (115,000 gal), using only 0.6 to 0.76 m (2 to 2.5 ft) for lixiviant penetration from the well bore external to the well-field dimensions. From a cursory material balance for sulfate, chloride, and sodium ions over the restoration phase, the staff estimates that at least twice this pore volume was affected by the lixiviant during mining. The staff conclusion is that fewer treated pore volumes will be needed for restoration than appears necessary from Fig. 4.2 because the percentage volume affected external to the injection well perimeters decreases radically with an increase in well-field area. The applicant was able to reinject only 62% of the RO unit input. An estimated improvement to 90% reinjection will further reduce the treatment pore volumes required.

4.3.3 Staff conclusions

In the opinion of the staff, the applicant has demonstrated that the restoration of the aquifer to its original/potential use condition is both practical and probable. The staff believes that the applicant can improve RO unit performance to achieve 90% reinjection; this improvement would reduce the water consumption for restoration as well as the evaporation pond volume and surface requirements. The staff considers it necessary for the applicant to mine sequentially; commencing restoration of each mined out unit as mining begins on the next mine unit or as soon as feasible. Sequential mining will be a condition of the license.

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

4.4 MONITORING PROGRAMS AND MITIGATING MEASURES

4.4.1 Preoperational surveys

4.4.1.1 Hydrological

Surface-water baseline

Baseline water quality samples for West Alkali Creek were collected during the spring of 1979. The stream was sampled at two locations — one upstream from the runoff from the project area and one downstream from the runoff from the project area (Fig. 4.3). The results of the baseline sampling are given in Sect 3.6.1, Table 3.15. The applicant is committed to further sampling in 1980 to develop better baseline data.

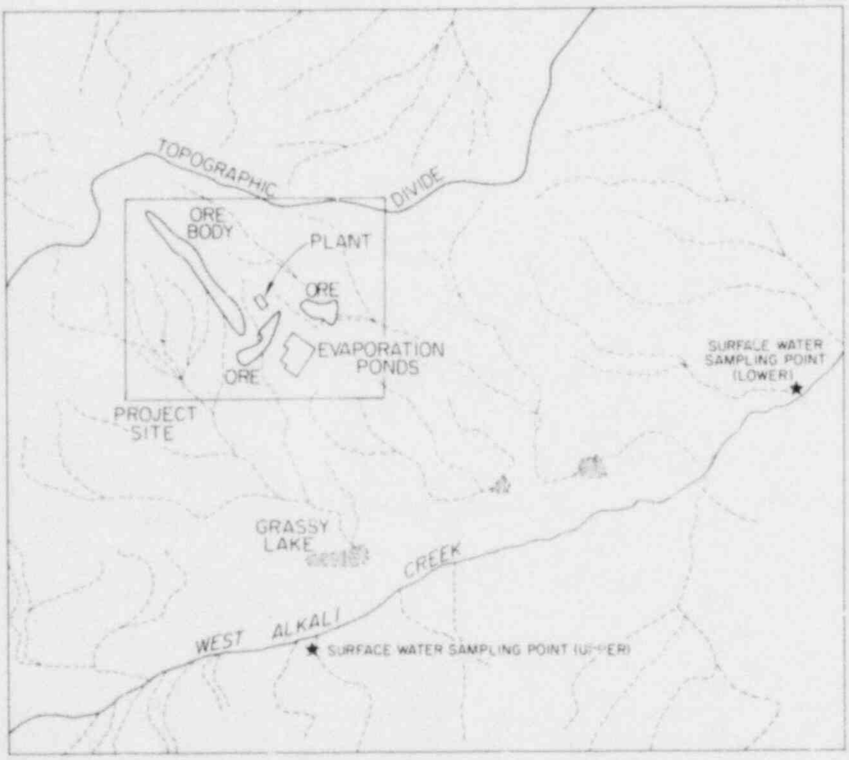

Fig. 4.3. West Alkali Creek surface-water sampling points locations. Source: Adapted from ER, Fig. 2.1-3.

Groundwater baseline

The applicant has obtained baseline groundwater data for the pilot demonstration test as reported in Sect. 3.6.2. The staff considers that the data are representative of the local groundwater and are adequate for assessment of potential impacts.

Except for the evaporation pond monitor wells, the applicant plans to establish baseline water quality for the monitor wells by collecting three rounds of samples from each well, with a minimum of one week between sampling events. Based on information obtained from the 136-m^3/d

(25-gpm) pilot test, the first round of sampling will be analyzed for the parameters on the long list; the second and third rounds will be analyzed for the parameters on the abbreviated list (Table 4.1). Samples will be collected after pumping about 2 casing volumes from the well being sampled. The baseline sampling program for the 136-m^3/d (25-gpm) pilot test established that specific conductivity stabilizes by the time two casing volumes are pumped from the monitor wells.

Table 4.1. Water quality parameter lists

Long list	
pH	As
Specific conductivity	Ba
Total dissolved solids	Cd
NH_4 as N	Cr
NO_3 as N	Cu
NO_2 as N	Fe
HCO_3^-	Pb
CO_3^{2-}	Mn
Ca	Hg
Cl^-	Ni
B	Se
F^-	Zn
Mg	Mo
K	V
Na	U
SO_4^{2-}	^{226}Ra
Al	^{230}Th
Abbreviated list	
pH	K
Specific conductivity	Na
Total dissolved solids	SO_4^{2-}
NH_4 as N	Mn
NO_3 as N	Fe
NO_2 as N	Pb
HCO_3^-	Se
CO_3^{2-}	Zn
Ca	U
Cl^-	

Baseline water quality for the evaporation pond monitor wells will be established by collecting two samples from each well a minimum of one week apart and by analyzing the samples for the parameters on the abbreviated list (Table 4.1).

The required baseline groundwater quality data for a mining unit will be obtained before injecting any chemicals into the production zone aquifer within the mining unit. Baseline for each parameter for each mine unit will be established as the highest value that is obtained from three rounds of sampling from any of the restoration wells in the mine unit. There will be approximately one restoration well per 1 ha (2.5 acres).

The water level in each well used to obtain baseline data will be measured on each sample collection event before pumping the two casing volumes. The water level data will be forwarded to the NRC with the water quality data. The baseline groundwater quality data for each mining unit will be forwarded to the NRC and the State of Wyoming as soon as it is received and compiled by Ogle Petroleum, Inc.

The staff considers the applicant's plans to establish baseline to be acceptable. The applicant must also comply with all requirements of the State of Wyoming.

4.4.1.2 Air quality

The closest current air quality measurements (Sect. 3.2) indicate that the background level of SO_2 and NO_x are quite low and that total suspended solid concentrations are moderate to high. In addition, concentrations of total suspended particulates (TSP) from site activity are likely to increase TSP levels there (Sect. 4.5). Therefore, operational monitoring of site air quality is recommended by the staff.

4.4.1.3 Ecological surveys

The applicant collected preoperational information on soils, vegetation, and wildlife. This information is discussed in Sects. 3.8 and 3.9. No operational monitoring appears warranted from the information presented in Sect. 4.5.6.

4.4.1.4 Radiological surveys

The applicant has conducted an extensive program to obtain radiological baseline data (see ER, pp. 159-177 for methodology). Of particular interest to the staff were the measured radon-222 concentrations from wells in the ore body. These measured concentrations are compared with theoretical concentrations normally used by the staff for radiological assessment in Sect. 4.5.7. Table 4.2 gives baseline concentrations of thorium-230, radium-226, and lead-210 in surface soil and gamma-ray survey results at eight locations.

Using thermoluminescent dosimeters, the applicant is also monitoring site radiological baseline (22 locations). These data average 2.01 ± 0.19 times the dose rate indicated in Table 4.3. The staff considers these data to be more representative of the actual dose rate at the site because of more uniform energy response. The staff calculates the annual terrestrial and cosmic component dose to be about 155 millirems/year.

The applicant has also established baseline values for site vegetation for total U, ^{230}Th, ^{226}Ra, and ^{210}Pb, as well as air sampling for gross alpha activity.

4.4.2 Operational monitoring

4.4.2.1 Surface water

Because no discharges to surface waters are expected, no surface-water sampling is required unless accidental spills occur. If significant releases occur on site [>19 m³ (5000 gal)], West Alkali Creek and Grassy Lake should be sampled after each rainfall or snowmelt runoff until the chemically or radiologically contaminated area has been decontaminated.

4.4.2.2 Air quality

The applicant must meet applicable Environmental Protection Agency (EPA) and State requirements for maintaining air quality and should practice approved methods of dust control. The staff recommends monitoring to demonstrate compliance.

4.4.2.3 Waste pond monitoring

The quality of the groundwater immediately underlying the evaporation ponds will be monitored by evaporation pond monitor wells. Each evaporation pond will have an evaporation pond monitor well located down gradient and within 30 m (100 ft) of the pond. The well will be completed in the first aquifer underlying the pond and will be sampled by using grab sample techniques so that the "top" of the unconfined aquifer is monitored.

In addition, a network of perforated pipe is located beneath the liner in a sand and gravel filter bed. The perforated pipe will be connected to a standpipe located at the low point in the system. The standpipes from each pond will be checked every two weeks for the presence of liquid. If liquid is present, its composition will be analyzed to determine whether or not liner failure has occurred. If failure is confirmed, the liquid in the pond will be pumped to an adjacent pond, and the damaged liner section will be repaired.

Table 4.2. Baseline gamma-ray surveys compared with soil sample analytical results

Location	Gamma-ray survey[a] exposure rate (μR/h)	Sample depth (cm)	Soil sample results			
			U (μg/g)	^{230}Th (pCi/g)	^{226}Ra (pCi/g)	^{210}Pb (pCi/g)
01	8.5	0–5	1.8	0.64 ± 0.11	0.60 ± 0.16	0.94 ± 0.49
		5–10	2.6	0.75 ± 0.16	1.1 ± 0.2	0.7 ± 0.48
		10–15	2.0	0.47 ± 0.09	0.59 ± 0.16	0.00 ± 0.45
02	8.9	0–5	2.4	0.50 ± 0.09	0.61 ± 0.16	0.76 ± 0.48
		5–10	0.7	0.35 ± 0.10	0.86 ± 0.16	0.[illegible]5 ± 0.48
		10–15	2.0	0.66 ± 0.11	0.62 ± 0.15	0.00 ± 0.45
03	8.3	0–5	2.0	0.48 ± 0.10	0.78 ± 0.17	0.61 ± 0.48
		5–10	2.6	0.50 ± 0.06	0.57 ± 0.15	0.77 ± 0.50
		10–15	1.6	0.57 ± 0.08	0.67 ± 0.16	0.56 ± 0.43
09	9.4	0–5	2.9	0.61 ± 0.10	0.93 ± 0.18	1.0 ± 0.5
		5–10	3.4	0.80 ± 0.09	0.39 ± 0.13	0.00 ± 0.45
		10–15	2.5	0.77 ± 0.08	0.69 ± 0.16	0.00 ± 0.45
10	9.0	0–5	0.8	0.60 ± 0.06	0.45 ± 0.03	0.77 ± 0.45
		5–10	2.4	0.48 ± 0.10	0.53 ± 0.02	0.65 ± 0.45
		10–15	2.3	0.63 ± 0.11	0.76 ± 0.03	0.00 ± 0.45
13	9.0	0–5	1.7	0.64 ± 0.14	0.95 ± 0.03	0.56 ± 0.45
		5–10	1.6	0.77 ± 0.14	0.68 ± 0.02	0.55 ± 0.43
		10–15	0.8	0.45 ± 0.08	0.90 ± 0.18	1.2 ± 0.5
14	8.5	0–5	2.8	0.94 ± 0.30	0.63 ± 0.03	1.2 ± 0.5
		5–10	2.2	0.73 ± 0.11	0.60 ± 0.03	0.67 ± 0.44
		10–15	2.8	0.90 ± 0.08	0.82 ± 0.17	0.65 ± 0.45
15	9.0	0–5	1.4	0.84 ± 0.18	1.0 ± 0.1	0.63 ± 0.45

[a]Gamma measurements were made with an Eberline SPA-3 scintillation detector [5 X 5 cm (2 X 2 in.) NaI(Tl) calibrated to ^{137}Cs] and a portable scaler. The detector was attached to an aluminum tripod and positioned 74 cm (29 in.) above the ground.

Source: ER, Table 2.9-5.

Table 4.3. Radiological baseline monitoring

Sample type	Number of locations	Frequency	Analysis
Air	3	48 h per quarter	^{222}Rn
Air particulate	3	24 h per quarter	U, ^{230}Th, and ^{226}Ra
Environmental dosimeters	22	Changed quarterly	Radiation dose
Surface water	2	Springtime and when flowing	U, ^{230}Th, and ^{226}Ra
Groundwater			U, ^{230}Th, and ^{226}Ra
Soil	8[a]	Once before startup and every 3 y during plant operation	U, ^{230}Th, ^{226}Ra, and ^{210}Pb
Vegetation	8	Once before startup and every 3 y during plant operation	U, ^{230}Th, ^{226}Ra, and ^{210}Pb
Gamma dose rate survey	22	Once before startup and every 3 y during plant operation	Radiation dose

[a]Sampling was done at depths of 0–5, 5–10, and 10–15 cm (0–2, 2–4, 4–6 in.).

4.4.2.4 Radiological monitoring

The applicant's radiological monitoring program (Table 4.3), which may be modified by the staff, will continue throughout all phases of operation to achieve better estimates of radon releases from well-field surge tanks. These activities will be license conditions.

The sampling frequency and the number of sampling locations may be changed in the future because of changing environmental and demographic patterns. Such modifications will be subject to approval by the NRC.

4.4.2.5 Well-field monitoring

Well-field monitoring procedures will define an area of containment for leachate injected during the mining operation. Well-field monitoring will be the surveillance technique for initiating corrective actions in the event of leachate migration. It will be effected through the use of monitor wells and may be supplemented by trend wells installed by the applicant for production control. The specific well-field monitoring program will be specified in the mine permit application and approved by the Wyoming Department of Environmental Quality.

Monitor wells

Monitor well location involves both surface spacing and subsurface placement to effectively determine the containment of the leach solution. On the surface, wells will be spaced around the perimeter of the well field so that any migrating leach solution (excursion) will be detected. Subsurface emplacement involves the location of monitor wells in the aquifers above and below the production zone aquifer. Monitor wells should be located to ensure that the injected leach solution is effectively confined to the production zone. The staff considers that aquifer monitor wells must be placed for timely detection of any potential fault interconnection between aquifers. Monitoring of the faults will be a condition of the license.

To minimize environmental impact, monitor wells must effectively act as a control to contain the leach solution within the production zone. For effective containment, a number of factors must be considered to determine the surface spacing of monitor wells. These include the following:

1. Site geological and hydrological variations must be evaluated, including (a) local variations in groundwater flow rates and direction, (b) local variations in permeability or zones of significant hydraulic conductivity, and (c) presence of subsurface geologic features (channels, clay lenses, facies changes, 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: (a) the zone of influence during monitor well sampling must be considered and (b) sufficient distance should be available so that trend wells can be installed for normal operational controls.

The applicant proposes to place monitor wells about 91 m (300 ft) from the well field and 180 m (600 ft) between wells (see Fig. 2.4). The staff considers this arrangement to be acceptable. The specific location of monitoring wells will be approved and made a condition of the license. This action will be taken in consultation with the State of Wyoming.

Trend wells

Trend wells have been proposed to be drilled within the monitor well ring by the applicant. These wells will be for production control and will not necessarily be analyzed for the same parameters as required for monitor wells. Changes in the water quality of samples from trend wells will not signal the need for corrective action by the operator; rather, they will initiate a production evaluation by the operator to determine the cause of this occurrence. Appropriate adjustment action by the operator will then take place. The staff believes that the use of trend wells by an operator will reduce the potential for leach solution to migrate to a monitor well.

Shallow and deep monitor wells

These wells will be installed to permit monitoring of the aquifer or dry formation immediately above or below the confining mudstone or shale that overlies or underlies the mineralized formation. Shallow wells should be placed within the well-field area, and these should be a minimum or one shallow well for each 2 ha (5 acres) of well field. The applicant proposed not to have deep monitor wells, and the staff finds this to be acceptable because there is no underlying aquifer closer than 91 m (300 ft) to the production zone.

Monitor well sampling

Monitor wells will be sampled every two weeks during project operations. The permit to mine approved by the State of Wyoming Department of Environmental Quality will require, for each routine sampling, water level measurements in the wells and groundwater sample analyses for conductivity, Cl^-, alkalinity (as $CaCO_3$), Na, U, and SO_4. Excluding sulfate, the analyses of these parameters will serve as "lead indicators" to establish the presence of a potential leachate excursion. The indicators were selected on the basis of relative mobilities in the aquifers, and laboratory results are to be available within 48 h of the sampling.

Upper control limit

An upper control limit (UCL) will be used to indicate a deviation in groundwater chemistry from the baseline concentrations. This deviation would indicate that migration (excursion) of lixiviant may be occurring and would initiate the appropriate corrective action(s). For the lead indicators identified above, the application for the permit to mine submitted to the State established the UCLs as 20% above the highest baseline for total carbonate, 20% above baseline for conductivity, 20% above baseline for chloride, and 1 mg/liter for uranium. The staff considers that the UCL limit should be defined as two standard deviations above the mean baseline value, where practicable. If a biweekly monitor well assay exceeds the UCL values for two indicators, sampling will be repeated each day for 7 d. If the repeated analysis shows that two parameters still exceed the UCL, the well will be considered in excursion status and appropriate corrective action initiated. Notification of the State and NRC of the excursion status and corrective actions will be made by telephone within 24 h and followed by written details within 7 d. Thereafter, a monthly report will be submitted until recovery from excursion status.

Corrective actions

A corrective action procedure will ensure the 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 release.

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 as follows:

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 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. 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. Detection wells would be necessary if a public water supply could be affected or should a prolonged excursion occur. The detection well(s) would be sampled during corrective action to verify that the excursion is being controlled or has been corrected.

The applicant will be required to report in writing to the NRC within 7 d after an excursion has been detected. The report will describe the corrective action taken and an evaluation of the results achieved. If corrective action is continuing at the time of the report, a subsequent report that describes and evaluates the final results shall be filed. Depending on the nature of the event, the NRC may require periodic reporting on the status of the corrective action. The applicant will also notify the appropriate Wyoming State agency in accord with state requirements.

Postrestoration monitoring

After completion of restoration of the first production well field, the applicant will be required to conduct a postrestoration monitoring program. This program will be used to evaluate the effectiveness of the proposed restoration plan. The staff will require the following: a minimum of two wells to establish baseline in the mining zone, a minimum of two monitor wells in the direction of maximum hydraulic conductivity, and a minimum of two trend wells (if used) to form the basis for postrestoration monitoring. If trend wells are not used, then at least two wells should be drilled between the well field and monitor well for this purpose. These wells should be sampled quarterly for a six month period to evaluate restoration effectiveness.

As a license condition, the applicant will propose a postrestoration monitoring program prior to the beginning of restoration.

Postmining monitoring

After mining and restoration have been completed in mining units, the applicant will take samples every 45 d for a six-month period to verify restoration stabilization.

The staff will require that at least one monitor well per production unit and a shallow and a deep monitor well, if used, from a production unit be made available for monitoring use throughout the duration of the licensing period. Quarterly sampling and analysis should be conducted for each well.

Record keeping and reporting

All officially transmitted monitor well records will be maintained at the Bison Basin site for reporting requirements and site cumulative records. Unless otherwise specified, required reporting will be to both the State of Wyoming and the NRC.

Ecological monitoring

The applicant's plans for hydrological monitoring and erosion-control measures should prevent the release of sediments or other constituents harmful to biota. If significant releases of sediments or other constituents occur, the applicant will undertake an ecological survey of West Alkali Creek to assess the extent of any damage to biota.

4.5 DIRECT EFFECTS AND THEIR SIGNIFICANCE

4.5.1 Impacts on air quality

The pollutant concentrations expected from operation of the project were calculated from site χ/Q values (ER, Table 5.3-1) and from expected emissions at the site,[3] at a distance of 300 m (984 ft) from emission sources (Table 4.4). Background pollutant concentrations are based on data from Rock Springs and Patrick Draw.[4] Calculated concentrations at 3 km (1.9 miles) from the sources decline by two orders of magnitude from those calculated at 300 m (ER, Table 5.3-1).

Table 4.4. Expected atmospheric concentrations, in $\mu g/m^3$, of pollutants at 300 m from project sources

Direction	CO	Hydrocarbons	NO_2	SO_2	Total TSP	Offsite TSP
N	31.83	4.97	107.90	11.58	94.55	331.78
NNE	20.39	3.18	69.13	7.42	60.57	212.54
NE	18.16	2.83	61.54	6.60	53.92	189.22
ENE	39.29	6.13	133.19	14.29	116.71	409.54
E	37.64	5.87	127.57	13.69	111.78	392.26
ESE	16.75	2.61	56.76	6.09	49.74	174.53
SE	36.39	5.68	123.36	13.24	108.09	379.30
SSE	7.47	1.17	25.32	2.72	22.18	77.85
S	10.36	1.62	35.12	3.77	30.78	108.00
SSW	7.11	1.11	24.11	2.59	21.13	74.13
SW	23.05	3.60	78.12	8.38	68.45	240.19
WSW	24.87	3.88	84.30	9.05	73.87	259.20
W	19.32	3.02	65.47	7.03	57.37	201.31
WNW	9.87	1.54	33.44	3.59	29.30	102.82
NW	23.38	3.65	79.24	8.50	69.43	243.65
NNW	15.17	2.37	51.42	5.52	45.06	158.11

Source: ER, Table 5.3-1, and Ogle Petroleum, Inc., "Responses to U.S. Nuclear Regulatory Commission Questions, Dated November 26, 1979," Docket No. 40-8745, Dec. 7, 1979, Response No. 29.

Expected maximum concentrations of carbon monoxide (39.29 $\mu g/m^3$, ENE) (Table 4.4), hydrocarbons (6 $\mu g/m^3$), and SO_2 (14 $\mu g/m^3$) are well below applicable State and Federal standards. Combined with background concentrations, atmospheric NO_2 generated at the site will likely exceed the State and Federal standard (100 $\mu g/m^3$) a considerable portion of the time (Table 4.4). Maximum NO_2 concentrations are estimated at 162 $\mu g/m^3$ (ENE, including 29 $\mu g/m^3$ background concentration). Most onsite NO_2 will be released from solution mining equipment; passenger vehicle emissions will account for less than 1% of NO_2 concentrations. No measurable effects have been detected in animals and humans exposed to chronic NO_2 concentrations an order of magnitude greater than those expected at the project site.[5] At concentrations similar to those expected at the site, the growth and yield of tomatoes and oranges were reduced, but the growth and yield of sunflowers were increased.[5] The sparseness of crop plants near the project site appears to preclude economic damage to plants there.

The estimated offsite TSP caused by emissions from the vehicles of workers from Sweetwater Station could not be estimated. The point-source diffusion model provides a maximum concentration (410 $\mu g/m^3$, ENE) that is about the same as State and Federal 24-h standards. The TSP will be produced primarily during commuting periods rather than continuously, thus elevating peak TSP values. More important, however, TSP will be produced across a 45-km (28-mile) line from Sweetwater Station to the project site. Therefore, the staff believes that TSP values will be considerably lower than State and Federal standards.

Total suspended particulate concentrations at the site are likely to exceed State and Federal standards. Normal background TSP concentrations (21 to 130 $\mu g/m^3$ average) are close to State single-day standards (150 $\mu g/m^3$) and surpass the State and Federal annual standard (60 $\mu g/m^3$).

Estimated TSP emissions, excluding background concentrations, at the project site exceed the State annual standard in one-half of the modeled directions and exceed the Federal annual standard in one-fourth of the modeled directions. Most of the TSP (87.7%) generated at the project site would result from wind erosion and dust from site activities, with much less emitted from project equipment (12.2%) and from vehicle exhaust and tire wear (0.1%). Chronic exposures to particulate concentrations even ten times greater than those expected at the project site are unlikely to harm living plants, animals, or humans.[6]

Considering the estimated TSP concentrations and the lack of onsite atmospheric monitoring, the staff recommends that Ogle Petroleum, Inc., submit plans to mitigate TSP emissions. The plans could include watering programs, use of crushed rock on heavily traveled roadways, application of dust-suppressing chemicals, and strict adherence to speed limits. The staff also recommends that an atmospheric monitoring program be established to measure the efficacy of TSP suppression measures.

4.5.2 Impacts on land use

The impacts of project construction and of operation on land use will be insignificant. Evaporation ponds, building sites, and roads will preempt less than 6.8 ha (16.8 acres)[3] for the life of the project. This amount is equivalent to 2 AUM (animal unit months) utilized during the five-year life of the project. Areas fenced to exclude wildlife and livestock cover a 5.5-ha (13.6-acre) rectangle, which is unlikely to impede movement of migratory antelope (Sect. 3.9.1).

The reclamation program is aimed at restoring premining uses by wildlife and livestock. At the time of reclamation, excavations at the site will be backfilled, compacted, and covered with stockpiled topsoil. Refuse pits will be covered with 1.7 m (5.6 ft) of fill, and all previously excavated surfaces will be seeded with grass and sagebrush seed in proportions of 53:1. After revegetation, fences will be removed; nonexcavated areas will be scarified and seeded. Larger disturbed areas will also be mulched to retain moisture. The staff can find nothing to suggest that reclamation plans will be unsuccessful.[3] The Land Quality Division of the Wyoming Department of Environmental Quality concurs that routine reclamation procedures should result in productive rangeland.[4]

The average ore grade to be mined is estimated to be 0.07% U_3O_8. The uranium ore that occurs as interstitial filling between the sand grains is expected to be the primary material removed from the host rock during mining. Because such a small percentage of material will be removed from the host rock, land subsidence is not anticipated.

If the injection pressure exceeds the fracturing pressure of the formation, fractures that could result in undetected excursions or loss of leach solution to overlying units could be produced. Such events are highly unlikely at Bison Basin because injection pressures will be maintained at levels well below the formation fracturing pressure (Sect. 2.3.10.1).

4.5.3 Water

4.5.3.1 Surface water

Construction of additional facilities at the central processing plant, additional evaporation ponds, and well fields will increase erosion in the project site area, subsequently increasing sedimentation in Grassy Lake and the unnamed playas into which the remainder of the site drains. West Alkali Creek should experience little or no impact because of these activities. Construction and improvement of roads, particularly where they cross drainage channels, leading to the project site will also increase erosion in the affected drainages and increase sedimentation in playas and streams in the area. Small amounts of oil and grease from drilling rigs and heavy equipment, including vehicles, may be washed into the playas and eventually into West Alkali Creek.

Increased suspended sediment loading to Grassy Lake, other playas, or West Alkali Creek would temporarily reduce productivity through light reduction and partial burial of benthic organisms. In addition, water might be less palatable to terrestrial wildlife. These effects will be temporary and inconsequential — with the possible exception of effects from road-bank erosion and increased sediment loadings downstream from drainage channel crossings. However, careful construction, riprapping of road banks, and installation of properly sized culverts at all channel crossings would make these impacts from erosion and increased sediment loadings inconsequential as well. In the unlikely event that large amounts of oil and grease are spilled during construction and washed into the playas and eventually into West Alkali Creek, effects on the aquatic communities could be relatively severe and long lasting. High mortality would be caused by surface coating with oil, reduced dissolved oxygen concentrations, and direct toxicity that accompany a large oil spill. Aquatic communities would remain depressed because of prolonged durability of these compounds.

Plant operation is designed to produce no discharge to surface waters. As discussed in Sects. 4.4.2.5 and 4.5.3.2, the possibility of underground releases of lixiviant migrating to surface waters in the area is remote because of (1) the isolation of the ore body by confining layers of impermeable shale, (2) the relatively great depth to the water table of the unconfined aquifer in this area, and (3) the applicant's proposed plan to monitor the ore-bearing aquifer and the aquifer immediately above to detect excursions early and, if needed, to apply corrective action. Surface-water impacts would only occur as the result of accidental spills. The major sources of potential spills are failures of (1) aboveground or buried pipelines carrying barren or pregnant lixiviant, (2) lixiviant surge tanks or storage tanks, or (3) evaporation ponds. Of these, evaporation-pond failures would pose the greatest potential threat because of the large volume of waste that could be involved and the high concentration of toxic substances contained. Surface spills on the project site during wet periods would be washed into Grassy Lake, into one of two unnamed playas, or possibly into West Alkali Creek (Fig. 3.3). During dry periods, surface spills would infiltrate the soil; during wet periods, spills would be washed directly into water bodies through surface runoff. Saturated or unsaturated subsurface flow following precipitation would also flush previously spilled contaminants from the soil downslope and into surface waters.

The impacts of spills on surface waters would vary with the amount and kinds of liquids released, the point of release, and the dilution achieved within the receiving water. Small pipeline or storage tank ruptures would likely never reach surface waters but would contaminate shallow-soil water immediately surrounding the point of release. Large pipeline or storage tank ruptures or major evaporation-pond failures would result in serious surface-water impacts, particularly during wet periods when overland runoff or saturated subsurface flow occur.

Because of the use of a sodium carbonate and sodium bicarbonate lixiviant, mobilization of most trace elements in the ore-bearing strata will be minimal. Table 4.5 compares estimated process wastewater concentrations with various water quality criteria. Besides uranium, trace elements of particular concern in solution mining operations are As, Mo, Se, and V. In wastewater from these operations, these elements, as well as most others, appear to be at or below water quality criteria. Even relatively large failures of pipelines carrying the barren lixiviant or process wastewater probably would result in only minor aquatic impact because potentially toxic elements would be further diluted before reaching aquatic habitats. The pregnant lixiviant would contain similar concentrations of trace elements, with the exception of uranium, which would be considerably higher. Aquatic impacts from pregnant lixiviant pipe ruptures could be substantial because dilution would have to be large to achieve water quality criteria.

Pipelines transporting RO reject brine from well-field restoration will contain higher trace element concentrations than the process wastewater presented in Table 4.5, but concentrations will decline as restoration proceeds to completion. Assuming that a process stream similar in composition to the process waste stream and a 100% RO efficiency exist, initial concentrations in the reject brine will be about seven times as concentrated as the process waste stream (ER, Sect. 4.2.1.2). This concentration represents an initial potential maximum; concentrations will decrease rapidly with restoration. Ruptures of pipelines carrying RO reject brine will only result in significant aquatic impacts if (1) ruptures result in large releases, (2) the point of rupture is close to a drainage channel, or (3) the rupture occurs during a wet period very early in the restoration phase.

The major potential aquatic impact from operation of the proposed solution mine would be an evaporation-pond failure. A worst-case accident can be estimated by assuming that all wastes produced during the proposed 5-year lifetime of the project were released from the evaporation ponds. By further assuming that the waste streams to the evaporation ponds had an average composition similar to the process wastewater of Table 4.5, the total volume of dilution to decrease concentrations of contaminants to levels similar to the original process wastewater levels would be 2.2×10^5 m^3, the total volume of water pumped to the ponds (ER, Sect. 3.4.2). This volume of water is similar to that discharged in West Alkali Creek in 1 d during an event with a 1- to 2-year recurrence interval, as computed from mean stream width,[7] but is at least

Table 4.5. Estimated chemical composition of the pregnant lixiviant and wastewater to the evaporation ponds and water quality criteria

All values in milligrams per liter unless otherwise indicated.

Parameter	Process wastewater[a]	Drinking water standard[b]	Wyoming DEQ wildlife and livestock criteria[c]	Recommended limit for protection of aquatic life[d]	Lowest toxic concentration reported[e]
TDS	5000	500	5000		
Cl	1700	250	2000		
SO_4^{2-}	1800	250	3000		
Na	1500				
Ca	200				
As	0.02	0.05	0.2		0.022
B	<1.0		0.5		0.69
Ba	<0.05	1.0			8.0
Cd	<0.02	0.01	0.05	0.0004–0.0012	
Cr	<0.01	0.05	1.0	0.05–0.10	
Cu	0.06	1.0	0.5		0.006
F^-	0.28	0.7–1.2	2.0		0.02
Fe (total)	0.12	0.3		1.0	
Hg	<0.001	0.002	0.1	0.00005	
Mn	10.08	0.05			17
Mo	<0.05				47
Ni	0.11	1.0[f]			0.05
Pb	<0.05	0.05	0.1	0.03	
Se	<0.01	0.01	0.05		1.0
U	1.7				1.7
V	<0.05				4.8
Zn	0.30	5.0	25		0.0001
^{226}Ra, pCi/liter	104	5.0			
pH, units	7–9	6.5–8.5	6–9	6.5–9	

[a]Data from Ogle Petroleum, Inc., *Environmental Report for NRC Source Material License Application Production Scale In Situ Mining, Bison Basin, Wyoming,* Sect. 3.4.2 and "Response to U.S. Nuclear Regulatory Commission Questions Dated November 26, 1979," Docket No. 40-8745, Dec. 7, 1979, Response No. 33.

[b]Data from the following sources: U.S. Environmental Protection Agency, *Quality Criteria for Water,* EPA-440/9-76-023, July 1976; "Proposed National Secondary Drinking Water Standards," *Fed. Regist.* 42(62): 17143–16147 (March 31, 1977); and U.S. Public Health Service, *Drinking Water Standards,* PHS Publication 956, 1962.

[c]Data from Wyoming Department of Environmental Quality, Land Quality Division, Guideline No. 4 (rev.), Nov. 9, 1976, pp. 3–41.

[d]Data from the following sources: National Academy of Sciences, Environmental Studies Board, *Water Quality Criteria 1972,* EPA/R3/73-033, March 1973; and U.S. Environmental Protection Agency, *Quality Criteria for Water,* EPA-440/9-76-023, July 1976.

[e]Data from U.S. Nuclear Regulatory Commission, *Final Impact Statement Related to Operation of Irigaray Uranium Solution Mining Project, Wyoming Mineral Corporation,* NUREG-0481, September 1978.

[f]Data from T. Kirkor, "Protecting Public Waters from Pollution in the USSR," *Sewage Ind. Wastes* 23(7): 938–940 (1951).

twice as great as the maximum storage in Grassy Lake.[8] Further dilution of about 5 times (1.1×10^6 m^3) would bring concentrations of all waste constituents, with the exception of manganese, uranium, and radium-226, down to levels within 50% of West Alkali Creek concentrations (Table 3.15). About 50 times greater dilution (1.1×10^7 m^3) would be required to reduce manganese, uranium, and radium-226 concentrations to within 50% of those in West Alkali Creek. This latter volume of water is greater than the flow in 1 d during a 100-year flood event (4.4×10^6 m^3) and is at least 100 times greater than the maximum storage in Grassy Lake. Thus, a worst-case analysis indicates that water quality impacts could be quite severe in Grassy Lake, West Alkali Creek, and downstream waters if major evaporation-pond failures occurred, particularly in the latter stages of the proposed operation. The Sweetwater River could be adversely affected because additional dilution between the site and the confluence with the Sweetwater River would probably amount to no more than three to four times. This analysis, however, depicts a situation that is very unlikely to occur. In addition, wastes released during evaporation pond failures would likely drain into Grassy Lake and would not directly contaminate West Alkali Creek. More likely, accidents that could have measurable adverse effects on Grassy Lake or, less likely, on West Alkali Creek would involve smaller failures and lower containment concentrations.

It is the staff's conclusion that impacts on water quality of surface waters from construction and operation of the project will be minor except in the unlikely event of a major evaporation pond failure. The establishment of monitoring wells below the pond and downslope will permit early detection of pond failure and will allow potential impacts on surface-water quality to be minimized. Mitigating measures described in Sect. 4.6.2.1 will ensure that any spill into Grassy Lake will be contained and will not affect West Alkali Creek.

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) 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. Though preliminary results of restoration at the Bison Basin research and development project indicate that groundwater quality can be returned to baseline, complete aquifer restoration on a production scale remains unproven. If mechanical, chemical, or natural restoration processes prove successful, groundwater degradation from commercial-scale activities at Bison Basin will be temporary.

Temporary and permanent groundwater degradation may result from surface- and deep-mining methods. Uranium and associated trace elements (V, As, Se, and Mo) 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.

The in situ leaching of uranium and the restoration of the ore-bearing aquifer use groundwater. 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. Ores resulting from surface or deep mining operations have to be processed at a mill that uses additional quantities of groundwater.

Groundwater use

Total use of groundwater from the Laney member of the Green River formation as a result of solution mining is estimated to be about 2.96 x 10^5 m^3 (240 acre-ft). This net withdrawal of groundwater will occur over the five-year life of the project and will not effect the availability of groundwater.

Groundwater quality

Local groundwater quality in the Laney member of the Green River formation will deteriorate during the in situ leaching of uranium. The Laney member will be the only aquifer affected by in situ leaching, and this impact will be local and temporary.

Leakage of leach solution between aquifers through old exploration holes, which were left full of bentonitic mud when they were abandoned, is considered very unlikely at Bison Basin. At the low aquifer pressures that will be induced by solution mining, the mud column is an effective seal against fluid interchange between the various aquifer units penetrated by the drilling. Additional sealing has been caused by the rapid swelling and bridging of the isolated shales between the sandstone aquifer units. However, to check for communication between aquifers, monitor wells, which will be checked regularly to detect changes in aquifer pressure and water quality, will be completed in the overlying "B" sands. The staff considers the plan to monitor the "B" sand sufficient to give early warning so degradation of water quality can be mitigated.

4.5.4 Mineral resources

At this time, uranium is the only known economically recoverable mineral resource at this site. The probability does exist that uranium deposits could be present in the underlying Battle Springs and Fort Union formations. The applicant 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. Based on available data, the staff concurs with the applicant's assessment.

4.5.5 Soils

Soil disturbance at the project site will be moderate. The applicant has divided soil disturbance into two categories (ER, Sect. 9.2.3). The first category is soils that are excavated that require storage. Soil storage mounds will be seeded with wheat grass to preclude wind erosion (ER, p. 266). Excavation will occur on 5.43 ha (13.5 acres), which includes construction of the processing building, support facilities, evaporation ponds, septic tank and leach field, diesel fuel and carbon dioxide storage tanks, solid waste landfill, and mud sites (ER, p. 263). The second category is nonexcavation soil disturbance, which will affect 17.37 ha (42.90 acres) and will include well fields; roadways; equipment storage; vehicle parking; outside chemical storage; trailers for office space, personnel, and storage; and liquid propane gas storage tanks. Because of the gently rolling topography and the surface reclamation plans by the applicant, these disturbances should be transitory and insignificant.

4.5.6 Biota

4.5.6.1 Terrestrial environment

The primary impact on vegetation will be the loss of 22.8 ha (56.3 acres) of sagebrush and cushion-plant communities (Sect. 3.9.1). No unique plant communities or endangered plant species will be affected by the proposed action. Dust deposition may occasionally reduce plant productivity in the project vicinity, but this effect will be minor and temporary. An accidental spill (Sect. 4.6.2) could destroy vegetation in areas surrounding the accident, depending on the nature of the chemicals involved.

Impacts on wildlife will be minimal because no endangered or threatened animal species are involved (Sect. 3.9.1). Loss of 22.8 ha (56.3 acres) of antelope browsing area is considered negligible because of the low carrying capacity of the vegetation (Sect. 3.9.1). Wildlife mortality from collisions with vehicle traffic is likely to be slight because of the undissected terrain (Sect. 3.3) and the resulting unrestricted visibility along most stretches of road from Sweetwater Station. The relatively small area of disturbance and the likelihood of successful reclamation indicate that wildlife losses should be few and temporary.

4.5.6.2 Aquatic environment

The scarcity of aquatic life in the intermittent playas and drainage channels near the project site precludes significant impact from construction of additional facilities. Only minor impacts on aquatic biota will occur as a result of construction of additional facilities and roads, provided that properly sized culverts are installed and proper riprapping techniques are used at channel crossings.

Because the mine operation is designed to have no discharge, impacts on aquatic biota would occur only as a result of accidents involving pipeline ruptures or evaporation-pond failures. If spills reached Grassy Lake, other playas, or West Alkali Creek, increases in dissolved solids or trace-contaminant concentrations might result in reduced productivity and high levels of mortality. In such an event, the effects could be long lasting because of adsorption and sediment contamination. In the absence of catastrophic evaporation-pond failures, however, impacts on near-site aquatic biota and downstream fish production will be minor. These events are unlikely (see Sect. 4.6.2).

4.5.6.3 Comparison with alternatives

Open-pit and underground mining pose substantially greater hazards to surface-water quality and to biota in the area than does solution mining because of (1) increased land surface disturbance; (2) the necessity to dispose of large quantities of poor-quality mine water; (3) the establishment of relatively large tailings-holding facilities and overburden piles, which can be sources of contaminants through leaching and failures; and (4) extensive milling operations, which increase the likelihood for accidental releases of hazardous liquids. In contrast, accidental spills during solution mining at the proposed site pose less hazard primarily because of the lack of a milling operation and the limited amount of land disturbance. With a detailed spill prevention and cleanup plan, particularly for large evaporation-pond or pregnant lixiviant pipeline failures, adequately trained personnel can minimize this hazard.

The alternative of no action certainly would eliminate potential hazards at the proposed site; however, no mining would likely result in increased uranium mining elsewhere, perhaps at a location more ecologically sensitive.

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 Bison Basin Project are naturally occurring cosmic and terrestrial radiation and naturally occurring radon-222 (Sect. 2.10). The average annual total-body dose rate to the population in the site vicinity, including doses from natural background radiation and diagnostic medical procedures, is estimated to be about 225 millirems. Continuous exposure to concentrations of naturally occurring radon-222 in the air, estimated to be between 500 to 1000 pCi/m^3, could result in doses up to 625 millirems per year.

This section describes the results of the staff's analysis of the project-contributed incremental radiological impacts to the environment and the population in the vicinity of the Bison Basin solution mining site. The analysis is primarily based on the estimated annual release of the radionuclide radon-222, which is 499.0 Ci/year (where 1 Ci = 3.7 x 10^{10} Bq), and on the models, data, and assumptions discussed in Appendix D. Based on actual measurements of the concentration of the radon-222 in the pore water pumped from pilot wells, the maximum release of radon-222 to the atmosphere is estimated to be 209 Ci/year. However, based on conservative generic parameters and projected production capacity the calculated radon-222 release is estimated to be 499 Ci/year. The staff decided to use this latter amount in its analysis of radiological impacts. The calculations of the radon release are shown in Appendix C. All internal doses in this report represent 50-year dose commitments; that is, the dose calculated for one year of radionuclide intake is an estimate of the total dose an individual will receive integrated over the next 50 years of his life as a result of that year's exposure. Detailed analyses of the radiological impacts of the solution mining operation to nearby individuals and the entire population within 80 km (50 miles) have been performed. All potential exposure pathways likely to result in significant fractions of the project's total radiological impact have been included (Fig. 4.4). Considerations have also been given to the occupational exposures received by the project employees and to radiation exposures of biota other than man.

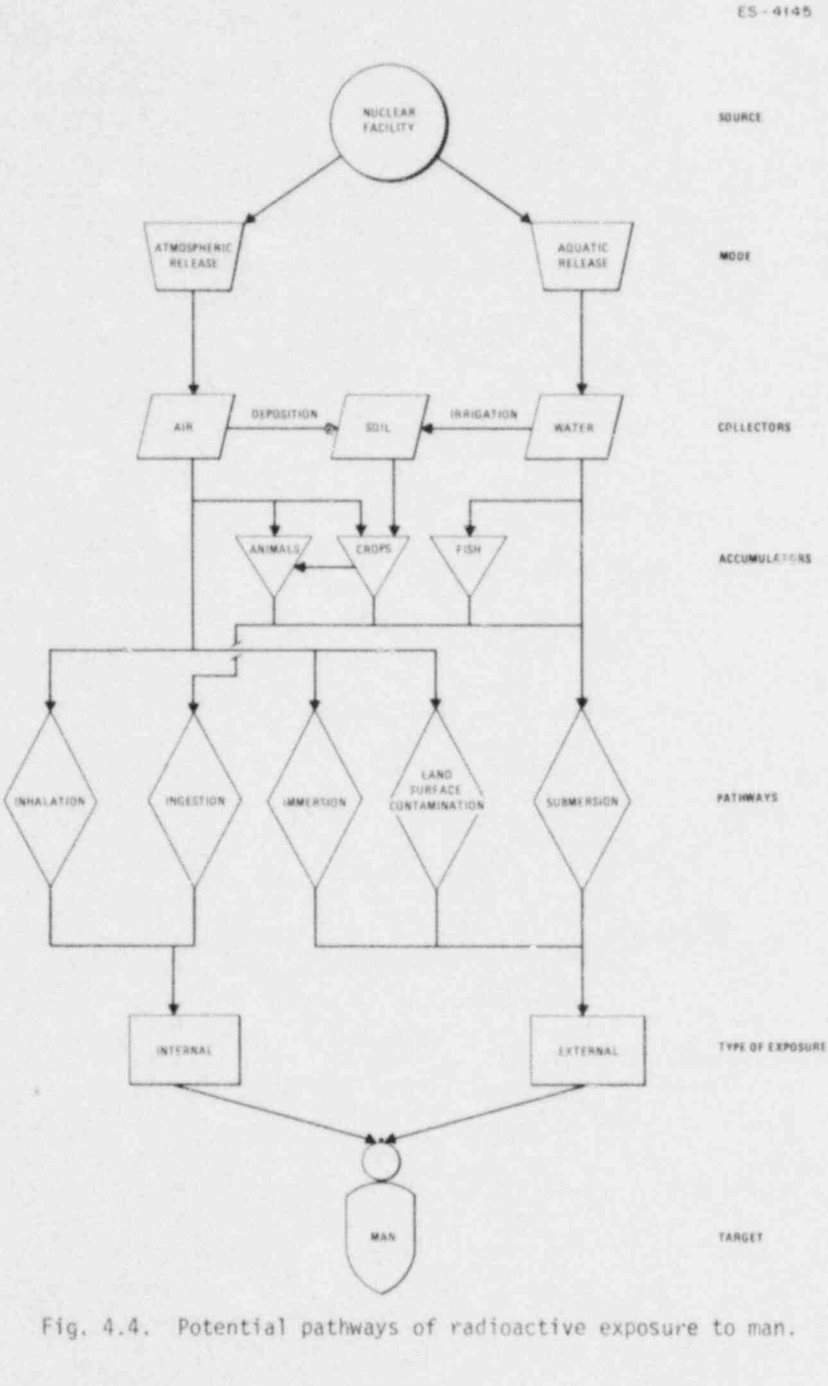

Fig. 4.4. Potential pathways of radioactive exposure to man.

4.5.7.2 Exposure pathways

Potential environmental exposure pathways by which people could be exposed to radioactive effluents of the well field and recovery plant are presented schematically in Fig. 4.4. Estimates of 50-year dose commitments to man have been based on the proposed plant design and actual characteristics of the site environs. The staff's analysis has included considerations of radioactive particulate and gaseous releases to the atmosphere. The plant will not release radioactive waste directly into surface waters, and no seepage from waste ponds into local groundwater is anticipated. Thus, no aquatic release to the environment is considered likely.

Controlled flow rates producing a pressure gradient, which forces a net movement of groundwater around the leached zone, reduces the possibility of contaminating the groundwater outside the well field. Therefore, the likelihood of groundwater contamination is minimized. Furthermore, the applicant will be required to conduct environmental and other monitoring programs to provide early detection of any uncontrolled groundwater contamination and to take appropriate mitigating measures.

Because only radon-222 is released from the Bison Basin facilities, the environmental exposure pathway of concern for airborne effluents is the inhalation of radioactive materials in the air. External exposures to radioactive materials in the air and on the ground surfaces and ingestion of contaminated food products (meat, milk, and vegetables) are less important contributors to dose.

4.5.7.3 Radiation dose commitments to individuals

Currently, the nearest residents to the proposed site of the Bison Basin facilities are at the oil field caretaker's cottage, about 11.0 km (6.8 miles) ENE of the site. Dose commitments were also estimated for the nearest community, Sweetwater Station, Wyoming, 30 km (19 miles) NNE of the site. Land use in the area is primarily for grazing of livestock. In the absence of site-specific information, it is conservatively assumed that all foods and milk consumed are produced locally. Table 4.6 presents a summary of the individual dose commitments calculated for the nearest residence and for Sweetwater Station.

Table 4.6. Dose commitments to individuals from radioactive releases from the Bison Basin Project

Location	Exposure pathway	Dose (millirems)[a]			
		Total body	Bone	Lung	Bronchial epithelium[b]
Nearest residence (11 km ENE)	Inhalation	1.9E-2[c]	1.8E-2	1.2	1.7
	Immersion in air	8.8E-3	1.0E-2	8.4E-3	
	Ground surface	2.8E-3	3.3E-3	2.9E-3	
	Total	3.1E-2	3.1E-2	1.2	
Sweetwater Station (30 km NNE)	Inhalation	5.0E-3	4.5E-3	3.1E-1	3.1E-1
	Immersion in air	3.3E-3	3.8E-3	3.1E-3	
	Ground surface	1.0E-3	1.1E-3	1.0E-3	
	Total	9.3E-3	9.4E-3	3.1E-1	

[a] 1 millirem = 0.01 millisievert.

[b] Doses to the bronchial epithelium result from the inhalation of short-lived radioactive daughters of ^{222}Rn.

[c] Read as 1.9×10^{-2}.

4.5.7.4 Radiation dose commitments to population

The dose commitment to the population estimated to exist within 80 km (50 miles) of the plant site for the year 1977 is presented in Table 4.7, along with estimated doses to the same population from natural background radiation sources. Population dose commitments resulting from the operation of the Bison Basin Project represent no more than about 0.029% of the doses from natural background.

Table 4.7. Population dose commitment[a] within an 80-km (50-mile) radius of the Bison Basin site

Receptor organ	Dose (man-rems)[b]	
	Project effluents	Natural background[c]
Total body	4.8E−3[d]	3,358
Lung	1.5E−1	4,197
Bone	5.3E−3	2,798
Bronchial epithelium	3.4	11,660

[a]Based on a 1977 population of 23,320 persons; does not include contributions from medical uses of radiation.

[b]Man-rem = 0.01 man-sievert.

[c]Dose from naturally occurring ^{222}Rn to the total body is assumed to be 144 millirems per year; to the lung, 180 millirems per year; to the bone, 120 millirems per year; and to the bronchial epithelium, 500 millirems per year.

[d]Read as 4.8×10^{-3}.

4.5.7.5 Evaluation of radiological impacts on the public

All radiation doses, which result from the uranium solution mining operation at the Bison Basin site and which are estimated for the surrounding population, are small fractions of those arising from naturally occurring background radiation (Table 4.7). The doses are also small when compared with the average medical and dental x-ray exposures currently being received by the public for diagnostic purposes.

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, as specified in 10 CFR Part 20 ("Standards for Protection Against Radiation"). Dose commitments to the nearest residents are not compared to the limits specified in the EPA's "Radiation Protection Standards for Normal Operations of the Uranium Fuel Cycle" (40 CFR Part 190), which is to become effective for uranium milling operations in December 1980, because these limits do not apply to radon-222 or its radioactive daughters. Table 4.8 provides a comparison of calculated air concentrations compared to limits established by the NRC for public protection.

As indicated in Table 4.8, the radiation dose commitments to the organs of the individuals living near the project site fall well below NRC limits. To ensure that offsite doses are maintained below the permissible limits, the staff will require the applicant to (1) implement a monitoring and control program involving groundwater seepage and particulate and radon-222 releases and (2) perform and document land-use surveys to determine any variations in land use (e.g., for residence and well locations).

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 yellow cake slurry. Where any spillage occurs and the yellow cake becomes dry, some airborne radioactivity may result. However, this operation will be designed to minimize the release of radioactive contamination to the room air. Even at uranium mills, where drying and packaging of yellow cake is routinely performed, a recent

Table 4.8. Comparison of air concentrations during solution mining operations with 10 CFR Part 20 limits

	Total air concentration (pCi/m³)				WL concentration[a] (Outdoors)
	^{222}Rn	^{218}Po	^{214}Pb	^{214}Bi	
Predicted values[b]					
Nearest residence (11 km ENE of site)	2.0	2.0	1.4	0.80	1.4×10^{-5}
Sweetwater Station (30 km NNE of site)	0.34	0.34	0.34	0.32	2.4×10^{-6}
Maximum at site boundary (ENE)	167.3	107.6	7.2	0.48	1.2×10^{-3}
10 CRF Part 20 limits[b]	3×10^3	3×10^3	3×10^3	3×10^3	3.3×10^{-2}

[a]WL denotes "working level." A one-WL concentration is defined as any combination of air concentrations of the short-lived ^{222}Rn daughters, ^{218}Po, ^{214}Pb, ^{214}Bi, and ^{214}Po, 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 ^{210}Pb.

[b]Values are from 10 CFR Part 20, Appendix B, Table II, col. 1. The radon concentrations are appropriate for protection from ^{222}Rn combined with its short-lived daughters.

review revealed that few exposures of drying and packaging operators exceeded 25% of the specified NRC limit for such exposure averaged over the year.[9] 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 the element.

Worker inhalation of radon and its daughters is another potential exposure condition. The ventilation system in the recovery plant is expected to minimize this type of exposure. Elevated radon concentrations may occur in the well-field pump buildings, but the time of occupancy of these buildings should be short. Employee exposure should not exceed about 10% of the annual limit specified by the NRC; again, this exposure is comparable to that encountered by some employees at existing uranium mills.

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. The applicant will be required to perform periodic gamma radiation surveys, particularly adjacent to the resin columns, to ensure that radium buildup does not occur and result in unnecessary radiation exposure.

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.[10-17] 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.

4.6 INDIRECT EFFECTS AND THEIR SIGNIFICANCE

4.6.1 Socioeconomic effects

4.6.1.1 Summary

The socioeconomic impacts of the proposed Bison Basin Project will be minimal. The total direct employment will be about 30 to 40 persons; the secondary employment will be about 50 persons. These employment demands are small; therefore, despite the low unemployment rate in the area, the majority of both direct and secondary employees is expected to come from local labor pools.

Because few in-migrants will be needed, population-induced impacts will be negligible. The extremely remote location of the project and the proposed method of mining combine effectively to eliminate public impacts caused by onsite activities.

4.6.1.2 Employment

The proposed project will employ about 30 persons at the site and four or five persons in Casper. Because, in order to avoid winter weather as much as possible, drilling operations will be seasonal, the applicant will hire about ten additional persons; some of these may be on contract. This potential mining-related employment increase of 40 represents only about 1.8% of 2192 persons, the average number employed in Fremont County in uranium mining during the third quarter of 1978 (Table 3.7). Secondary or induced employment will, as an upper limit, be about 50 additional persons. Therefore, the increment to total employment will not exceed 90, about 0.5% of the estimated 17,107 persons to be employed in Fremont County in 1980 (Table 3.8).

4.6.1.3 Population

The current ratio of employee to population for Fremont County is 0.52. Assuming future validity of this ratio and all site labor imported, the predicted maximum site-related employment of 90 would result in a population increase of 175. This figure represents 0.5% of Fremont County's 1977 estimated population of 33,653 (Table 3.3) and 0.6% of the combined 1989 estimated population of 39,207 for the areas within 16 km (10 miles) of Riverton and Lander (Table 3.5).

4.6.1.4 Housing

About 5300 new housing units of all types will be needed in Fremont County to accommodate projected population increases (Table 3.6). Assuming a worst-case scenario, that is, (1) that there will be a project-related employment increase of 90 (basic plus secondary), (2) that none of the basic and secondary workers are from the same family, and (3) that all workers are in-migrants, 90 new housing units would be required. These incremental housing needs, though unrealistically high, are only a small fraction of anticipated requirements. Therefore, the project will have very little effect on local housing markets.

4.6.1.5 School enrollment

The project will minimally impact school enrollments. The total fall 1979 school enrollment for Fremont County School Districts 1 (includes Lander) and 25 (includes Riverton) was 5534 (Table 3.13). The staff estimates that, as an upper limit, about 40 to 50 additional students would be enrolled in these school districts. Because the majority of the project's workers will probably be hired from the local labor pools, the actual enrollment increase should be substantially less.

4.6.1.6 Personal income

If any of the unemployed members of the local labor pools are hired or if any project employees relocate to the regions of interest near the project site, additional personal income will be generated. This income will stem directly from their wages and indirectly from induced employment in service jobs. The staff estimates that the project will maximally increase total annual personal income in Fremont County by \$1.3 million (1979 dollars) – only a fraction (~0.4%) of the total personal income of Fremont County. This estimated income does not include income to county residents from incremental markups on materials, interest, or mortgages resulting from the project.

4.6.1.7 Other public services and facilities

Public facilities and services will be minimally impacted by project-induced population increases. Assuming the worst case, an increase in population of about 175, the impacts will be (1) that water usage will increase about 106 m^3/d (28,000 gpd) and (2) that wastewater will be increased by about 87 m^3/d (23,000 gpd).

Because the ratios of physicians to residents in the Riverton and Lander areas are very high (see Sect. 3.4.4.4), health services and facilities are more than sufficient to supply incremental health needs. Additional fire and police protection requirements will be negligible.

4.6.1.8 Public sector finances

Since very few in-migrants will be hired, public-sector finances will be minimally impacted by the project. Some additional funds will have to be expended by Fremont County, Lander, and Riverton for potable and wastewater treatment facilities, for school and medical facilities, and for fire and police equipment and staff. However, compared to current outlays, these additional expenditures will be negligible. The project should generate through payment of property, sales, and severance taxes sufficient funds to cover additional public-sector expenditures.

4.6.1.9 Other socioeconomic criteria

Traffic

The small number of mining employees will not generate a noticeable increase in traffic on public highways. On the 45 km (28 miles) of dirt road from the site to Sweetwater Station, the vehicles of mine employees and the vehicles transporting materials and products will undoubtedly cause a large increase in traffic because the road currently serves only a few oil-field employees and a few hunters during the hunting season.

Aesthetics

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. The mine site will not be visible from any public highways.

Noise

Because the mine site is 11 km (7 miles) from the nearest human habitation, noise impacts to the public will be negligible.

4.6.2 Potential effects of accidents

Accidents during the operation of the Bison Basin 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 to maintain safe operations in accordance with NRC Regulatory Guide 3.5. The NRC will maintain surveillance over the facility and its individual safety systems by conducting periodic inspections and by requiring reports of effluent releases and 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 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

Most piping at the Bison Basin site will be surface piping to permit ready detection and repair of leaks. The applicant indicates that fiberglass, high-density polyethylene and polyvinyl chloride (PVC), or coated steel piping will be used. Some of these materials introduce problems of low impact strength at freezing temperatures and of gradual deterioration because of weathering. Through proper design of main trunk and distribution piping, normal operating pressures and stresses may be handled with minimal probability of failure. However, the piping systems must be protected against excessive stresses generated by thermal effects and by vehicle and personnel movements.

The main pipelines will either be buried or will lie in utility corridors that are generally safe distances from service roads. Suitable protection of pipeline casing will be provided at road crossings. Within the well fields, personnel and vehicles may inadvertently break smaller injection or production distribution lines; however, only small fluid losses would be realized.

Winter temperatures at the Bison Basin site will fall below freezing. The salts in the lixiviant will be too dilute to lower the solution freezing point significantly. However, the operating pipelines will be immune to freezing because of the relatively high flow rates and short residence times of fluids in the leaching circuit.[18] However, thermal insulation may be added as necessary to prevent freezing and flow blockage during winter months. Flow interruption in cold weather may result in the freezing and possible cracking of lines. 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 fully report pipe breaks that result in any significant release to the surface. 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 273,000 liters (72,000 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 compositions of the lixiviant solutions are listed in Table 4.9.

Table 4.9. Estimated concentrations of principal radionuclides and other constituents in leach solutions

Values are in mg/liter except as noted

Metal or radionuclide	Concentration
SO_4	1200
Cl	600
Na	1150
Mg	20
K	20
Ca	115
U (as U_3O_8)	75–300 (pregnant solution)
HCO_3^-	1500
^{230}Th, pCi/liter	20
^{226}Ra, pCi/liter	500

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 Grassy Lake. It is unlikely that even the postulated 273,000-liter (72,000-gal) spill would leave the site because, evenly distributed, it would cover only 25 ha (10 acres) 0.64 cm (0.25 in.) deep, without infiltration. Conceivable leakage from evaporation ponds would be of similar magnitude.

In the unlikely event of a spill reaching Grassy Lake, cleanup would consist of processing the water contained in the lake through the project water treatment plant and/or recovery and disposal of the upper crust of salts and sediments after lake evaporation (if the concentration of toxic materials in the crust requires such action). Contaminated materials, whether deposited onsite or offsite, would be disposed of in the evaporation reservoir.

Contact with the soil should decrease the oxidation potential of the lixiviant. Vegetation in the vicinity of the spill may be harmed as direct effects 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 273,000 liters (72,000 gal), up to 0.006 mCi of thorium-230, 0.15 mCi of radium-226, and (for pregnant solution) 51 mCi each of uranium-238 and uranium-234 could be released. Evaporation of spilled solutions would cause precipitation of these radionuclides on the native soils. The NRC license will require that all spill sites be decontaminated to levels consistent with central plant decommissioning requirements.

For conventional uranium milling operations, pipeline failures will result in similar problems. Tailings dam failures could produce substantially greater impacts.

Failure of chemical and fuel storage tanks

At the Bison Basin Project, chemical storage facilities will be maintained both inside and around the plant building and in the well-field areas. A listing of chemical and fuel storage facilities will include surge tanks for lixiviant and eluant solutions, and a number of small tanks for yellow cake precipitation and water treatment. The probability of a chemical spill will be minimized through proper design and operating procedures.

Tanks containing hazardous liquids will be equipped with high- and low-level alarms and valving to minimize the probability of an overflow. Leaks from tanks within the plant building will drain to the building sump and be returned to the process. External process chemical and fuel storage tanks will each be surrounded by earthen dikes capable of containing the capacity of the tank. Contaminated soils within the diked area will be removed to the waste impoundment area.

Oxidant tankage will be used in the well fields. Oxygen, which presents no environmental hazard, will normally be used. If hydrogen peroxide is used, accidental releases could damage biota.

Releases from the carbon dioxide tank should not result in any environmental damage, but releases from propane tanks could result in fire or explosion danger. 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. 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.

Major fire or gas explosion in the yellow cake drying area

The yellow cake will not be dried onsite. It will be shipped as slurry. Therefore, the possibility of a major fire or gas explosion onsite is eliminated.

Failure of air-cleaning system serving the yellow cake drying area

There is no yellow cake drying area.

Tornadoes

The probability of a tornado in the 1° square in which the Bison Basin site is located is low. Using the closest available data, the probability is approximately 3×10^{-4} per year.[19] The area is categorized as region 3 in relative tornado intensity.[20] For this category, the wind speed of the design tornado is 390 km/h (240 mph), of which 310 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 yellow cake 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 product may be accumulated before shipment. the tornado was assumed to lift 1590 kg (3500 lb) of yellow cake.

Because the yellow cake is in slurry form, no dispersion as powder can occur. Therefore, the environmental effects would be much less than if dry powder dispersed. Assuming dry U_3O_8 powder and a conservative model (i.e., all the yellow cake is in respirable form for the dispersion analysis,[21] and all the material was entrained as the vortex passed over the site), one can assume 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 lung of 4.6×10^{-5} millirems would result. The maximum annual lung dose to the nearest residence, 11 km (6.8 miles) from the recovery plant, was 2.5×10^{-4} millirems. The 50-year lung dose as a function of distance is plotted in Fig. 4.5.

A similar accident can occur in conventional milling facilities.

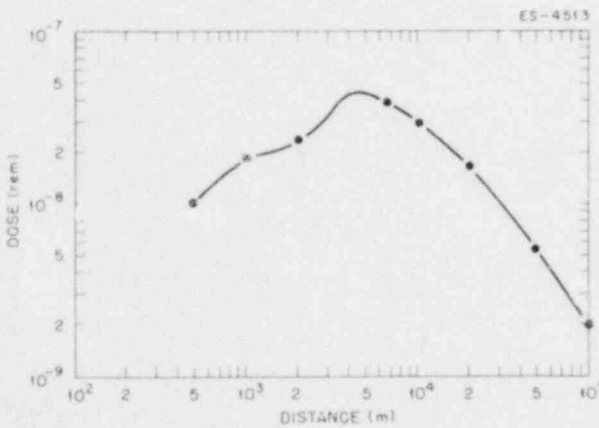

Fig. 4.5. Fifty-year lung dose commitment as a function of distance.

Transportation accidents

Shipments of yellow cake. Because the applicant will ship yellow cake as slurry, the yellow cake dryer and its associated emissions are eliminated. The product dewatering centrifuge will reduce the yellow cake water content to 50% by weight. The slurry will be bulk loaded in a type-B tank truck for shipment. The staff estimates that approximately 22 shipments will be required annually. The yellow cake slurry will be shipped to the Kerr McGee Nuclear Corporation hexafluoride plant in Gore, Oklahoma.

From published accident statistics,[22,23] 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 side. Accidents classified as "other events" include personal injuries suffered on a vehicle, records of persons falling from or being thrown against a standing vehicle, cases of stolen vehicles, and fires occurring on a standing vehicle. The probability of a truck shipment of yellow cake from the mill being involved in an accident of any type during a one-year period is approximately 0.04.

No analysis has been made for an accident involving yellow cake slurry, but potential risks are much less than for dry U_3O_8 discussed below.

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.[24] These magnitudes vary, as does the frequency with which they occur, with the severity of the accident. A generalized evaluation of accident risks by NRC classifies accidents into eight categories, depending upon the combined stresses of impact, puncture, crush, 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 4.10. 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 4.10). 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 Model I and Model II, the expected fractional release in any given accident is approximately 0.45 and 0.03 respectively.

Table 4.10. Fractional probabilities of occurrence and corresponding package release fractions for each of the release models for 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
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 Model I and Model II, the quantity of yellow cake released to the atmosphere in the event of a truck accident is estimated to be about 7400 kg (16,200 lb) and 500 kg (1100 lb) respectively. Most of the yellow cake 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.[23] The following empirical expression was derived for the dispersal of the material to the environment through the air following an accident involving a release from the container:

$$f = 0.001 + (4.6 \times 10^{-4})[1 - \exp(-0.15ut)]u^{1.78} \quad ,$$

where

f = the fractional airborne release,

u = the wind speed at 15.2 m (50 ft) expressed in meters per second, and

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,[25] the consequences of a truck accident involving a shipment of yellow cake 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.

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 52 people per square kilometer (160 people per square mile). This dose can be compared to a 50-year integrated lung dose 1427 man-rems from natural background.

The applicant has submitted to the NRC an emergency action plan for yellow cake transportation accidents. This emergency action plan is intended to ensure that personnel, equipment, and materials are available to contain and to decontaminate the accident area.

All U_3O_8 production sources risk this shipping accident.

Shipments of chemicals to the site. Truck shipments of process chemicals to the Bison Basin plant, if involved in a severe accident, could conceivably result in a local environmental impact. Small quantities of analytical reagents are 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.

*Doses integrated over a 50-year period following exposure.

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 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.

Conclusion

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

4.6.3 Final waste disposal

The estimated annual volume of waste solids (after normal compaction) from construction, production, and restoration activities is tabulated below:

Activity	Nonradioactive, m^3 (yd^3)	Radioactive, m^3 (yd^3)
Construction	57 to 76 (75 to 100)	0 (0)
Production	15 to 23 (20 to 30)	3 to 4.6 (4 to 6*)
Restoration	Included in production	3 to 4.7 (4 to 6*)

The amount of solid residue that will be generated each year as a result of the plant and reverse osmosis unit bleeds based on estimated total dissolved solids concentrations of 5000 mg/liter and 7000 mg/liter (9000 μmhos/cm conductivity), respectively, and 342 d of operation per year is approximately 280 t (308 tons) per year.

The staff position is that these small quantities of waste (after liquid evaporates from the waste ponds) should be removed to a licensed waste site (i.e., a mill tailings disposal site). The staff cannot legally require the owner of such a site to accept wastes from the Bison Basin Project.

The applicant must demonstrate to the satisfaction of the staff that he has made a sincere effort to achieve such an agreement and failed before onsite disposal will be considered. If onsite final disposal is permitted, the applicant must prepare a decommissioning plan consistent with the mining and milling waste disposal objectives discussed in Sect. 2.3.6. The implementation of this plan will ensure the health and safety of the public and the environment.

4.6.4 Lack of resource development

If uranium is not extracted from this site, other sources must be explored; expansion of U_3O_8 production is necessary (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.

*These figures include materials trapped by the injection line filter system, sediments periodically cleaned out of surge tanks, spent ion exchange resin, and contaminated worn equipment. The volume of dissolved solids in the plant bleed and reverse osmosis unit bleed that will become the residue in the ponds after evaporation is complete is not included in these figures.

4.6.6 Effects on urban quality, historical and cultural resources, and society

The only potential effect on urban quality would occur if sufficient U_3O_8 were not available when required for reactor fuel. In many urban areas, a shortfall of electric energy would degrade the quality of life.

The project is not expected to affect historical or cultural resources. The short-term societal effects will be minimal, and there will be no long-term effects after restoration and reclamation.

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 project requires less energy per pound of U_3O_8 produced than does other mining methods.

4.8 UNAVOIDABLE ADVERSE ENVIRONMENTAL IMPACTS

4.8.1 Air quality

The unavoidable impacts of solution mining activities upon the air quality in the area will be minimal. Although some increase in suspended particulates from vehicular traffic on roads will occur, the resulting impact upon the regional air quality will be minor. The anticipated small chemical emissions from the recovery facility and evaporation ponds will have a negligible impact on the air quality of the area.

4.8.2 Land use

A temporary change in land use of about 23 ha (57 acres) from livestock grazing to mineral extraction will result during the project operations as proposed by the staff. Ranchers and wildlife will be inconvenienced by changes in land-use patterns.

The project area presently reveals a low potential for intensive recreation use and development because no unique scenic or natural features occur. There are no existing recreation facilities within the project area. For these reasons, it is considered unlikely that any significant adverse environmental impacts, except some loss of hunting opportunities, will occur.

4.8.3 Water

4.8.3.1 Surface water

Although no surface discharges are planned during project operations, some local deterioration of water quality may occur. Additionally, removal of protective vegetative cover and other soil disturbance will cause increased sedimentation during the development and mining activities.

4.8.3.2 Groundwater

Approximately 2.96×10^5 m^3 (240 acre-ft) of groundwater will be permanently removed from the aquifer, mostly during restoration activities. Some project-induced degradation of groundwater quality may occur.

4.8.4 Mineral resources

Other than the extraction of the uranium, no unavoidable adverse effects on mineral resources are expected. In addition to the environmental effects of the solution mining of uranium discussed herein, other subsequent and related impacts will occur. The kind and intensity of such impacts will be dependent on the disposition of the refined ore. Assuming that the uranium will be used to fuel steam-electric systems, the environmental effects associated with the production of uranium hexafluoride, isotopic enrichment, fuel fabrication, reprocessing of irradiated fuel, transport of radioactive materials, and management of radioactive wastes are relevant to the proposed project.[26]

4.8.5 Soils

The alteration of near-surface soil characteristics that have developed over long periods of geologic time cannot be avoided. Disturbance of soils may lower the natural soil productivity to some degree because of soil compaction and accelerated erosion.

Soil disturbance on the 23 ha (57 acres) used for the recovery process building site, evaporation ponds, and well fields cannot be avoided.

4.8.6 Ecological

4.8.6.1 Terrestrial

Vegetation on about 23 ha (57 acres) will be disturbed during operation. Plant species composition and diversity will be altered because of the disruption of the natural vegetation and subsequent revegetation.

Loss of habitat for most wildlife populations on disturbed areas will occur as a result of project operations; however, habitat removal is expected to be temporary.

4.8.6.2 Aquatic

Because of increased sedimentation caused by well-field operations, some minor impacts on the aquatic system are expected.

4.8.7 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.

4.8.8 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 will result in not over 16 ha (40 acres) of vegetative cover lost during the limited operation proposed by the staff.

Waste ponds, pipelines, access roads, and plant buildings will occupy only a small portion [6.6 ha (16.3 acres)] of the site.

Proposed monitoring and mitigating measures will assure that 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 2.96×10^5 m^3 (240 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. If unsuccessful on a larger sca.., 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 16 ha (40 acres) of aquifer area.

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; and 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 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 Bison Basin 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 Bison Basin Project involves comparing the societal benefit of an assured U_3O_8 supply (ultimately providing energy) against local environmental costs for which there is no directly related compensation. For the project, these uncompensated environmental costs are basically three: groundwater impact, radiological impact, and disturbance of the land. The radiological impacts of the project are small, and eventually radioactive wastes will probably 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 other 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 0.9×10^6 kg (1×10^6 lb) of U_3O_8 is considered to offset the risk that the groundwater quality underlying the 16-ha (40-acre) mining zone will not be completely restorable. Moreover, development and demonstration of an acceptable restoration technique is an integral part of the project (Sect. 4.3.1).

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 long-term disturbance of land, and mitigable nature of the societal impacts, the staff has concluded that the overall benefit-cost balance for the Bison Basin 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 source material license for this solution mining project with the conditions specified in the Summary and Conclusions.

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5. PROFESSIONAL QUALIFICATIONS OF THE BISON BASIN PROJECT DES 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.

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.

Jeffrey S. Baldwin
Energy Division
Oak Ridge National Laboratory

Jeffrey Baldwin is a research associate in the Environmental Impacts Section. Since May 1979, his work has involved environmental impact assessments of various nuclear fuel cycle facilities such as fuel fabrication facilities, uranium ore-buying stations, uranium ore-processing mills, and in situ solution mining of uranium. Before coming to Oak Ridge National Laboratory, Baldwin was a research associate with the National Uranium Resource Evaluation at the Oak Ridge Gaseous Diffusion Plant. His training has been in trace element geochemistry, hydrogeology, uranium geology, and coal geology. Baldwin's research has included the development of geochemical exploration models using trace element data from stream sediment, stream water, and groundwater to delineate areas of uranium mineralization; research concerning trace element, pyrite, and sulfur distribution in eastern U.S. coals; and various research topics relating to surface- and groundwater quality.

Education:

- Received an A.B. degree in geology from West Georgia College in 1973
- Received an M.S. degree in geology from the University of South Carolina in 1976
- Is currently working toward an M.B.A. degree at the University of Tennessee

Gorman S. Hill
Health and Safety Research Division
Oak Ridge National Laboratory

Gorman Hill is a research associate in the Technology Assessments Section. Since 1973, he has participated in the radiological assessment of fuel cycle environmental statements and for a series of studies establishing "as low as reasonably achievable" guides for the nuclear fuel cycle. He has been involved in the calculation of radiological dose to man and other biota and in the evaluation of impacts to the maximum exposed individual and to the population. He has worked as a junior chemist, a health physicist, and as a research associate in the field of radiation. Hill assisted in editing material for the International Commission on Radiological Protection Report on Reference Man.

Education:

- Received a B.A. degree in biology from Lincoln Memorial University in 1944
- Received an M.S. degree in zoology with emphasis on radiation biology from the University of Tennessee in 1951

Affiliations:

- Holds membership in the Health Physics Society
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Ronald Kaufmann is a project management technical consultant for the New Facilities Section of the Uranium Recovery Licensing Branch. His technical training is in groundwater geology and geochemistry. As a project manager, Kaufmann oversees the licensing of new uranium in situ extraction facilities. In addition, he provides other project managers with technical assistance in the area of groundwater geology. He also manages and coordinates groundwater research for the Uranium Licensing Branch. Kaufmann's experience with industry includes evaluating the impact of a Florida phosphate mine on groundwater quality for the International Minerals and Chemical Corporation and, as a consultant to the NUS Corporation, evaluating the siting and impact of nuclear power plants, uranium in situ facilities, and waste disposal facilities. While with the NRC, Kaufmann has arranged for the licensing of several other in situ extraction facilities.

Education:

- Received a B.A. degree in geology from the State University of New York at Buffalo, 1975
- Received an M.S. degree in geology from the University of South Florida, 1979

Minton J. Kelly
Energy Division
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Minton Kelly is the manager of the Nuclear Fuel Cycle Projects in the Environmental Impacts Section. He coordinates the preparation of Environmental Assessments and Statements using interdisciplinary groups of specialists chosen by the requirements of each project. His original experience with environmental studies was in 1947-1948 when he supervised collection of chemical, meteorological, and physical data in estuarine Louisiana as part of a long-range ecological study on oyster mortality. From 1968 through early 1971, he worked with an interdisciplinary team whose responsibilities were to develop methods to assess the radiological impact of proposed Plowshare projects. With the passage of the National Environmental Policy Act, he became a member of the original team at Oak Ridge National Laboratory developing impact statement methodology. He also supervised the preparation of Nuclear Reactor Environmental Statements until mid-1974. Kelly accepted his present job assignment in August 1977. His other experiences include (1) supervision of instrument integration for the bottom stage of the initial manned moon rocket; (2) electrical and communications design for the Arabian American Oil Company; and (3) development of instrumentation for chemical kinetic studies, radiation resistant insulators, and equipment for studying postulated breeder reactor accidents.

Education:

- Received a B.S. degree in electrical engineering from Texas A&M University in 1947
- Received an M.S. degree in physical chemistry from Texas A&M University in 1951
- Received a Ph.D degree in physical chemistry from Texas A&M University in 1955

Affiliations:

- Elected a Fellow in the American Institute of Chemists
- Holds membership in Sigma Xi

Larry B. Lamonica
Science Applications, Inc.
Oak Ridge, Tennessee

Larry Lamonica is a chemical engineer with additional training and experience in the areas of nuclear engineering, air pollution control, and water-quality management. He has been responsible for assessing proposed milling processes and for aiding in the preparation of project description, accident, and alternative sections of seven uranium milling and mining projects. Lamonica's contribution to a study on comparative risks of electricity generation with uranium and coal involved definition of a model mine/mill complex and the ensuing definition of source terms based on generic effluent data from this type of facility.

Education:

- Received a B.S. degree in chemical engineering from Brigham Young University in 1977
- Is working toward an M.S. degree in chemical engineering at the University of Tennessee

Samuel C. Martin
Science Aplications, 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 socio-economic 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

Patrick J. Mulholland
Environmental Sciences Division
Oak Ridge National Laboratory

Patrick Mulholland is a research associate in the Aquatic Ecology Section. Actively involved in the Environmental Impacts Program, his work includes environmental impact assessments of various nuclear fuel cycle facilities and coal-fired power plants as well as studies involving harvesting peat for use as an energy source. Mulholland's training has been in aquatic ecology, wetland ecology, sanitary engineering, and ecosystem modeling; and his research has included phytoplankton growth modeling, water-quality studies of coastal plain streams, and organic carbon cycling in swamp ecosystems.

Education:

- Received a B.S. degree in civil and environmental engineering from Cornell University in 1973
- Received an M.S. degree in sanitary engineering from Cornell University in 1975
- Received a Ph.D degree in environmental biology and chemistry from the University of North Carolina in 1979

Affiliations:

- Holds membership in the Ecological Society of America, American Society of Limnology and Oceanography, and Sigma Xi

Allen M. Solomon
Environmental Sciences Division
Oak Ridge National Laboratory

Al Solomon is a terrestrial ecologist for the Environmental Impacts Section. His technical specialties are plant ecology, palynology, aerobiology, desert ecology, and paleoecology. Solomon's experience with impacts associated with nuclear power plants includes the Erie and Virgil C. Summer nuclear plant projects where he made significant contributions in areas including alternate sites, transmission line right-of-way maintenance, and endangered plant species. He has also worked on projects involving nuclear fuel fabrication plants, uranium enrichment plants, and uranium mining and milling.

Education:

- Received a B.A. degree in biology from the University of Michigan in 1965
- Received a Ph.D. degree in plant ecology from Rutgers in 1970

Affiliations:

- Holds membership in the Ecological Society of America, American Association for Advancement of Science, Society of Sigma Xi, American Quaternary Association (newsletter editor), International Aerobiology Association, and American Institutes of Biological Sciences

In addition, the Environmental Statement was reviewed by cognizant members of the Nuclear Materials Safety and Safeguards 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

Ronald S. Kaufmann
U.S. Nuclear Regulatory Commission
Mail Stop 483-SS
Washington, DC 20555

6. LIST OF AGENCIES RECEIVING DRAFT ENVIRONMENTAL STATEMENT

The following Federal, State, and local agencies have been se , copies of and asked to comment on the Draft Environmental Statement:

Department of Commerce
Department of the Interior
Department of Health and Human Services
Federal Energy Regulatory Commission
Department of Energy
Department of Transportation
Environmental Protection Agency
Department of Agriculture
Advisory Council on Historic Preservation
Department of Housing and Urban Development
Office of the Governor, State of Wyoming
State Planning Coordinator, State of Wyoming
Department of Agriculture, State of Wyoming
Department of Environmental Quality, State of Wyoming
Department of Game and Fish. State of Wyoming
Board of Commissioners, Fremont County, Wyoming
Planning Commission, Fremont County, Wyoming

Appendix A

RESERVED FOR COMMENTS ON THE DRAFT ENVIRONMENTAL STATEMENT

Appendix B

AQUIFER TESTS FOR ANALYSIS OF GROUNDWATER QUALITY

Appendix B

AQUIFER TESTS FOR ANALYSIS OF GROUNDWATER QUALITY

The hydrologic properties of the "D" sands (production zone aquifer) in the project area were established from the results of three separate aquifer tests conducted in both the north portion and the south portion of the elongated 16-ha (40-acre) ore body. The locations of the aquifer tests are shown in Fig. 3.7. Two of the tests were performed during the period from June 7, 1977, to June 23, 1977; the third test was performed on November 3 and 4, 1978.

The Jacob-modified Theis equation and the Hantush-Jacob unsteady, leaky artesian-type curve methods were used to analyze individual well data obtained from the June 1977 tests; the Jacob-modified Theis equation was used to analyze the well data from the November 1978 test. Two major assumptions inherent in these methods are

1. The aquifer is confined and homogeneous within the radius of influence. The assumption of confined conditions was verified by water level and curve response. Because consistent values of transmissivity were found on all observation wells, it is assumed that the aquifer is behaving in a homogeneous manner.

2. The pumped well fully penetrates the entire thickness of the aquifer. Wells OP-140-TC, OP-141-TC, and 303-6-P22C — the pumping/injection — were fully screened across the aquifer.

B.1 AQUIFER TEST 1

Aquifer Test 1 was conducted in the southern portion of the ore body between June 6, 1977, and June 14, 1977. It consisted of one step drawdown test using formation water, one injection test using formation water, one injection test using leach fluid, and one pump test using uranium-bearing production fluid. The pumping/injection well for these tests was OP-140-TC; the observation wells were OP-94, OP-95C, OP-135, and OP-136. The location of the observation wells relative to the pumping/injection well is shown in Fig. 3.11. The pumping/injection well and all four observation wells are completed (screened) only in the production zone aquifer, the screen assembly fully penetrating the aquifer.

Wells OP-94, OP-135, and OP-136 have a 5-cm (2-in.) PVC casing; their field-fabricated screens are made by cutting slots into the PVC pipe. Wells OP-95C and OP-140-TC have a 10-cm (4-in.) PVC casing with a 5-cm-diam (2-in.) plastic screen and a 7.6-cm-diam (3-in.) stainless steel screen respectively. The top of the aquifer in Test Area 1 is approximately 116 m (380 ft) below the land surface; the aquifer itself is approximately 4.5 m (15 ft) thick; and the potentiometric water level is about 35 m (115 ft) below the land surface.

Table B.1 is a summary of the results of Aquifer Test 1. The average transmissivity and hydraulic conductivity are 1.6 m^2/d (130 gpd/ft) and 0.27 m/d (6.5 gpd/ft^2) respectively.

The radii of influence during the injection and pump tests of Aquifer Test 1 were approximately 107 to 122 m (350 to 400 ft). No large-scale discontinuities in permeability and no significant leakage or hydraulic boundary were detected within the region of influence of the hydrologic tests.

B.2 AQUIFER TEST 2

Aquifer Test 2 was conducted in the northern portion of the ore body between June 16, 1977, and June 23, 1977. It consisted of one step drawdown test using formation water, one injection test using leach fluid, one pump test with uranium-bearing production fluid, and two pressure buildup tests.

Table B.1. Summary of Aquifer Test 1

Date	Test type	Well no.	Transmissivity [m^2/d (gpd/ft)]		Hydraulic conductivity [m/d (gpd/ft^2)]		Permeability (darcy)		Storage coefficient		Well efficiency (%)	Flow rate [m^3/d (gpm)]
			Jacob	Hantush	Jacob	Hantush	Jacob	Hantush	Jacob	Hantush		
6-7-77	Step drawdown	OP-140-TC									64	32.71–54.51 (6–10)
6-8-77	Injection	OP-94	1.63 (130)	1.69 (135)	0.27 (6.50)	0.28 (6.75)	0.36	0.37	1.47E–4[a]	1.49E–4		
		OP-95-C	1.63 (130)	0.63 (50)	0.27 (6.50)	0.10 (2.50)	0.36	0.14	1.05E–4	2.00E–3		
		OP-135	1.63 (130)		0.27 (6.50)		0.36		2.53E–4			
		OP-136	1.63 (130)	1.25 (100)	0.27 (6.50)	0.20 (5.00)	0.36	0.27	1.44E–5	2.65E–5		
		OP-140-TC									53	51.18 (9.39)
6-13-77	Pump	OP-94	1.69 (135)	1.75 (140)	0.28 (6.75)	0.29 (7.00)	0.37	0.38	1.68E–4	1.70E–4		
		OP-95-C	1.50 (120)	0.30 (24)	0.25 (6.00)	0.05 (1.20)	0.33	0.07	5.28E–5	2.76E–4		
		OP-135	2.06 (165)		0.34 (8.25)		0.45		2.91E–4			
		OP-136	1.46 (117)	0.53 (42)	0.24 (5.85)	0.09 (2.10)	0.32	0.12	9.40E–6	2.52E–5		
		OP-140-TC									70	45.79 (8.4)

[a] Read as 1.47×10^{-4}

The pumping/injection well for these tests was OP-141-TC; the observation wells were OP-41, OP-42, OP-132 and OP-133. The location of the observation wells relative to the pumping/injection well is shown in Fig. 3.13. The pumping/injection well and all four observation wells are completed (screened) only in the production zone aquifer, the screen assembly fully penetrating the aquifer. Wells OP-41, OP-42, and OP-132 have a 5-cm (2-in.) PVC casing; their field-fabricated screens are made by cutting slots into the PVC pipe. Wells OP-133 and OP-141-TC have a 10-cm (4-in.) PVC casing and a 5-cm-diam (2-in.) plastic screen and a 7.6-cm-diam (3-in.) stainless steel screen respectively. The top of the aquifer in Test Area 2 is approximately 108.5 m (356 ft) below the land surface; the aquifer itself is approximately 4.5 m (15 ft) thick; and the potentiometric water level is about 45.7 m (150 ft) below the land surface.

Table B.2 is a summary of the results of Aquifer Test 2. The average transmissivity and hydraulic conductivity are 2.48 m^2/d (198 gpd/ft) and 0.41 m/d (10 gpd/ft^2) respectively.

The radii of influence during the injection and pump tests of Aquifer Test 2 were approximately 107 to 122 m (350 to 400 ft). No large-scale discontinuities in permeability and no significant leakage or hydraulic boundary were detected within the region of influence of the hydrologic tests.

B.3 AQUIFER TEST 3

Aquifer Test 3 was conducted on November 3 and 4, 1978, in the southern portion of the ore body near the location of Aquifer Test 1. The test was performed primarily as part of the research and development mining operation to determine whether or not there is hydraulic communication between the injection/recovery wells and the monitor wells. Additionally, the test was used to check the results of Aquifer Test 1 by applying the Jacob-modified Theis method to the test data. Well 303-6-P22 was the pumped well; Wells 303-6-P7, 303-6-P8, 303-6-P10, 303-6-P16, 303-6-P19, 303-6-P21, 303-6-P30, 303-6-P31, 303-6-P32, OP-94, 303-6-M1, 303-6-M2, 303-6-M3, 303-6-M4, 303-6-M5, and 303-6-M6 were the observation wells. The location of the observation wells relative to the pumping well is shown in Fig. 3.14.

The pumped well, 303-6-P22, and observation wells 303-6-P7, 303-6-P8, 303-6-P10, 303-6-P16, 303-6-P19, 303-6-P21, 303-6-P30, 303-6-P31 and 303-6-P32 have 10-cm (4-in.) PVC casings and 7.6-cm (3-in.) stainless steel screens. Observation wells 303-6-M1, 303-6-M2, 303-6-M4, 303-6-M5, and 303-6-M6 have 10-cm (4-in.) PVC casings and 5-cm (2-in.) plastic screens. Well OP-94 has a 5-cm (2-in.) PVC casing and a field-fabricated screen made by cutting slots into the PVC pipe. The pumped well and all observation wells except Well 303-6-M3 are completed (screened) only in the production zone aquifer, the screen assembly fully penetrating the aquifer.

Observation well 303-6-M3 was completed in the upper ("B" sands) aquifer to monitor possible vertical excursions of leach chemicals during operation. The upper aquifer is also under confined conditions and is separated from the production zone aquifer by about 33.5 m (110 ft) of mudstone and siltstone. The potentiometric water level in Well 303-6-M3 is approximately 18.6 m (61 ft) below the land surface. There was no lower aquifer monitor well constructed for the operation because of the lack of a persistent sandstone unit within 10.7 m (35 ft) of the bottom of the production zone aquifer.

The constant pumping of Well 303-6-P22 at approximately 44 m^3/d (8 gpm) for 25 h produced drawdowns at all observation wells completed in the production zone aquifer ranging from 4.20 to 10.25 m (13.77 to 33.64 ft). The drawdown measured at Well 303-6-M3, the upper aquifer monitor well, was zero. This drawdown information successfully demonstrated that (1) the production zone monitor wells for the research and development well field (Wells 303-6-M1, 303-6-M2, 303-6-M4, 303-6-M5, and 303-6-M6) are in hydraulic communication with the injection/recovery wells and that (2) the upper aquifer is not hydraulically connected to the production zone aquifer.

A summary of the hydrologic results of Aquifer Test 3 is shown in Table B.3. The average transmissivity and hydraulic conductivity calculated from this test are 1.46 m^2/d (117 gpd/ft) and 0.24 m/d (5.8 gpd/ft^2), respectively, which compare favorably with the results of Aquifer Test 1 conducted in the same area.

Table B.2. Summary of Aquifer Test 2

Date	Test type	Well number	Transmissivity [m²/d (gpd/ft)]		Hydraulic conductivity [m/d (gpd/ft²)]		Permeability (darcy)		Storage coefficient		Flow rate [m³/d (gpm)]
			Jacob	Hantush	Jacob	Hantush	Jacob	Hantush	Jacob	Hantush	
6-16-77	Step drawdown	OP-141-TC									40.17–75.66 (7.37–13.88)
6-17-77	Injection	OP-41	2.31 (185)	2.13 (170)	0.38 (9.25)	0.35 (8.50)	0.51	0.47	5.86E–5[a]	7.43E–5	
		OP-42	2.00 (160)	2.00 (160)	0.33 (8.00)	0.33 (8.00)	0.44	0.44	7.64E–5	8.90E–5	
		OP-132	2.50 (200)	2.19 (175)	0.41 (10.00)	0.36 (8.75)	0.55	0.48	1.42E–4	5.24E–5	
		OP-133	2.44 (195)	1.94 (155)	0.40 (9.75)	0.40 (9.75)	0.54	0.43	1.21E–3	6.16E–3	
		OP-141-TC									84.49 (15.5)
6-17-77	Recovery	OP-41	2.62 (210)		0.43 (10.50)		0.58				
		OP-42	2.38 (190)		0.39 (9.50)		0.52				
		OP-132	2.88 (230)		0.47 (11.50)		0.63				
6-22-66	Pump	OP-41	2.38 (190)	2.25 (180)	0.39 (9.50)	0.37 (9.00)	0.52	0.49	7.07E–5	4.85E–5	
		OP-42	2.25 (180)	2.06 (165)	0.37 (9.00)	0.34 (8.25)	0.49	0.45	8.44E–5	6.04E–5	
		OP-132	3.75 (300)	3.56 (285)	0.61 (15.00)	0.58 (14.25)	0.82	0.78	1.15E–5	7.63E–5	
		OP-133									
		OP-141-TC									55.60 (10.2)
6-22-77	Recovery	OP-41	2.44 (195)		0.40 (9.75)		0.54				
		OP-42	2.25 (180)		0.37 (9.00)		0.49				
		OP-132	2.81 (225)		0.52 (12.75)		0.70				

[a] Read as 5.86×10^{-5}.

Table B.3. Summary of Aquifer Test 3

Well number	Transmissivity [m^2/d (gpd/ft)]	Hydraulic conductivity [m/d (gpd/ft^2)]	Storage coefficient
303-6-M1	1.38 (110)	0.22 (5.5)	6.1E–5[a]
303-6-M2	1.63 (130)	0.27 (6.5)	6.3E–5
303-6-M3[b]			
303-6-M4	1.38 (110)	0.22 (5.5)	5.4E–5
303-6-M5	1.38 (110)	0.22 (5.5)	3.4E–5
303-6-M6	1.50 (120)	0.27 (6.5)	4.4E–5
303-6-P7	1.50 (120)	0.27 (6.5)	1.7E–4
303-6-P8	1.50 (120)	0.27 (6.5)	3.4E–4
303-6-P10	1.50 (120)	0.27 (6.5)	3.4E–4
303-6-P16	1.38 (110)	0.22 (5.5)	5.5E–4
303-6-P19	1.38 (110)	0.22 (5.5)	2.6E–4
303-6-P21	1.50 (120)	0.27 (6.5)	4.7E–4
303-6-P30	1.50 (120)	0.27 (6.5)	2.7E–4
303-6-P31	1.50 (120)	0.27 (6.5)	3.6E–4
303-6-P32	1.50 (120)	0.27 (6.5)	4.8E–4
OP-94	1.38 (110)	0.22 (5.5)	5.9E–4

[a] Read as 6.1×10^{-5}.

[b] Upper aquifer monitor well, no drawdown.

Appendix C

RADON RELEASES FROM AREA SOURCES

Appendix C

RADON RELEASES FROM AREA SOURCES

This appendix describes the assumptions, data, and equations used to estimate the annual radon-222 released from the solution mining and restoration processes. Some of the production capacities and other parameters used in the radon release calculations are listed below:

Acres to be mined per year	11.5
Average production flow rate, gal/min	1200
Operating days per year	340
Formation Porosity, %	28
Average ore thickness, ft	6.3
Rock density, g/cm^3	2.5
Residence time for production solution, d	7.72
Equilibrium value for radon for 7.72 d, %	70
Residence time for restoration solution, d	15.4
Equilibrium value for radon for 15.4 d, %	88

C.1 RADON FROM PREGNANT LEACH SOLUTION

For uranium-238 in equilibrium with all its daughters, an ore body concentration of 225 pCi/g of radon is estimated. (This corresponds to an ore grading of 0.08%, which is higher than the expected ore grade of 0.07%.) One cubic foot of ore contains

$$28{,}300\ cm^3/ft^3 \times 2.5\ g/cm^3 \times (1 - 0.28) \times 225\ pCi/g \div 1 \times 10^{12}\ pCi/Ci = 1.15 \times 10^{-5}\ Ci/ft^3$$

A radon emanation coefficient of 0.20 is assumed. Thus the pore water contains:

$$\frac{1.15 \times 10^{-5}\ Ci/ft^3}{0.28} \times 0.20 = 8.21 \times 10^{-6}\ Ci/ft^3$$

of radon at equilibrium. The maximum radon release is calculated as

$$1200\ gal/min \times 8\ lb/gal \times \frac{1}{62.4\ lb/ft^3} \times 1440\ min/d \times 340\ d/year \times 8.21$$

$$\times 10^{-6}\ Ci/ft^3 = 618\ Ci/year\ ,$$

where 340 d/year is the number of days of operation yearly.

For pregnant leach solution it is assumed that the radon is at 70% of equilibrium with daughters. The annual radon release is then calculated to be

$$618 \text{ Ci/year} \times 0.70 = 433 \text{ Ci/year} .$$

In addition to the release of radon from the production solution, one pore volume of nonproduction water (where radon is in equilibrium with daughters) will be removed as each well is put into service over the 11.5 acres. The radon release from a nonproductive source, resulting from this start-up procedure is as follows:

$$11.5 \text{ acres} \times 43{,}560 \text{ ft}^2\text{/acre} \times 6.3 \text{ ft} \times 0.28 \times 8.21 \times 10^{-6} \text{ Ci/ft}^3 = 7 \text{ Ci/year} ,$$

where 6.3 ft is the thickness of the ore body and 0.28 is the porosity coefficient.

Thus the total release of radon from the uranium-bearing solutions would be

Production solution	433 Ci/year
Nonproduction solution	7 Ci/year
Total for operating wells	440 Ci/year

C.2 RADON RELEASE FROM RESTORATION

The applicant proposes to start restoration of the aquifer in the third year of operation at a pumping rate of 115 gal/min. For the restoration procedure, the radon release is calculated to be

$$115 \text{ gal/min} \times 8 \text{ lb/gal} \times \frac{1}{62.4 \text{ lb/ft}^3} \times 1440 \text{ min/d} \times 340 \text{ d/year} \times 8.21$$

$$\times 10^{-6} \text{ Ci/ft}^3 \times 0.88 = 52 \text{ Ci/year} ,$$

where 0.88 is the ratio of radon equilibrium.

The total release of radon from the first year of restoration procedures (year of maximum release) is as follows:

From restoration solution	52 Ci/year
From start-up solution	7 Ci/year
Total from restoration	59 Ci/year

C.3 RADON RELEASE FROM EVAPORATION RESERVOIR (WASTE POND)

Radon emission from the waste pond is considered to be negligible.

C.4 SUMMARY

The maximum annual release of radon will occur during the first year that restoration begins. The total annual release during this period is as follows:

Annual release from production	440 Ci
Annual release from restoration	59 Ci
Maximum annual release	499 Ci

It may be noted that these calculated values are probably very conservative in that

1. It is unlikely that the emanation coefficient will be as great for emanation into water as into air.

2. Release of 100% of the dissolved radon from the surge tanks and process lines is unlikely.

3. More than 60% leaching efficiency will decrease the amount of radon per pound of product. (The calculated in-place ore grade would be lower.)

On the other hand, the calculations were made by using slug flow (no mixing), a nonconservative practice for the fraction of equilibrium reached.

Appendix D

DETAILED RADIOLOGICAL ASSESSMENT

Appendix D

DETAILED RADIOLOGICAL ASSESSMENT

Supplemental information is provided below which describes the models, data, and assumptions utilized by the staff to perform its radiological impact assessment of the Bison Basin solution mining project. The primary calculational model employed by the staff in performing this assessment is the AIRDOS-EPA computer code[1] originated at the Oak Ridge National Laboratory.

Radioactive materials introduced into the body by the inhalation or ingestion pathways (internal exposure) continue to irradiate the body until removed by processes of metabolism or radioactive decay. Exposure is measured in terms of dose commitments: A 50-year dose commitment is determined by the dose calculated for an individual for one year of radionuclide intake. It represents the total dose he will receive integrated over the next 50 years (his remaining lifetime) as a result of that year's intake. In this report all internal doses are 50-year dose commitments.

D.1 METHODOLOGY AND ASSUMPTIONS

D.1.1 AIRDOS-EPA computer code

The radiation dose commitments resulting from the atmospheric releases of radionuclides are calculated by using the AIRDOS-EPA computer code.[1] The methodology is designed to estimate (1) the radionuclide concentrations in air; (2) rates of deposition on ground surfaces; (3) intake rates via inhalation of air and ingestion of meat, milk, and fresh vegetables; and (4) the radiation doses from airborne releases of radionuclides. The code is also used to determine the highest estimated dose to an individual in the area and the dose to the population living within an 80-km (50-mile) radius of the mining facilities. The doses may be categorized by radionuclide, by exposure pathway, or by exposure to significant organs of the body.

The basic equation used to estimate the dispersion of an airborne plume is the Gaussian plume equation of Pasquill[2] as modified by Gifford.[3] Radionuclide concentrations in meat, milk, and vegetables consumed by man are estimated by coupling the output of the atmospheric transport models with NRC terrestrial food chain models.[4] The models are also described in an Oak Ridge National Laboratory report.[5] Details for determining atmospheric dispersion and deposition are given in ref. 1.

D.1.2 Dose conversion factors

The International Commission on Radiation Protection determined the factors for converting internal exposure to dose (dose conversion factors).[6] These and other recognized values have been implemented by recent models for the lung[7] and GI tract.[8] Details of these models and the assumptions used in calculating the dose conversion factors are described in an NRC-sponsored research.[9]

The dose conversion factor for bronchial epithelium exposure from radon-222 is derived as follows:

1. 1 pCi/m^3 of radon-222 = 5×10^{-6} working levels (WL) where one WL concentration is defined as any combination of short-lived radioactive decay products of radon-222 in 1 liter of air which will release 2.08×10^{-8} J (1.3×10^5 MeV) of alpha-particle energy during their radioactive decay of lead-210 (the conversion factor used is one determined by the Environmental Protection Agency[10]);

2. continuous exposure to 1 WL = 25 cumulative working level months (WLM) per year: and

3. 1 WLM = 5000 millirems.[11]

Therefore,

$$\left(5 \times 10^{-6} \frac{\text{WL}}{\text{pCi/m}^3}\right) \left(25 \frac{\text{WLM}}{\text{WL}}\right) \left(5000 \frac{\text{millirems}}{\text{WLM}}\right) = 0.625 \frac{\text{millirem}}{\text{pCi/m}^3} .$$

Thus the radon-222 bronchial epithelium dose conversion factor is taken to be 0.625 millirem · m^3/pCi.

The dose conversion factors for external exposure were calculated using the computer code DOSFACTER.[12] The dose conversion factors for ground-surface exposure are calculated for a height of 1 m (3.3 ft) using the point-kernel integration method. The conversion factors for immersion in air and water are based on the requirement that all energy emitted is absorbed in the infinite medium.

D.1.3 Radiation dose to the individual

Dose is estimated to the adult individual living in the nearest residence, which would be the location of the potential maximum exposure. The location is assumed to have the highest concentration of radionuclides in the surrounding air and on the land surface. Additional assumptions are that the exposed individual resides continuously at the location (no allowance is made for protective shielding provided by the residence) and that the location is the point of origin for all food consumed. Estimates of dose are made for the total body and a number of reference organs, and those radionuclides that contribute large fractions of the total dose are identified.

Dose to individuals have been calculated for inhalation; external exposure to air and ground concentration; and ingestion of vegetables, meat, and milk. The staff calculated internal doses by using conversions factors[9] that yield 50-year dose commitment, that is, the entire dose received over a period of 50 years following either inhalation or ingestion of one year's intake of radionuclides. The one-year exposure period was taken to be the final year of plant operation when environmental concentrations resulting from plant operations are expected to be at their highest level.

D.1.4 Radiation dose to the populations

The total dose received by an exposed adult population because of the releases from well-field and recovery operations is estimated by the summation of individual dose estimates within the population. The area within a radius of 80 km (50 miles) of the project is divided into 16 sectors (22.5° each) and into a number of annuli. The average dose for an individual in each division is estimated; that estimate is then multiplied by the number of persons in the division, and the resulting products are summed across the entire area. The unit to express the population dose is man-rem.

D.2 ATMOSPHERIC DISPERSION (METEOROLOGY)

The basic equation used to estimate atmospheric transport to the terrestrial environment is Pasquill's equation[2] as modified by Gifford.[3] For particulate releases, the meteorological χ/Q values are used in conjunction with dry deposition velocities and scavenging coefficients to estimate air concentrations. Radioactive decay during plume travel must be added to the AIRDOS-EPA[1] source term. Concentrations in air for each sector are used to calculate doses received via inhalation — including daughter radionuclides building upon the ground as a result of the deposition of the parents[1] and from external radiation exposure. The ground deposits are also assimilated into food, which, when ingested, results in additional dose through the food chain pathways.

The meteorological data required for the calculation are joint frequency distributions of wind velocity and direction summarized by stability class for the Rock Springs, Wyoming meteorology (Tables D.1 and D.2). The χ/Q values for the residences nearest the project facilities and for other distances are shown in Tables D.3, D.4, and D.5.

Table D.1. Frequencies of wind directions and true-average wind speeds

Rock Springs, Wyoming, meteorological data (1960–1964)

Wind direction (toward)	Frequency	Wind speeds for each stability class[a] (m/s)					
		A	B	C	D	E	F
N	0.057	0.30	0.60	1.40	4.50	3.60	0.60
NNW	0.031	0.30	0.60	1.40	4.50	3.60	0.60
NW	0.034	0.30	0.60	1.40	4.50	3.60	0.60
WNW	0.018	0.30	0.60	1.40	4.50	3.60	0.60
W	0.033	0.30	0.60	1.40	4.50	3.60	0.60
WSW	0.048	0.30	0.60	1.40	4.50	3.60	0.60
SW	0.059	0.30	0.60	1.40	4.50	3.60	0.60
SSW	0.018	0.30	0.60	1.40	4.50	3.60	0.60
S	0.020	0.30	0.60	1.40	4.50	3.60	0.60
SSE	0.019	0.30	0.60	1.40	4.50	3.60	0.60
SE	0.151	0.30	0.60	1.40	4.50	3.60	0.60
ESE	0.055	0.30	0.60	1.40	4.50	3.60	0.60
E	0.134	0.30	0.60	1.40	4.50	3.60	0.60
ENE	0.164	0.30	0.60	1.40	4.50	3.60	0.60
NE	0.109	0.30	0.60	1.40	4.50	3.60	0.60
NNE	0.050	0.30	0.60	1.40	4.50	3.60	0.60

[a] Value for class G is 0.00.

Table D.2. Frequency of atmospheric stability classes for each direction

Rock Springs, Wyoming, meteorological data (1960–1964)

Sector	Fraction of time in each stability class[a]					
	A	B	C	D	E	F
N	0.0167	0.0367	0.0851	0.5576	0.0367	0.2671
NNW	0.0125	0.0500	0.0781	0.4563	0.1813	0.2219
NW	0.0114	0.0427	0.0741	0.2991	0.2251	0.3476
WNW	0.0105	0.0524	0.0942	0.4607	0.1309	0.2513
W	0.0146	0.0583	0.1079	0.2974	0.2478	0.2741
WSW	0.0100	0.0433	0.0837	0.4721	0.1514	0.2390
SW	0.0179	0.0700	0.1222	0.5342	0.1010	0.1547
SSW	0.0265	0.1323	0.1852	0.4392	0.0741	0.1429
S	0.0293	0.1659	0.1951	0.2829	0.1073	0.2195
SSE	0.0253	0.1263	0.1414	0.2778	0.2929	0.1364
SE	0.0076	0.0158	0.0348	0.8176	0.0481	0.0760
ESE	0.0293	0.0828	0.1517	0.5983	0.0431	0.0948
E	0.0114	0.0506	0.1056	0.6812	0.0606	0.0906
ENE	0.0058	0.0350	0.0905	0.7541	0.0444	0.0701
NE	0.0114	0.0572	0.1048	0.7544	0.0537	0.0185
NNE	0.0114	0.0341	0.1004	0.6553	0.0265	0.1723

[a] Value for class G is 0.00.

Table D.3. χ/Q values at receptor points

Location and distance	χ/Q values (s/m^3)	
	Particulates	^{222}Rn
Caretaker Cottage (11 km ENE)	3.37E–8[a]	1.26E–7
Sweetwater Station (30 km NNE)	1.59E–9	2.17E–8

[a] Read as 3.3×10^{-8}

Table D.4. Ground-level χ/Q values for particulates at various distances in each compass direction

Distance (m)	χ/Q toward indicated direction (s/m^3)							
	N	NNW	NW	WNW	W	WSW	SW	SSW
500	0.659E–5[a]	0.326E–5	0.471E–5	0.208E–5	0.404E–5	0.528E–5	0.525E–5	0.165E–5
1,500	0.986E–6	0.488E–6	0.714E–6	0.311E–6	0.605E–6	0.792E–6	0.766E–6	0.231E–6
2,500	0.310E–6	0.158E–6	0.222E–6	0.991E–7	0.193E–6	0.255E–6	0.256E–6	0.770E–7
3,500	0.137E–6	0.726E–7	0.964E–7	0.445E–7	0.863E–7	0.115E–6	0.121E–6	0.362E–7
4,500	0.742E–7	0.408E–7	0.514E–7	0.245E–7	0.474E–7	0.641E–7	0.698E–7	0.208E–7
7,500	0.221E–7	0.132E–7	0.147E–7	0.756E–8	0.146E–7	0.202E–7	0.239E–7	0.700E–8
15,000	0.592E–8	0.385E–8	0.400E–8	0.212E–8	0.419E–8	0.577E–8	0.708E–8	0.208E–3
25,000	0.223E–8	0.149E–8	0.150E–8	0.812E–9	0.161E–8	0.222E–8	0.279E–8	0.822E–9
35,000	0.126E–8	0.867E–9	0.881E–9	0.468E–9	0.944E–9	0.128E–8	0.159E–8	0.463E–9
45,000	0.802E–9	0.558E–9	0.569E–9	0.301E–9	0.610E–9	0.827E–9	0.102E–8	0.297E–9
55,000	0.537E–9	0.362E–9	0.364E–9	0.197E–9	0.392E–9	0.540E–9	0.674E–9	0.198E–9
65,000	0.375E–9	0.235E–9	0.227E–9	0.131E–9	0.244E–9	0.354E–9	0.456E–9	0.135E–9
75,000	0.284E–9	0.176E–9	0.170E–9	0.984E–10	0.183E–9	0.267E–9	0.343E–9	0.101E–9
	S	SSE	SE	ESE	E	ENE	NE	NNE
500	0.224E–5	0.176E–5	0.926E–5	0.412E–5	0.933E–5	0.102E–4	0.548E–5	0.452E–5
1,500	0.317E–6	0.252E–6	0.139E–5	0.581E–6	0.136E–5	0.149E–5	0.777E–6	0.670E–6
2,500	0.101E–6	0.862E–7	0.504E–6	0.202E–6	0.479E–6	0.541E–6	0.303E–6	0.221E–6
3,500	0.454E–7	0.416E–7	0.257E–6	0.993E–7	0.239E–6	0.276E–6	0.165E–6	0.103E–6
4,500	0.249E–7	0.245E–7	0.159E–6	0.592E–7	0.145E–6	0.170E–6	0.106E–6	0.587E–7
7,500	0.758E–8	0.868E–8	0.617E–7	0.216E–7	0.540E–7	0.658E–7	0.439E–7	0.196E–7
15,000	0.216E–8	0.274E–8	0.190E–7	0.655E–8	0.165E–7	0.203E–7	0.[illegible]40E–7	0.561E–8
25,000	0.840E–9	0.110E–8	0.759E–8	0.261E–8	0.657E–8	0.810E–8	0.569E–8	0.218E–8
35,000	0.476E–9	0.643E–9	0.431E–8	0.146E–8	0.372E–8	0.459E–8	0.322E–8	0.122E–8
45,000	0.306E–9	0.415E–9	0.275E–8	0.935E–9	0.238E–8	0.294E–8	0.206E–8	0.783E–9
55,000	0.201E–9	0.265E–9	0.184E–8	0.626E–9	0.1[illegible]9E–8	0.197E–8	0.138E–8	0.527E–9
65,000	0.134E–9	0.165E–9	0.128E–8	0.437E–9	0.111E–8	0.138E–8	0.962E–9	0.372E–9
75,000	0.998E–10	0.123E–9	0.973E–9	0.330E–9	0.836E–9	0.105E–8	0.728E–9	0.282E–9

[a] Read as 0.659×10^{-5}

Table D.5. Ground-level χ/Q values for ^{222}Rn at various distances in each compass direction

Distance (m)	χ/Q toward indicated direction (s/m^3)							
	N	NNW	NW	WNW	W	WSW	SW	SSW
500	0.731E–5	0.360E–5	0.523E–5	0.230E–5	0.449E–5	0.584E–5	0.582E–5	0.185E–5
1,500	0.202E–5	0.953E–6	0.150E–5	0.623E–6	0.122E–5	0.157E–5	0.141E–5	0.421E–6
2,500	0.934E–6	0.440E–6	0.697E–6	0.288E–6	0.564E–6	0.728E–6	0.643E–6	0.190E–6
3,500	0.573E–6	0.269E–6	0.429E–6	0.177E–6	0.346E–6	0.446E–6	0.391E–6	0.114E–6
4,500	0.406E–6	0.191E–6	0.305E–6	0.125E–6	0.245E–6	0.316E–6	0.275E–6	0.800E–7
7,500	0.201E–6	0.941E–7	0.151E–6	0.618E–7	0.121E–6	0.156E–6	0.134E–6	0.387E–7
15,000	0.835E–7	0.392E–7	0.634E–7	0.257E–7	0.507E–7	0.649E–7	0.553E–7	0.159E–7
25,000	0.453E–7	0.213E–7	0.347E–7	0.140E–7	0.277E–7	0.353E–7	0.298E–7	0.860E–8
35,000	0.300E–7	0.141E–7	0.231E–7	0.927E–8	0.184E–7	0.234E–7	0.197E–7	0.567E–8
45,000	0.218E–7	0.103E–7	0.169E–7	0.677E–8	0.135E–7	0.171E–7	0.143E–7	0.414E–8
55,000	0.169E–7	0.798E–8	0.131E–7	0.523E–8	0.104E–7	0.132E–7	0.111E–7	0.320E–8
65,000	0.135E–7	0.641E–8	0.105E–7	0.420E–8	0.839E–8	0.106E–7	0.890E–8	0.257E–8
75,000	0.111E–7	0.529E–8	0.867E–8	0.347E–8	0.693E–8	0.857E–8	0.734E–8	0.212E–8
	S	SSE	SE	ESE	E	ENE	NE	NNE
500	0.253E–5	0.196E–5	0.100E–4	0.459E–5	0.102E–4	0.111E–4	0.596E–5	0.498E–5
1,500	0.622E–6	0.446E–6	0.223E–5	0.982E–6	0.226E–5	0.236E–5	0.101E–5	0.127E–5
2,500	0.283E–6	0.201E–6	0.101E–5	0.439E–6	0.102E–5	0.106E–5	0.434E–6	0.583E–6
3,500	0.172E–6	0.122E–6	0.612E–6	0.263E–6	0.614E–6	0.638E–6	0.254E–6	0.356E–6
4,500	0.121E–6	0.852E–7	0.429E–6	0.183E–6	0.430E–6	0.445E–6	0.173E–6	0.251E–6
7,500	0.590E–7	0.415E–7	0.208E–6	0.883E–7	0.208E–6	0.214E–6	0.805E–7	0.123E–6
15,000	0.246E–7	0.172E–7	0.832E–7	0.357E–7	0.837E–7	0.853E–7	0.304E–7	0.506E–7
25,000	0.134E–7	0.940E–8	0.437E–7	0.190E–7	0.444E–7	0.447E–7	0.153E–7	0.272E–7
35,000	0.888E–8	0.624E–8	0.284E–7	0.124E–7	0.290E–7	0.290E–7	0.969E–8	0.179E–7
45,000	0.650E–8	0.458E–8	0.205E–7	0.903E–8	0.210E–7	0.210E–7	0.693E–8	0.130E–7
55,000	0.503E–8	0.356E–8	0.157E–7	0.696E–8	0.162E–7	0.161E–7	0.528E–8	0.100E–7
65,000	0.404E–8	0.287E–8	0.125E–7	0.558E–8	0.130E–7	0.129E–7	0.420E–8	0.805E–8
75,000	0.334E–8	0.237E–8	0.103E–7	0.459E–8	0.107E–7	0.106E–7	0.345E–8	0.662E–8

An Oak Ridge National Laboratory report[1] discusses parameter requirements for characterizing a site that is releasing radionuclides, requirements for meteorological data, and a detailed description of the atmospheric dispersion and deposition models used in this report.

D.3 OTHER PARAMETERS USED IN RADIOLOGICAL ASSESSMENT

Other parameters used in the radiological assessment of the Bison Basin Project (Table D.6) were provided by the applicant or calculated from information from the Environmental Report.[13]

Table D.6. Some parameters and conditions used in the radiological assessment of the solution mining project

Parameter	Value
Average ore grade (U_3O_8), %	0.08
Operating days/year	340
Millwater throughout–pregnant solution throughout, m^3/year	2.24×10^6
Land use and grazing of cattle	
Fraction of year spent grazing locally, %	33
Fraction of feed from pasture grass, %	100
Fraction of stored feed grown locally, %	0
Stack effluent (height), m	10
Temperature at site (annual av), °C	6.15
Precipitation (annual av), cm/year	19.8
Mixing height (annual av), m	1250

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Appendix E

GLOSSARY OF TERMS RELATED TO SOLUTION MINING OF URANIUM

Appendix E

GLOSSARY OF TERMS RELATED TO SOLUTION MINING OF URANIUM

Adsorptive capacity. Physical limit of adhesion of ions in solution to the surfaces of solids with which they are in contact.

ADU. Ammonium diuranate. Approximate chemical composition is given as $[UO_2(OH)_2 \cdot H_2O\ NH_4^+]$ salt. ADU is not the oxide form of uranium, namely, U_3O_8 (triuranium octaoxide), commonly called yellow cake.

Alkalinity. A measure of the power of a solution to neutralize hydrogen ions expressed in terms of an equivalent amount of calcium carbonate.

Alluvium. Clay, silt, sand, gravel, or other rock materials transported by flowing water and deposited in comparatively recent geologic time as sorted or semisorted sediments.

Annular space (annulus). The space between casing or well screen and the wall of the drilled hole.

Aquiclude. Formation that, although porous and capable of absorbing water, does not transmit it at rates sufficient to furnish an appreciable supply for a well or spring.

Aquifer. Porous water-bearing formation (bed or stratum) of permeable rock, sand, or gravel capable of yielding significant quantities of water.

Aquifer, leaky. Aquifer overlain and/or underlain by a thin semipervious layer through which flow into or out of the aquifer can take place.

Aquitard. Geological formation of a rather impervious and semiconfining nature, which transmits water at a very slow rate compared with an aquifer.

Area of influence. Area around a pumping well in which the water table or the potentiometric surface (in confined aquifers) is lowered by pumping.

Artesian. The occurrence of groundwater under greater than atmospheric pressure.

Artesian (confined) aquifer. An aquifer overlain by confining beds containing water under artesian conditions.

Artesian well. Well tapping a confined artesian aquifer in which the static water level stands above the surface of the ground.

Assessment actions. Those actions taken during or after an accident to obtain and process information that is necessary to make decisions to implement specific emergency measures.

Backflowing. Reversal of flow of water under pressure, for example, in a well to free the screen or strainer and the aquifer of clogging material.

Baseline. The environmental condition that existed prior to mining as determined by physical and/or chemical parameters and their natural variability.

Bleed system. A production adjustment technique whereby more fluids are pumped from the production zone than are injected, creating an inflow of groundwater into the production area.

Borehole. An uncased drilled hole.

Boundary, geohydrologic. Lateral discontinuity in geologic material, making the transition from the permeable material of an aquifer to a material of significantly different geohydrologic properties.

Boundary, impervious. Boundary of a flow domain through which no flow can take place because of greatly reduced permeability at the other side of the boundary.

Brine. A highly mineralized solution (usually greater than 10^5 mg/liter), especially of chloride salts.

Capacity. Volume that can be contained by a tank, pond, etc.; rate of flow that can be carried by any conveying structure.

Capacity, specific. Ratio of discharge of a well to drawdown at equilibrium.

Capillary diffusion. Movement of water by capillarity in a porous medium.

Capillary water. Water held in the soil above the water table by capillarity; soil water above hygroscopic moisture and below the field capacity.

Casing. Steel or plastic pipe or tubing that is placed in a borehole to prevent entry of loose rock, gas, or liquid or to prevent loss of drilling fluid.

Chemical water quality. The nature of water as determined by the concentration of chemical and biological constituents.

Clogging. Deposition of fine particles such as clay or silt at the surface and in the pores of a permeable porous medium, for example, soil, resulting in the reduction of permeability.

Concentration. The weight of solute dissolved in a unit volume of solution.

Conductivity, hydraulic. Combined property of a porous medium and the fluid moving through it in saturated flow, which determines the relationship, called Darcy's law, between the specific discharge and the head gradient causing it.

Cone of depression. The depression, ideally conical in shape, that is formed in a water table or potentiometric surface when water is removed from a well.

Confining bed. Formation overlying or underlying a much more permeable aquifer.

Consumptive use. That part of the water withdrawn that is no longer available because it has been evaporated, transferred, incorporated into products or crops, or otherwise removed from the immediate water environment.

Contamination. The degradation of natural water quality as a result of man's activities to the extent that its usefulness is impaired. There is no implication of any specific limits since the degree of permissible contamination depends upon the intended end use, or uses, of the water.

Corrective actions. Those measures taken to ameliorate or terminate a situation at or near the source of the problem in order to prevent an uncontrolled release of radioactive or toxic material or to reduce the magnitude of a release, for example, shutting down equipment, controlling damage and repair, or reorganizing pumping arrangements.

Curie. The quantity of any radioactive material giving 3.7×10^{10} disintegrations per second. A picocurie is one trillionth (10^{-12}) of a curie, or a quantity of radioactive material giving 2.22 disintegrations per minute.

Darcy. Unit of intrinsic permeability defined as the permeability of a medium in which a liquid of dynamic viscosity of 1 centipoise discharges 1 cm^3/sec through a cross section of 1 cm^2 under a gradient normal to the section of 1 atm/cm.

Darcy's law. Law expressing the proportionality of the specific discharge of a liquid flowing through a porous medium to a hydraulic gradient in laminar flow (low Reynolds numbers).

Degradable. Capable of being decomposed, deteriorated, or decayed into simpler forms with characteristics different from the original; also referred to as biodegradable when readily decomposed by organisms.

Degradation of water quality. The act or process of reducing the level of water quality so as to impair its original usefulness.

Depletion. Continued withdrawal of water from groundwater at a rate greater than the rate of replenishment; reduction of groundwater storage in an aquifer or of the flow of a stream or spring caused by discharge exceeding natural recharge.

Dewatering. Removing water by gravity or by pumping.

Dewatering coefficient. Amount of water removed per unit horizontal area and unit drawdown.

Diffusivity (of an aquifer). Coefficient of transmissivity of an aquifer divided by its coefficient of storage.

Dispersivity. Property of a porous matrix to cause spreading of a tracer traveling through it.

Dissolved solids, total (TDS). Total weight of dissolved material constituents in water per unit volume or weight of water in the sample.

Dominant direction of groundwater movement. The principal expected direction of groundwater flow. This dominant direction of movement is a result of three major variables: the transmissivity of the aquifer, the hydraulic gradient, and the differential applied hydraulic pressure.

Downstream. In the direction of the current.

Drawdown. Lowering of the water table or piezometric surface caused by the extraction of groundwater by pumping, by artesian flow from a borehole, or by a spring emerging from an aquifer.

Drawdown, equilibrium. Drawdown of the water table or of the piezometric surface near a pumping well, at constant discharge, after a stationary condition has been reached.

Effluent. A waste liquid, solid, or gas, in its natural state or partially or completely treated, that discharges into the environment.

Eluant. The solution that removes (elutes) a material (uranium) adsorbed on ion exchange resin.

Emergency action levels. Specific contamination levels of airborne, water-borne, or surface-deposited concentrations of radioactive or toxic materials; or specific instrument indications that may be used as thresholds for initiating such specific emergency measures as designating a particular class of emergency, initiating a notification procedure, or initiating a particular protective action.

Excursion. The movement of lixiviant (leachate solution) out of a mine zone as evidenced by measured movement past a trend or monitor well. Measurement is by an increase of selected parameter values above their established upper control limits.

Freeboard. Vertical distance between the normal maximum level of the surface of the liquid in a conduit, reservoir, tank, canal, etc., and the top of the sides of an open conduit, the top of a dam or levee, etc.

Groundwater. Water beneath the land surface in the saturated zone that is under atmospheric or artesian pressure; the water that enters wells and issues from springs.

Groundwater management. The development and utilization of the underground resources (water, storage capacity, and transmission capacity), frequently in conjunction with surface resources, in a rational and optimal manner to achieve defined and accepted water resource development objectives. Quality as well as quantity must be considered. The surface water resources involved may include imported and reclaimed water as well as tributary streams.

Groundwater, mining of. Withdrawal from a groundwater reservoir in excess of the average rate of replenishment.

Groundwater recession. Natural lowering of the groundwater level in an area.

Grout. To fill, or the material filling, the space around the pipe in a well, usually between the pipe and the drilled hole. The material is ordinarily a mixture of portland cement and water.

Hardness, carbonate. Hardness of water resulting from the presence of dissolved calcium and magnesium bicarbonates (temporary hardness).

Hardness, noncarbonate. Hardness of water resulting from the presence of dissolved calcium and magnesium salts other than carbonates (permanent hardness).

Hardness of water. That property of water, due mainly to bicarbonates, chlorides, and sulfates of calcium and magnesium, which prevents the production of abundant lather with soap.

Hazardous waste. Any waste or combination of wastes (which pose a substantial present or potential hazard to human health or living organisms) whose properties include flammability, evolution of toxic or irritating vapors, contact irritation, or human or animal toxicity.

Heads grade. The uranium content of recovered lixiviant, normally expressed in parts per million.

Heavy metals. Metallic elements, including the transition series, which include many elements required for plant and animal nutrition in trace concentrations but which become toxic at higher concentrations. Examples are mercury, chromium, cadmium, and lead.

Hydraulic gradient. The change in static head per unit of distance along a flow path.

Impoundment. A body of water formed by collecting water, as by a dam.

Infiltration. The flow of a liquid into soil or rock through pores or small openings.

Injection well. A well used for injecting fluids into an underground stratum or ore body by gravity flow or under pressure.

Ion exchange. Reversible exchange of ions absorbed on a mineral or synthetic polymer surface with ions in solution in contact with the surface. In the case of clay minerals, polyvalent ions tend to exchange for monovalent ions.

In situ. In its original or natural position.

Isopach. A line on a map drawn through points of equal thickness of a designated geological unit.

Leachate. The liquid that has percolated through solid ore, waste, or other man-emplaced medium and has extracted dissolved or suspended material from it.

Leakage. In groundwater, the flow of water from or into an aquifer through an underlying or overlying semipervious layer.

Lignite. A brownish-black coal in which the alteration of vegetal material has proceeded farther than in peat but not so far as in subbituminous coal.

Lixiviant. Leachate solution pumped underground to a uranium ore body; it may be alkaline or acid in character.

Mean. For a given set of data points,

$$\bar{x} = \frac{\sum x_i}{N} .$$

Mill Tailings. That portion of a metal-bearing ore after some or all such metal (such as uranium) has been extracted. The definition is from the Uranium Mill Tailings Radiation Control Act.

Mine field. Refers to the well-field area(s) and affected surface associated with solution mining. The term is often used interchangeably with well field.

Mine zone. The area from which uranium is extracted, including related buildings and structures. In this instance, it would include the ore body, all associated surface areas, and related well fields, process equipment, and buildings.

Mining unit (production unit). A segment or portion of an ore body capable of economically supporting mineral extraction; the minable limits of an ore body, which would normally include several production fields.

Monitor well. A surveillance (observation) well located usually along the periphery of a well field. It is used to indicate containment and/or lixiviant migration beyond the well field boundary. When the upper control limit of a monitor well is exceeded, corrective action is initiated.

Monitor well zone. The area of possible monitor well location. This zone is normally outside the limits of mineralization.

Nonpoint source. A source from which the contaminant enters the receiving water in an intermittent and/or diffuse manner.

Nonproduction zone(s). Those stratigraphic intervals underlying and overlying the production zone that are aquifers or that are relatively permeable.

Ore body. The mineralized portion of the sandstone formation where uranium is found in various grades and concentrations that can be extracted economically.

Osmosis. Passage of a solvent from a dilute solution to a more concentrated one through a semipermeable membrane (one that is permeable to the solvent only).

Oxidation. A chemical reaction in which there is an increase in positive valence of an element from a loss of electrons; in contrast to reduction.

Percolation. Movement under hydrostatic pressure of water through unsaturated interstices of rock or soil.

Permeability. Property of a porous medium to allow for the movement of liquids and gases through it under the combined action of gravity and pressure.

Permeable rock. Rock having a texture that permits water to move through it perceptibly under a head gradient ordinarily found in subsurface water (pervious rock).

pH. Minus the logarithm of the hydrogen ion concentration (activity). It is used as an indicator of acidity (pH less than 7) or alkalinity (pH greater than 7).

Phreatic divide (groundwater divide). Line on a water table along the sides of which the groundwater flows in opposite directions.

Piezometric surface. The surface defined by the levels to which water under artesian conditions will rise in tightly cased wells; also called potentiometric surface.

Plume. A body of contaminated groundwater originating from a specific source and influenced by such factors as the local groundwater flow pattern, density of contaminant, and character of the aquifer.

Point source. Any discernible confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, or concentrated animal feeding operation, from which contaminants are or may be discharged.

Pollutants (water). Substances that may become dissolved, suspended, absorbed, or otherwise contained in water and impair its usefulness.

Pollution (water). The degradation of natural water quality, as a result of man's activities, to the extent that its usefulness is impaired.

Ponds. Small storage reservoirs.

Population at risk. Those persons for whom protective actions are being or would be taken.

Pore. An open space in rock or soil.

Porosity. The relative volume of the pore spaces between mineral grains in a rock as compared with the total rock volume.

Porous medium. Solid body containing interconnected pores more or less evenly distributed.

Potentiometric surface. An imaginary surface representing the static head of groundwater and defined by the level to which water will rise in a well; also called piezometric surface.

Production area. The area of injection and production activity, which can be portrayed by a plan view of the well field area and vertically by a cross section extending from the surface to at least 3 m (10 ft) below the bottom of the lowest production zone.

Production cell. The grouping of injection wells arranged in various configurations and varying in number about a production or recovery well.

Production field (zone, unit). Mine or well field(s) actively used for production. It could consist of one or more well fields.

Production module. A process plant that is modularized for ease of installation and removal and is capable of handling a given production flow and output.

Production well (recovery well). A well from which lixiviant is recovered for conveyance to a process plant.

Production zone. That stratigraphic interval into which leaching chemicals are introduced. This interval extends horizontally in all directions in and beyond the production area.

Pump test. Extraction of water from a well at one or more selected discharge rates, during which potentiometric or phreatic levels are measured regularly at the pumped well and at nearby observation wells. The data are used for determining the aquifer parameters in the vicinity of the pumped well.

Purification. Treatment of water for the removal of harmful or undesirable physical properties, chemical substances, and living organisms.

PVC. Polyvinyl chloride; a high-density chlorinated plastic.

Radius of influence. Distance from the axis of a pumped or recharged well at which the effect of the well on the potentiometric or the phreatic surface is no longer perceptible.

Recharge. The addition of water to the groundwater system by natural or artificial processes.

Reclamation. The return of the surface environment to acceptable preexisting conditions. This normally includes equipment removal, well plugging, surface contouring, reseeding, etc.

Recovery actions. Those actions taken after an emergency to restore the plant or facility as nearly as possible to its preemergency condition.

Reduction. A chemical reaction in which there is a decrease in positive valence as a result of gaining of electrons.

Restoration. The returning of all affected groundwater to its potential premining use by employing the best practical technology.

Reynolds number. Defined as $R = av\rho/\eta$, where ρ is the fluid density, η is the fluid viscosity, a is a length characteristic of the porous structure, such as the average pore size, and v is the volume of fluid crossing unit area per unit time.

Roll front. Uranium deposition localized as a roll or interface separating an oxidized interior from a reduced exterior. The reduced side of this interface is significantly enriched in uranium.

Runoff. Direct or overland runoff is that portion of rainfall which is not absorbed by soil, evaporated, or transpired by plants but finds its way into streams as surface flow.

Saturated zone. The zone in which interconnected interstices are saturated with water under pressure equal to or greater than atmospheric.

Sedimentary rock. Rocks formed from the accumulation and compaction of sediment.

Seepage. Slow movement of water in unsaturated rock material; loss of water by infiltration into the soil from a canal or other body of water.

Semiconfining bed. Poorly pervious yet water-transmitting layer.

Solution channels (holes or cavities). Fractures, joints, bedding planes, or other openings in soluble rocks, through which flow can occur (especially in limestone).

Sorption. A general term used to encompass processes of adsorption, absorption, desorption, ion exchange, ion exclusion, ion retardation, chemisorption, and dialysis.

Specific conductance. The ability of a cubic centimeter of water to conduct electricity; varies directly with the amount of ionized minerals in the water.

Standard deviation. For a given set of data points, the positive square root of a variance — that is,

$$\sigma = \sqrt{\frac{\sum(x_i - \bar{x})^2}{N - 1}} ,$$

where $\bar{x}$ is the mean.

Stratigraphy. Concerning the sequence of rock types formed on the earth's surface. Each stratum is defined by its composition, distribution, succession, and geologic era.

Subsidence. Surface caving or distortion brought about by collapse of deep mine workings or cavernous carbonate formations, or from overpumping of certain types of aquifers.

Surface water. That portion of water that appears on the land surface (oceans, lakes, rivers).

Toxicity. The ability of a material to produce injury or disease upon exposure, ingestion, inhalation, or assimilation by a living organism.

Transmissivity. Rate at which water is transmitted through a unit width of the aquifer under a unit hydraulic gradient. It is expressed as the product of the hydraulic conductivity and the thickness of the saturated portion of the aquifer.

Trend well. Surveillance well for production control and/or monitoring located between the well field and the monitor wells.

Unsaturated zone. Consists of interstices occupied partially by water and partially by air and is limited above by the land surface and below by the water table.

Upconing. The upward migration of groundwater from underlying strata into an aquifer caused by a reduced hydrostatic pressure in the aquifer as a result of pumping.

Upper control limit (UCL). A concentration value for any designated chemical species (indicator species) that must not be exceeded in a monitor well. Corrective actions are initiated when the upper control limits are exceeded and are continued until migration is brought under control.

Upstream. In the direction opposite to the main current.

Waste. Solids or liquids from solution mining or associated processes of no further value and subject to no additional productive processing. These are normally stored for concentration and ultimate disposal. Some process streams may be waste streams.

Water, brackish. Water containing significantly less salt than seawater. The concentration of total dissolved solids is usually in the range of 1,000-10,000 mg/liter.

Water conservation. Measures introduced to reduce the amount of water used for any purpose and/or to protect the water from pollution.

Water demand. Actual quantity of water required for various needs over a given period as conditioned by economic, social, and other factors to satisfy a known or estimated requirement.

Water, drinking. Water suitable for drinking.

Water, fresh. Water neither salty nor bitter to the taste and in general chemically suited for human consumption (having a low dissolved solids content).

Water quality. Pertaining to the chemical, physical, and biological constituents found in water and its suitability for a particular purpose.

Water resources. Supply of water in a given area or basin interpreted in terms of availability of surface and underground water.

Water supply system. All storage reservoirs, pumps, pipes, and works required for providing water of a desired quality to the different sectors of consumption.

Water table. That surface in an unconfined groundwater body at which the pressure is atmospheric. It defines the top of the saturated zone.

Water table aquifer. An aquifer containing water under atmospheric conditions.

Water yield. Total runoff from a drainage basin through surface channels and aquifers.

Well capacity. Maximum rate at which a well will yield water under a stipulated set of conditions, such as a given drawdown.

Well completion. Techniques used to control horizontal underground movement of injected fluids from a well and to maintain the integrity of over- and underlying layers.

Well, disposal. Well used for the disposal of polluted or drainage water brines, etc.

Well field (mine field). Several production cells capable of supplying a given feed to a process plant.

Well, fully penetrating. Well that extends through the whole saturated depth of an aquifer and is constructed in such a manner that water is permitted to enter the well throughout its length.

Well, partially penetrating. Well in which the length of water entry is less than the thickness of the saturated aquifer that it penetrates.

Well radius, effective. Horizontal distance from the axis of a well.

Yield of aquifer (economic). Maximum rate at which water can be artifically withdrawn from an aquifer in the foreseeable future without continuously lowering the water table, depleting the supply, or altering the chemical character of the water to such an extent that withdrawal at that rate is no longer economically feasible.

Yield, optimal. Amount of water that can be withdrawn annually from an aquifer or from a basin according to some predetermined criterion of optimal exploitation.

Yield, safe. Amount of water (in general the long-term average amount) that can be withdrawn from a groundwater basin or surface water system without providing undesirable results.

Zone of saturation. That part of the lithosphere in which the pores are completely filled with water.