NUREG-0706
Vol. II

Final Generic Environmental Impact Statement
on uranium milling
Project M-25

Appendices A-F

September 1980

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

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Safety and Safeguards
U.S. Nuclear Regulatory Commission**

FOREWORD

Volume II contains Appendices A-F, which support the discussions in Volume I. In some cases, the appendices expound upon arguments developed in the main document. In other cases, supplementary material considered to be relevant, but not present in Volume I, is included.

VOLUME II

TABLE OF CONTENTS

CONTENTS (continued)

CONTENTS (Continued)

FIGURES

TABLES

APPENDIX A. COMMENTS ON DRAFT ENVIRONMENTAL STATEMENT AND NRC STAFF RESPONSES

Including 99 direct written submittals and the transcripts of public meetings, approximately 2,000 pages of public comment materials were developed in response to the issuance of the draft GEIS and the associated proposed rules. These materials were fully and carefully reviewed by the NRC staff to identify all substantive and relevant issues and concerns raised by commenters. Due to the unusually heavy volume of comment materials received, the staff has departed from the more customary procedure of reproducing all comment materials in full, and responding on a line-by-line basis. Instead, using the procedures described in Appendix A-1, the staff has summarized public comments received, in accordance with §51.26(b) of 10 CFR Part 51, and responded accordingly. The summarized comments, and staff responses, are presented individually in Appendix A-2. They have been organized according to topic of concern, and are presented in Appendix A-2 by category, as indicated in the table of contents below. In addition, the staff has identified what are believed to be the major issues raised by commenters; these are presented and discussed separately, in Section 9 of the Summary of this document.

APPENDIX A. TABLE OF CONTENTS

CONTENTS (continued)

APPENDIX A-1. INTRODUCTION

The draft GEIS was issued in April of 1979 as NUREG-0511. Subsequently, in August of 1979, the staff issued proposed regulation changes implementing conclusions of the draft GEIS and provisions of the Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978 (44 FR 50015). Public comment materials accumulated concerning the draft GEIS and the proposed rules have amounted to about 2,000 pages, including 99 written submittals and the transcripts of four days of public hearings held in Denver (October 1 and 2, 1979) and Albuquerque (October 17 and 18, 1979). Extensive comments were received from private individuals, industrial concerns, trade organizations, public interest groups, and state and Federal government agencies. These comments represent a full range of viewpoints and concerns and have been given due consideration in the preparation of this final statement and the companion final regulation changes.

Due to the heavy volume of comment materials received, it was determined to be impractical to reproduce all comments in full and respond to them on a line-by-line basis (as is customary with the smaller volumes of comment materials normally received with respect to site-specific statements issued in support of individual licensing actions). Full reproduction of all comment materials, with line-by-line responses, would have added approximately 2,000 pages to the size of this document. This would have been exorbitantly expensive and would have resulted in massive repetition of comments and responses. Also, such a procedure would not have allowed for comments and responses to be organized in any fashion, such as by topic of concern, and the results would be very unwieldy from the standpoint of utility to the reader.

For these reasons the staff has elected, in accordance with §51.26(b) of 10 CFR Part 51, to summarize public comments received, and respond accordingly. This effort was performed in accordance with the following basic procedure:

A. All public comment materials were reviewed to identify independent, substantive, and relevant comments;

B. Each identified comment was assigned to a category on the basis of the central topic of concern (these categories form the organization of Appendix A-2, as given in the Table of Contents for Appendix A);

C. Within each category, comments were combined as necessary to avoid unnecessary repetition;

D. Substantive and relevant comments were restated as necessary to summarize the issue or concern addressed; and

E. Substantive and relevant comments, after being combined with like comments and restated in summarized form, were then responded to by individual reviewers.

The end result of this process is provided in Appendix A-2, which consists of an itemized listing of synthesized comments and individual responses, organized according to topic of concern. Each synthesized comment is followed by one or more numbers in parentheses which represent the assigned identification numbers of the commenters making, or contributing to, the synthesized comment. Table A-1.1 provides a list of all commenters and their assigned identification numbers.

The staff considers this approach to have been invaluable with respect to providing an organized and consistent method for responding to public comments in a timely, effective, and useful manner. The structuring of comments and responses by topic allows both readers and commenters to quickly find and review the staff's positions with respect to any particular area of interest. By minimizing repetition and summarizing comments, the bulk size of this appendix has been kept within reason by providing clear and concise statements of both commenters and staff positions. The staff is confident, given the number and scope of comments and responses provided in Appendix A-2, that all substantive and relevant issues raised by commenters have been responded to in full. In addition, Section 9 of the Summary of this document identifies and discusses what the staff considers to be the major issues raised by commenters.

All written comments and hearing transcripts are available for review at the NRC Public Document Room, 1717 H Street, N.W., Washington, D.C. These are filed under Project M-25.

Table A-1.1 List of Commenters

IDENTIFICATION NUMBER	NAME	ORGANIZATION	CITY & STATE
--------SUBMITTING WRITTEN COMMENTS--------			
1	R. A. Ginman	Department of Community Affairs State of New Jersey	Trenton, NJ
2	J. Haverly	State Clearinghouse State of Ohio	Columbus, OH
3	P. H. Springell	N. T. Environment Council	Darwin, Australia
4	J. L. Madden	State of Alaska Division of Policy Development & Planning	Juneau, AK
5	J. E. Velehradsky	Corps of Engineers U.S. Department of the Army	Omaha, NB
6	P. V. DeGaeta	Division of State Planning & Research State of Kansas	Topeka, KS
7	L. E. Banks	State Planning Division State of North Dakota	Bismarck, ND
8	R. G. Whittle, Jr.	Division of State Planning State of Florida	Tallahassee, FL
9	E. Neary	State Planning Office State of Vermont	Montpelier, VT
10	Federal Funds Coordinator	State Clearinghouse State of Iowa	Des Moines, IA
11	H. L. Barrows	Science and Education Administration U.S. Department of Agriculture	Beltsville, MD
12	G. P. Gullett	Department of Urban and Community Affairs State of Louisiana	Baton Rouge, LA
13	J. L. Madden	Division of Policy Development and Planning State of Alaska	Juneau, AK
14	N. Hayward III	Office of Management, Budget and Planning State of Delaware	Dover, DE
15	L. Pohl	Office of Administration State of Missouri	Jefferson City, MO
16	T. Kubicek	State Office of Planning and Programming State of Nebraska	Lincoln, NB
17	J. M. Heinemann	Federal Energy Regulatory Commission Department of Energy	Washington, DC
18	A. E. Eaglesfield	State Clearinghouse State of Indiana	Indianapolis, IN

Table A-1.1 List of Commenters (Continued)

IDENTIFICATION NUMBER	NAME	ORGANIZATION	CITY & STATE
19	K. Wilcox	Intergovernmental Relations Division State of Oregon	Salem, OR
20	T. E. Hornbacker	Bureau of the Budget State of Illinois	Springfield, IL
21	J. W. Burns	The Resources Agency of California State of California	Sacramento, CA
22	M. Nolan	Governor's Office of Planning Coordination State of Nevada	Carson City, NV
23	R. A. Heiss	State Clearinghouse State of Pennsylvania	Harrisburg, PA
24	J. B. Jackson, Jr.	Council on the Environment Commonwealth of Virginia	Richmond, VA
25	M. I. Lewis	pro se	Philadelphia, PA
26	T. A. Wolff	Environmental Improvement Division State of New Mexico	Santa Fe, NM
27	C. Baggett	Division of State Budget and Management State of North Carolina	Raleigh, N.C.
28	L. R. Chong	pro se	Rumney, NH
29	T. A. Mahar	Office of Financial Management State of Washington	Olympia, WA
30	J. A. Youngblood	State Clearinghouse State of Arizona	Phoenix, AZ
31	P. Demo-Rybus	Division of Budget, Policy Planning and Coordination State of Idaho	Boise, ID
32	J. H. Johnsrud	Environmental Coalition on Nuclear Power	State College, PA
33	A. Hiserberg	State Clearinghouse State of New Mexico	Santa Fe, NM
34	E. E. Varanini III	Energy Resources Conservation and Development Commission State of California	Sacramento, CA
35	C. Custard	Office of Environmental Affairs U.S. Department of Health, Education and Welfare	Washington, DC
36	B. Ellison	Black Hills Alliance	Rapid City, SD
37	R. E. Young	pro se	Nederland, CO
38	L. E. Meierotto	Office of the Secretary U.S. Department of the Interior	Washington, DC

Table A-1.1 List of Commenters (Continued)

IDENTIFICATION NUMBER	NAME	ORGANIZATION	CITY & STATE
39	M. R. Amos	Office of State Planning and Federal Programs State of Alabama	Montgomery, AL
40	W. D. Dexter	Game and Fish Department State of Wyoming	Cheyenne, WY
41	D. E. Harley	Budget and Planning Office State of Texas	Austin, TX
42	D. K. Lacker	Department of Health State of Texas	Austin, TX
43	H. S. Sanger, Jr.	Tennessee Valley Authority	Knoxville, TN
44	E. Gabriel	Council of Energy Resource Tribes	Washington, DC
45	L. Howell	Planning & Coordination State of Mississippi	Jackson, MS
46	J. Sanderford	Black Hills Energy Coalition	Rapid City, SD
47	H. Linker	Natural Resources Defense Council, Inc.	San Francisco, CA
48	D. L. Durler	Texas Uranium Operations United States Steel Corporation	Corpus Christi, TX
49	Grey Bogden	Western Nuclear, Inc.	Lakewood, CO
50	D. C. Williams	Americans for Rational Energy Alternatives, Inc.	Albuquerque, NM
51	C. R. Hosking	Pikes Peak Justice and Peace Commission	Colorado Springs, CO
52	D. C. Ridinger	Newmont Services Limited	San Manuel, AZ
53	K. R. Schendel	Wyoming Mineral Corporation	Lakewood, CO
54	C. Kepford	Environmental Coalition on Nuclear Power	State College, PA
55	(unsigned)	Rocky Mountain Energy Company	Denver, CO
56	D. Berick	Environmental Policy Institute	Washington, DC
57	G. D. Ortloff	Exxon Minerals Company, U.S.A.	Houston, TX
58	E. Gabriel	Council of Energy Resource Tribes	Washington, DC
59	M. I. Ritchie	Pathfinder Mines Corporation	San Francisco, CA
60	B. Stevens	Kerr-McGee Nuclear Corporation	Oklahoma City, OK
61	J. F. Spisak	Federal-American Partners	Gas Hills, WY
62	M. Lewis	pro se	Philadelphia, PA
63	A. Bates	Ethos Research Group	Summertown, TN
64	L. Provost	The Surety Association of America	Iselin, NJ

Table A-1.1 List of Commenters (Continued)

IDENTIFICATION NUMBER	NAME	ORGANIZATION	CITY & STATE
65	D. Berick	Environmental Policy Institute	Washington, DC
66	E. E. Kennedy	United Nuclear-Homestake Partners	Grants, NM
67	W. H. Marshall	Mobil Oil Corporation	New York, NY
68	W. H. Marshall	Mobil Oil Corporation	New York, NY
69	R. L. Eikum	Designing with Nature	Moose Lake, NM
70	L. Anderson	Department of Health State of Utah	Salt Lake City, UT
71	C. B. Scott	Union Oil	Los Angeles, CA
72	L. E. Meierotto	Office of the Secretary U.S. Department of the Interior	Washington, DC
73	C. B. Scott	Union Oil	Los Angeles, CA
74	L. J. Danielson	National Wildlife Federation	Boulder, CO
75	R. D. Dellwo	Dellwo, Rudolf & Schroeder, P.S.	Spokane, WA
76	L. J. Danielson	National Wildlife Federation	Boulder CO
77	R. G. Beverly	Union Carbide Corporation	Grand Junction, CO
78	R. W. Weiss	pro se	Grand Junction, CO
79	W. A. Lochstet	Environmental Coalition on Nuclear Power	State College, PA
80	E. D. Eberhard	pro se	Albuquerque, NM
81	L. Perry	Black Hills Energy Coalition	Rapid City, SD
82	D. East	Wyoming Outdoor Council	Cheyenne, WY
83	K. S. Canfield	United Nuclear-Homestake Partners	Grants, NM
84	A. Hazle	Department of Health State of Colorado	Denver, CO
85	J. A. Overton, Jr.	American Mining Congress	Washington, DC
86	E. A. Lang	Atomic Industrial Forum, Inc.	Washington, DC
87	A. Weiss	pro se	Colorado Springs, CO
88	B. Phillips	Greenpeace Foundation of America	San Francisco, CA
89	D. Knapp	Uranium Information Network	Denver, CO
90	R. O. Pohl	Cornell University	Ithaca, NY
91	B. E. Lewis	Colorado Open Space Council	Denver, CO
92	J. Miller	pro se	Denver, CO
93	G. D. Ortloff	Exxon Minerals Company, U.S.A.	Houston, TX
94	D. C. Ridinger	Newmont Services Limited	San Manuel, AZ

Table A-1.1 List of Commenters (Continued)

IDENTIFICATION NUMBER	NAME	ORGANIZATION	CITY & STATE
95	C. H. Badger	Office of Planning and Budget State of Georgia	Atlanta, GA
96	J. H. Johnsrud	Environmental Coalition on Nuclear Power	State College, PA
97	W. A. Lochstet	pro se	University Park, PA
98	S. R. Barley	pro se	Hershey, PA
99	W. N. Hedeman, Jr.	Office of Environmental Review U.S. Environmental Protection Agency	Washington, DC
-------------- SUBMITTING ORAL COMMENTS, DENVER, COLORADO, OCTOBER 1-2, ----------------------			
100	R. C. Beverly	American Mining Congress	Grand Junction, CO
101	M. Taylor	American Mining Congress	Englewood, CO
102	S. Schermerhorn	American Mining Congress	Littleton, CO
103	J. Montgomery	State of Colorado	Denver, CO
104	E. Johnson	State of Wyoming	Cheyenne, WY
105	G. G. Beach	Department of Environmental Quality State of Wyoming	Cheyenne, WY
106	A. E. Dearth	Atlas Minerals	Denver, CO
107	L. J. Danielson	National Wildlife Federation	Boulder, CO
108	J. F. Spisak	Federal-American Partners	Gas Hills, WY
109	R. E. Young	Rocky Mountain Sierra Club	Nederland, CO
110	D. East	Wyoming Outdoor Council	Lander, WY
111	M. Pollock	Department of Energy State of Oregon	Salem, OR
112	J. Miller	pro se	Denver, CO
113	A. Mitterer	Atomic Industrial Forum	Denver, CO
114	R. E. Peak	Atomic Industrial Forum	Washington, DC
115	L. Dickey	Powder River Council	Sheridan, WY
------------- SUBMITTING ORAL COMMENTS, ALBUQUERQUE, NEW MEXICO, OCTOBER 17-18, 1979 -------			
116	(panel of 5)	American Mining Congress	Washington, DC
117	R. G. Beverly	Union Carbide Corporation	Grand Junction, CO
118	R. Tregembo	Kerr-McGee Nuclear Corporation	Oklahoma City, OK
119	G. T. Davis	Physicians for Social Responsibility	Albuquerque, NM

Table A-1.1 List of Commenters (Continued)

IDENTIFICATION NUMBER	NAME	ORGANIZATION	CITY & STATE
120	A. G. Hector	Southwest Research & Information Center	Albuquerque, NM
121	M. Lopez	American Indian Environmental Council	Albuquerque, NM
122	A. A. Topp, Jr.	Environmental Improvement Division State of New Mexico	Santa Fe, NM
123	G. W. Stewart	Environmental Improvement Division State of New Mexico	Santa Fe, NM
124	T. Buhl	Environmental Improvement Division State of New Mexico	Santa Fe, NM
125	E. D. Bailey	Department of Health State of Texas	Austin, TX
126	P. Robinson	Southwest Research & Information Center	Albuquerque, NM
127	D. Riccitiello	Southwest Research & Information Center	Albuquerque, NM
128	A. Mitterer	Atomic Industrial Forum	Denver, CO
129	M. I. Goldman	Atomic Industrial Forum	Rockville, MD
130	L. Berger	Physicians for Social Responsibility	Albuquerque, NM
131	J. R. Velasquez	Phillips Uranium Corporation	Albuquerque, NM
132	D. L. Durler	Texas Uranium Operations United States Steel Corp.	Corpus Christi, TX
133	C. Shirley	Los Alamos Technical Associates, Inc.	Los Alamos, NM
134	T. C. Frazee	Radiation Control Program State of Washington	Olympia, WA
135	E. P. Elliston	Sandoval Environmental Action Community	Albuquerque, NM
136	M. Davidson	Sandoval Environmental Action Community	Placitas, NM
137	N. Harmon	Citizens Against Nuclear Threat	Albuquerque, NM
138	R. N. Mason	Committee on Mining & the Environment	Boulder, CO
139	J. Miller	pro se	Denver, CO
140	B. E. Lewis	Colorado Open Space Council	Denver, CO
141	J. Price	Colorado Plateau Project	Colorado Springs, CO

Table A-1.1 List of Commenters (Continued)

IDENTIFICATION NUMBER	NAME	ORGANIZATION	CITY & STATE
142	G. Thompson	American Indian Environmental Council	Albuquerque, NM
143	L. Sandman	Utah International, Inc.	San Francisco, CA
144	R. D. Andrews	Rocky Mountain Energy Company	Denver, CO
145	L. Watchempino	American Indian Environmental Council	San Fidel, NM
146	R. Grado	Bern County Mental Health	Albuquerque, NM
147	K. R. Schendel	Wyoming Mineral Corporation	Lakewood, CO

APPENDIX A-2. PUBLIC COMMENTS AND STAFF RESPONSES

1. SCOPE OF DOCUMENT

1.1 Geographical Coverage

> Commment: Uranium extraction activities are presently under consideration in the eastern U.S., notably in New Jersey and Pennsylvania. Other areas of the U.S. also have natural uranium resources, such as Alaska, Tennessee, New Hampshire, and Florida. Environmental conditions in these areas are markedly different from those studied in the GEIS and should be considered. (6, 13, 25, 98, 99)

Response: The potential for uranium milling in the areas mentioned exists in varying degrees but does not compare with that of the regions studied. In this generic study, typical conditions are evaluated in some detail so that generalities may be established. It is simply not possible, in an undertaking such as this, to explicitly account for every possibility with respect to site variability, even among existing sites. In the locations described by commenters above as having uranium milling potential, the NRC would be the direct licensing agency and would undertake a complete documented evaluation of all site-specific conditions prior to approval of any license application, as described in Section 12.3.10.

1.2 Uranium Mining

> Comment: Uranium mining and uranium milling must be considered together because one cannot occur without the other. Any environmental assessment of the impacts of uranium milling cannot purport to be complete without a thorough and detailed analysis of the very large and permanently associated impacts of uranium mining, particularly with respect to radon emissions and groundwater pollution. (Commenters also argue that because of the large associated impacts of uranium mining, it is: all the more important to curtail milling impacts; or, not cost-effective to reduce milling impacts beyond a certain degree). (26, 42, 53, 74, 84, 92, 115, 125)

Response: Early in the initial planning of the GEIS it was recognized that appropriate regulatory control of uranium milling operations was both sorely and rapidly needed, that uranium mining operations delivered large, well-associated, and similar environmental impacts, and that the inclusion of a detailed assessment of mining impacts would significantly retard the development of the needed regulatory controls for uranium milling. Because the NRC has no jurisdictional authority over uranium mining, the inclusion of a detailed evaluation of the impacts of uranium mining associated with uranium milling would be essentially fruitless with respect to providing needed regulatory control. The inclusion of such an assessment would have resulted in significant delay, however, and would therefore have unbeneficially postponed improvement of current regulatory programs with respect to uranium milling. The staff elected, on this basis, to address uranium mining impacts only very generally within the scope of this document. Mining impacts associated with specific proposed uranium milling facilities are evaluated as appropriate, however, within the context of environmental impact statements prepared in support of individual licensing actions.

Although the GEIS does not include a detailed assessment of mining impacts, the U.S. EPA, as directed by the Congress in Section 114(c) of the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA), is preparing a report on the potential health, safety, and environmental hazards of uranium mine wastes. This EPA report will contain recommendations for a program to minimize these hazards.

1.3 In Situ Uranium Extraction

> Comment: A model in situ facility could be established on the basis of present in situ operations, just as was done for the development of the model mill. Because in situ operations can yield very significant and long-lasting groundwater impacts, and constitutes a large and growing portion of total uranium recovery operations, in situ should be given detailed examination in the GEIS, on an equal basis with conventional milling. At the very least, the GEIS should discuss past experience with in situ operations. (21, 37, 41, 51, 84, 89, 92, 99)

Response: The technology of in situ extraction, and the application of that technology, have expanded greatly since the scope of this document was defined. However, while the staff considers in situ extraction to be an important and growing aspect of the uranium recovery industry in general, specifically within certain regions (e.g., Texas and Wyoming), the staff is unable to now include more discussion on in situ operations without unduly delaying the completion of the present effort. As such a delay would severely impact the promulgation of rules based on this document, and mandated by the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA), as amended, the staff has determined it necessary to go forward without a detailed examination of in situ operations. As was stated in Section 1.2, the staff has prepared a general study of in situ extraction (NUREG/CR-0311). Because of the intensely site-specific nature of the chief environmental impacts from in situ extraction, those involving groundwater contamination, the staff does not consider it of value to do further general assessment of such impacts. As called for in the UMTRCA and by NRC regulation (10 CFR Part 51), site-specific, documented environmental assessments of each operation is necessary and will be performed. Also, NRC will continue to conduct research into specific aspects of this technology.

> Comment: Unless coverage of in situ facilities is greatly expanded, the title of the GEIS should be changed to reflect its limited applicability to conventional milling operations. (42, 125, 132)

Response: The staff is unable to accommodate this comment because in situ aboveground wastes are treated, both in the text, and in the rules to be promulgated on the basis of this document.

2. URANIUM DEMAND AND PRODUCTION

2.1 Projected Nuclear Power Production, Uranium Demand

> Comment: Projections of nuclear power production to the year 2000 estimated prior to the accident at Three Mile Island should be revised using up-to-date projections. (25, 98)

Response: The installed nuclear power generation capacity schedule given in Chapter 3 has been revised to reflect current projections.

> Comment: Figure 3.2 does not show the uranium requirements to be met after the year 2000 and thus shows only a small portion of the total uranium requirements for reactors installed through the year 2000. (54)

Response: The scope of this document, as previously defined and announced (42 FR 13874), includes an assessment of the impacts of U.S. uranium milling occurring through the year 2000. An examination of the impacts occurring due to milling over this time span is quite sufficient for achieving the major objective of this statement, which is to identify and support regulation changes which are now needed.

> Comment: Cumulative impacts estimated in the GEIS are based on a projected year 2000 nuclear generating capacity of 380 GWe and an enrichment tails U-235 content of 0.25 wt %. Under more current conditions, uranium demand could be met by 50 model mills rather than 82. (59, 85, 86)

Response: Estimates of uranium demand through the year 2000 have been revised and are now based on an enrichment tails U-235 content of 0.2 wt % and a revised projection of 180 GWe of installed nuclear capacity in the year 2000.

> Comment: The data in Tables 3.4 and 3.6 should be updated. The Edgemont mill should be included under the inactive category. (99)

Response: The data in Table 3.4, which is a listing of operational uranium mills, has been updated. The Edgemont mill is inactive and is not listed. Table 3.6, which gives data on uranium ore reserves, has not been updated as suggested because estimates of reserves have not significantly changed.

2.2 Average Ore Grade, Uranium Recovery

> Comment: The assumed constant average ore grade of 0.15 percent is approximately equal to the present average grade. However, many presently operating facilities are processing lower ore grades, and projections for the future indicate that the average ore grade will continue to decrease. (25, 38, 99)

Response: The assumed average ore grade has been revised to 0.10 percent to reflect current estimates of the average ore grade processed over the period from the present to the year 2000.

> Comment: The uranium recovery rate is not entirely independent of ore grade, as apparently assumed (see Table K-6.2 of the draft GEIS). Perhaps a table of recovery rate vs. ore grade should be prepared. (54)

Response: The recovery rate of uranium is somewhat dependent on the ore grade. However, this is a second-order and minor effect, within the range or ore grades economically processed by conventional extraction techniques. Enhanced technology for uranium extraction will very likely compensate for decreasing ore grades in the future.

3. REPRESENTATIVENESS OF MODELS

3.1 Model Mill

> Comment: The model mill is not representative of a great part of the current uranium milling industry. (26, 52, 55, 59, 71, 85, 86, 98, 131)

Response: In the "base case," the model mill is assumed to possess only relatively crude equipment, controls, and design features for the mitigation of environmental impacts. This purposeful bias is instituted so as to enable the evaluation of a full range of environmental impacts, both in kind and magnitude, as well as the costs and benefits of implementing various available control techniques for minimizing environmental impacts. Otherwise, the staff considers the model mill to be quite representative of the industry as a whole, as other characteristics were selected so as to typify the industry. Since the model mill was not developed so as to be an exact replica of any particular existing facility, it is, of course, different from any presently operating mill.

> Comment: The assumption that currently operating mills will continue to operate until the year 2000 is questionable. (26)

Response: The evaluation of cumulative impacts is based on the assumption that enough model mills are in operation so as to satisfy uranium demands on a yearly basis, without specification as to whether or not any particular mill will, or will not, be in operation. Existing milling capacity as of 1979, expressed in terms of model mill equivalents, is herein assumed to be depleted by mill retirement at the rate of one model mill equivalent per year.

> Comment: The term "model" mill is a poor choice because it implies something to be emulated and will mislead readers into assuming that the base case is typical of the present rather than the past. (26)

Response: The staff has not sensed any confusion over the use of the term "model" mill and believes the proper meaning to be quite adequately conveyed. Also, the model mill is meant to be typical of the industry as a whole, although it is assumed in the base case to possess only minimal capabilities for the mitigation of environmental impact. As was stated in Sections 2 and 3 of the Summary, the levels of control featured in the base case are largely representative of past practice. This is done to bring into sharp focus the potential impacts that can occur and form a common basis upon which to the effect of alternative control measures.

> Comment: The model mill should not have embankments made of tailings because such construction is no longer standard practice, creates serious environmental problems, and should not be implicitly condoned by the NRC. (42, 99, 125)

Response: The staff does not condone construction of impoundments made of tailings, and such construction is no longer standard practice. However, past construction has employed tailings-constructed embankments at mills which continue to operate.

> Comment: The overly simplistic and standardized model mill, and evaluations thereon, do not allow any account to be made of the tremendous variability of the important determining factors throughout the actual industry. The results of such evaluations, therefore, cannot properly be used as the basis for assessing the real need for regulatory controls. (52, 55, 59, 85)

Response: The staff has performed this generic assessment for the express purpose of establishing generically required regulatory controls. In determining these requirements the staff has considered variability of all determining factors where these exist. For example, in evaluating tailings cover requirements, the full range of variable factors such as ore grade, tailings areas and volumes, soil cover types, unit costs and the like were explicitly considered (See Section 12.3.4). The model mill has served an essential function in these considerations by providing a point of departure for considering variability. Also, see Sections 12.3.1 and 12.3.10, which describe the staff position on case-by-case treatment of variable factors.

> Comment: The net water consumption of 1260 MT/d by the model mill may be too low. Most mills use more water than this, with twice this figure not being unusual. (38)

Response: The staff considers 1260 MT/d of consumptive water use to be reasonably typical, as an average figure. Higher consumption rates are, however, not unusual.

> Comment: The list of additives in Table 5.2 should be more complete, and with respect to Table 5.3, units should be mg/l, total and dissolved radium fractions should be reported, and representative ranges from an EPA study should be provided. (99)

Response: These comments have been incorporated as appropriate.

3.2 Model Environment

> Comment: The model region is only minimally representative of current uranium milling areas, and is not representative of areas where future uranium milling may occur. (25, 55, 85, 98)

Response: As stated in the description of the model region (Chapter 4), the assumed characteristics of the model region are based on weighted averages of the same characteristics in the six physiographic regions of the United States within which uranium is milled (see Chapter 3). Detailed descriptions of these regions are given in NUREG/CR-0597.

Also, as was discussed in the Chapter 4 introduction, the model mill that was developed recognized the variability that exists from site to site. It contains only sufficient detail to allow characterizing generally the nature and extent of potential impacts. Where there are regional variations that will influence decisions on specific aspects of the regulations, these are explicitly considered. (For example, see Section 12.3.4.)

> Comment: The seismic risk map should either be referenced or included. (99)

Response: The seismic risk map has been referenced.

> Comment: In the characterization of the regional eco-system no threatened or endangered flora are mentioned despite a very extensive Federal list. (26)

Response: This has not been considered necessary because impacts to threatened and endangered species must be, and are, considered on a site-specific basis, and because ample regulatory protection is already afforded to such species. NUREG/CR-0597, a supplement to the GEIS, provides lists of threatened and endangered flora and fauna on a regional basis.

3.3 Model Mill Cluster

> Comment: The "worst case" uranium milling density, as depicted by the model mill cluster, already exists in the Grants Mineral Belt. (26, 86)

Response: It is true that the capacity of the uranium mills in the Grants Mineral Belt is roughly equal to that postulated for the 12-mill cluster; this capacity, however, is concentrated in a few large mills. Some of the environmental impacts, e.g., water consumption, are proportional to capacity and for these the Grants Mineral Belt is close to the "worst case." Other environmental impacts, e.g., diversion of land from other uses, are more nearly proportional to the number of mills; for these impacts the cluster of 12 mills represents a worse case than does the Grants Mineral Belt.

4. ANALYSIS OF BASE CASE IMPACTS

4.1 Radioactivity Releases and Natural Radioactivity

4.1.1 Radioactivity Releases from the Model Mill

Comment: Radium-bearing ore and tailings particles spread by the wind from the mill to the surrounding surface of the ground constitute an appreciable and persistent source of radon which has not been considered. (26, 54)

Response: *This omission has been corrected. Please refer to Chapter 5 and Appendix G-1.*

Comment: Do the external doses which have been calculated include gamma radiation directly from the tailings pile? What is the significance of this component? (26)

Response: The doses to hypothetical individuals near the mill and tailings do not include a component of direct exposure from radioactivity present in the pile itself. The dose rate directly above the tailings would be substantial, perhaps 0.7 mrem/hr. This would contribute to total occupational exposure of mill workers (see Section 6.2.8.2.7.1), but not to exposure of the general public. Actual measurements at existing piles have clearly demonstrated that, where there has been no substantial movement of radioactivity from the pile by wind action onto the surrounding ground surface, the external dose rate drops to background levels within 100-200 meters from the edge of the pile. This indicates that direct radiation from the pile is inconsequential at greater distances.

Comment: Recent data from ANL and EPA do not support the assumption that 5% of the thorium originally present in the ore finds its way through the acid leach process to the yellowcake. (26)

Response: This information became available after the draft GEIS had been prepared; however, it was considered in preparing this document (see Appendix G-1). The assumed thorium carryover from ore to yellowcake has been reduced from 5% to 0.5%.

Comment: Open trucks hauling ore to the mills are an important contributor to total air contamination from uranium milling, but this source has been ignored in the GEIS. (51, 74)

Response: The omission of sources related to uranium mining, including transport of ore to the mill, throughout most of this document is deliberate, intentional and in accordance with the previously defined and announced scope of consideration (42 FR 13874). The decision was made as a matter of policy. However, contamination from ore hauling would be of about the same magnitude as that which originates from ore storage and transfer at the mill site. This source is included, but is almost insignificant in the base case compared to releases from the yellowcake stack and tailings pile (see Section 9.2). The U.S. EPA has been directed by the Congress (Section 114(c) of the UMTRCA) to prepare a report on the impacts of mining, and recommend actions to deal with such hazards.

Comment: The GEIS is inconsistent in considering the effect of moisture content on radon exhalation from tailings, but ignoring its influence on exhalation from natural soils. (54)

Response: The discussion in Appendix O of radon exhalation from natural soils contains the same explicit acknowledgement of the importance of moisture in determining the exhalation rate as does Appendix G-1 which concerns radon releases from tailings. In neither case does water content appear explicitly in the calculations but, as stated, it has a strong influence on the effective diffusion coefficient of radon through porous media. This subject is addressed in detail in revised Appendix P.

Comment: The ground concentrations of radionuclides presented in Figures G-4.7 thru 4.11 are applicable to what time in the life of the model mill? Are these ground concentrations related to the emission rates listed in Table 5.5? (54)

Response: The concentrations shown in these Figures represent those predicted at the end of fifteen years of mill operation, with annual releases equal to those which are listed in Table 5.5.

Comment: There are inconsistencies within the GEIS in the assumptions and, therefore, in the estimation of radon flux from tailings. Also, there is disagreement with field measurements by ANL. (55, 59, 85, 86)

Response: The apparent inconsistencies in assumptions regarding radon diffusion parameters are simply the result of misunderstanding the intent of different sections of the GEIS. For the analysis of the model mill a specific flux of 1 pCi Rn/meter^2-second per pCi Ra/gram of dry tailings was assumed. This choice is discussed in Section 3.2 of Appendix G-1 and it is observed that this specific flux implies a value of 4.7×10^{-2} cm^2/s for D/P, the effective diffusion constant, if one calculates this parameter using equation 16 of Appendix G-1.

In Appendix P, a description is given of the method the staff proposes to use in calculating the thickness of materials that will be required to cover reclaimed tailings piles. It was thought that a numerical example would be helpful, so a sample calculation was presented (in the draft GEIS) using arbitrary values for several parameters, including a value of 1×10^{-2} cm^2/s for the D/P of tailings. A value which is different from that which can be inferred from the model mill calculations (4.7×10^{-2} cm^2/s) was deliberately chosen in order to emphasize the point that the characteristics of tailings will vary from mill to mill, and that values appropriate for each pile will have to be determined and then used in calculating the required cover thickness.

The field measurements of specific flux from acid tailings recently reported by ANL (an average of 0.64 pCi/m^2-s per pCi/g) are within the range of other measurements and tend to support the assumption of a specific flux of 1.0 as a reasonable value for a model mill and a generic assessment such as this.

Comment: Although the GEIS states that inhalation dose calculations are based on the ICRP's Task Group Lung Model, this methodology has not been applied properly. (55)

Response: The ICRP recommends that dust sampling be done to determine the actual activity or mass median aerodynamic diameter (AMAD or MMAD) when the TGLM is to be used to estimate inhalation doses. However, when these data are not available, it recommends that an AMAD of 1.0 µm be assumed. In the case of ore dusts at uranium mills, there is no reliable data on the size distributions of airborne ore particulates (Figure G-1.1 refers to bulk ore feed material) and, therefore, the conservative recommendation of the ICRP has been followed.

Comment: The size of the ore storage pad and mean storage time assumed for the model mill are not realistic. (59, 85, 86)

Response: The assumed size of the ore pad has been reduced. It is acknowledged that there is a wide range in the amount of ore stored at various mills depending on their proximity to, and contractual arrangements with uranium mines. While stored supplies sufficient for 60 or 90 days are not uncommon, a 10-day reserve for the model mill is consistent with general industry practice. Coupling this to an assumed capacity factor of 85% (310 days of operation per year) yields an average ore storage time of about 12 days.

Comment: Assumptions in the DEIS concerning the capacity factor (fraction of the time the mill is processing ore) are inconsistent and unrealistic. (59)

Response: The draft GEIS distinguished between the maximum effects which might result from a single model mill, which conceivably could operate 365 days per year, and the impact of the entire milling industry, composed of mills which on the average were not expected to be in production more than about 85% of the time. In this final report, all impact assessments are based on the same assumed average capacity factor of 85%.

Comment: The assumed emission rate from the yellowcake stack of the model mill is unrealistically high. (59, 86)

Response: It is recognized that some mills have reduced their yellowcake stack losses to well below the 0.7 kg/day assumed for the base-case model mill in the draft GEIS. However, the base-case model mill is not meant to represent optimum conditions, but rather a base case with a relatively low level of environmental control. Actual field measurements which became available after the draft report had been prepared have shown that the release rate of 0.7 kg/day was probably too low and, as a result, the base case yellowcake emission rate assumed herein is 1.4 kg U_3O_8/day. The basis for this decision is discussed in Appendix G-1.

Comment: What is actually known about the relationship between moisture content of soils or tailings and radon exhalation rate from their surface? (74)

Response: A study of this specific topic was funded by the NRC and is reported in NUREG/CR-1081, March 1980. Results of this research are discussed in Section 9.4, summarized in new Appendix G-9, and further detailed in revised Appendix P.

> Comment: To what extent does radon exhalation rate depend on barometric pressure and, therefore, on altitude? (74)

Response: The variations in exhalation rate caused by changes in barometric pressure are believed to be transitory transport phenomena due to an exchange of bulk air (and radon) with the porous medium. This "pumping" phenomenon presumably would have little or no long-term influence on average exhalation rate as determined by the diffusion characteristics of the soil. No significant direct dependence of exhalation rate on average barometric pressure or altitude would be expected.

> Comment: The particle size assumed for the ore dust source term is too conservative and should be changed. (85)

Response: The staff considers that the characterization of all ore dust releases as being of 1 μm in size is probably conservative. Insufficient data is at hand on which to base a better and more realistic assumption. Even significant changes in the assumed ore dust particle sizes would have very little influence on the total radiological impacts predicted as a result of operation of the model mill, or on the conclusions and recommendations presented, because ore dust releases are comparatively insignificant.

> Comment: The particle size assumed for the yellowcake stack source term is inaccurate on the conservative side and further study is warranted to obtain necessary data. (85)

Response: The staff agrees that further study is warranted. A recently published report by EPA (ORP/LV-80-1, January 1980) on the particle size distribution of yellowcake emissions from one mill indicates that the GEIS assumption of 1 μm is not necessarily conservative.

> Comment: Recent measurements of Ra-226 concentrations in over burden and soil from uranium mining areas yield values well above 2 pCi/gram. In view of this, the 2 pCi/gram level recommended in the GEIS is inappropriate and should be changed. (86)

Response: The limit on radon exhalation rate from tailings which is proposed in the GEIS is intended to assure that the emissions from disposal areas are within the range of those occurring naturally. This limit is stated as an increment of 2 pCi/m^2-s above background, rather than as a multiple (e.g., twice) of the background exhalation rate, in order that the degree of control be uniform in all cases regardless of local variations from average background conditions.

The staff's analysis of background flux values is presented in full in Appendix O. Flux values can be related to radium concentrations in soil, and thus the variability in these concentrations is indicative of the kind of variability that will be experienced in radon flux. Analysis of the raw data summarized in Table O.2, and additional data, indicates they follow a lognormal distribution, the geometric mean being 1.0 pCi/gm with a standard deviation of 1.57. On this basis, 95% of radium concentration values in soil are less than 2.4 pCi/gm.

> Comment: Radon emission control to a level of 25-30 pCi/m^2-sec is reasonable given the objective of assuring that releases from tailings piles are within the normal range of background. (85)

Response: The thrust of this comment is taken to be that the "normal range" of radon exhalation rates in the U.S. extends above 40 pCi/m^2-s and, therefore, control to a level of 25-30 pCi/m^2-s meets the stated objectives of the staff, i.e., to limit emissions from covered tailings to a level comparable to that of the surroundings. While the basis for estimating the range of variability adopted by the commentor is open to question, the staff finds the suggested limit unacceptable regardless of the upper bound one chooses to place on natural exhalation rates. Small mineralized areas can be found to exhibit high radon flux levels. The intent of regulations is to assure that flux from the covered tailings piles (which are large area sources) are like those of most surrounding soils. That is, the intent of the staff was and is to limit radon emissions from inactive tailings to the upper end of what most individuals would consider a "normal range." (See Appendix O and the response to the previous comment concerning the variability in radon flux.)

> Comment: The estimate of the amount of ore dust released from the model mill storage pad is much too high. (86)

Response: The staff has reevaluated its estimate of dust loss from the storage pad and found it to be reasonable for the base case. This could be reduced substantially by sprinkling and, in a well managed situation, undoubtedly would be.

As a result of its review of the ore dust source term in the draft GEIS, the staff concluded that the estimated contribution from crushing and grinding was too low by a factor of six, and the emission rate from this source has been increased accordingly. The total ore dust emission rate, even if increased by factors of 2 or 3 above the rates used in this statement, would still have little or no effect on the size of the predicted dose commitments from all sources, or on final conclusions and recommendations. Although this source term is the least well defined, it is also the least important in determining the radiological impact of the model mill.

> Comment: Wind erosion of the tailings pile surface as estimated in the GEIS is much too high because fines would soon be blown away leaving coarser sand particles which are less easily dispersed. (86)

Response: The commenter has overestimated the thickness of tailings that would be lost from a static or inactive pile each year by more than two orders of magnitude. The relative size distribution and, therefore, the rate of particle emission from the surface would not be expected to change with time because new tailings would continually be discharged on the top of the pile. For the model mill, the tailings pile would grow in height by about 0.5 meter per year, less about 250 μm per year as a result of wind erosion.

> Comment: In estimating the rate of loss of radon gas from soil or tailings the GEIS fails to consider: (1) diffusion of radon atoms through sand; and (2) the sweeping effect of helium generated by alpha decay of radionuclides other than radium-226. (97)

Response: One of the factors which is used in calculating the rate of loss of radon from soil is the emanating power. This parameter represents the fraction of the radon which escapes by all possible mechanisms from the granules where it is produced into the surrounding pore space. Diffusion of radon atoms is so slow that virtually no intragranular movement via diffusion can occur before the radon decays. This mechanism, therefore, makes essentially no contribution to the observed or measured emanating power.

The amount of helium produced by alpha decay of all of the uranium series nuclides in secular equilibrium is miniscule relative to the number of "air" molecules present in the pore space of soil. All of the helium produced in one year by tailings with a specific activity of 280 pCi/g, if trapped in the pores, would create a partial pressure of less than 10^{-6} mm Hg. This is not likely to produce much "sweeping effect" on radon which has emanated into the pores.

> Comment: Contrary to the statement under alternative 4, page 8-2, significant particulate emissions may occur from ore piles unless the moisture content is above 8%. (99)

Response: The staff considers that the specific surface moisture content that must be maintained in order to "prevent" dust problems from uranium ore is not well established. This does not invalidate the general conclusion that sprinkling the ore stockpile is an effective method of dust control.

> Comment: With regard to alternative 5, page 8-2, for reducing dusting due to ore hauling, it is noted that wetting agents and chemical suppressants mixed with water are more effective than water alone when sprayed on roads. (99)

Response: The staff agrees with this comment and has noted the greater effectiveness herein (e.g., Table 9.1).

> Comment: Proposals to control radioactive emissions from the tailings pile by maintaining a water cover appear to conflict with the suggestion that contamination of groundwater by toxic tailings components be minimized by reducing the amount of moisture available. A consistent approach should be clearly delineated in the report. (26)

Response: This matter was explictly discussed in Section 12.3.6 of the draft GEIS (Section 12.3.7 of this final document); where it was concluded that staged covering of tailings impoundments was the most effective way to resolve the conflict cited, to the extent it exists. The proposed and final regulations call for consideration of this method of tailings disposal.

4.1.2 Background Radioactivity and Radiation

> Comment: The net radiological effects produced by mill operators in the western states may be biased by the assumption of lower background whole-body dose rates than have been reported elsewhere. (38)

Response: The range in reported background dose rates is quite large and comparisons can be biased in either direction by the choice of a source reference. The dose rates for several uranium mining states quoted in DOE/EIS-00 46-D are derived from ORP/CSD 72-1 and are 80% higher than the U.S. average annual whole body dose given in the same reference. The lower values listed in Table 4.14 and elsewhere in the GEIS are based mostly on NCRP Report No. 45, but also are 80% higher than the U.S. average suggested by NCRP. The latter reference includes allowances for shielding factors and, in the opinion of the staff, provides a realistic estimate of actual dose equivalents received by the population from background sources.

> Comment: There is no section on background radiological characteristics in the GEIS. (92)

Response: Please refer to Section 4.12, "Existing Radiation Environment," of Volume I, and Appendix C of Volume II, "Basic Concepts and Terminology of Radiological Health and Background Radiation." Also, Appendix O is devoted to this issue.

> Comment: The basis for the estimate of the natural radon exhalation rate and a discussion of its accuracy should be included in the GEIS since the releases from uranium milling activities are compared to it. (54)

Response: The estimated exhalation rate of 1.2×10^8 curies of radon per year from the natural soils of the contiguous United States is taken from NUREG/CR-0573, pages 105-108. This document was prepared by Oak Ridge National Laboratory directly in support of the GEIS. It briefly discusses seasonal variability and provides sufficient information for the reader to judge, at least semi-quantitatively, the accuracy of the estimate. Also, Appendix O discusses this matter in detail.

> Comment: The range of typical natural WL (working level) radon daughter concentrations should be provided to add perspective to the predicted increases due to uranium milling. (85)

Response: Typical values for indoor and outdoor working level concentrations have been added to Table 6.33.

> Comment: If the more current data and rationale presented in references 7 and 9 of Appendix C are used, the doses for the first four radiation sources (listed in Table 4.14, page 4-19) should be updated. (99)

Response: The annual dose equivalents from background radiation listed in Table 4.14 are hypothetical estimates for the model (i.e., nonexistent) region. They were derived from current references by methods which are described in Appendix C. Other means of developing reasonable values for the model region could be used, and different annual doses would result; however, they would not differ substantially from the values which appear in the draft and their use would not alter any conclusions.

> Comment: The definition of "lung" dose commitment and the discrepancy between background values quoted in Tables 6.28 and 6.37 are inconsistent. (26)

Response: The lung dose commitments given in Table 6.37 are the sum of pulmonary and bronchial epithelium doses. In the same table, the background dose commitments to the U.S. population are adapted from NCRP Report No. 45, except that for lung tissue the dose conversion factors used in the GEIS were applied to the "standard concentrations" given in Table 29 of the NCRP report. The result should have been given as 174 mrem/year rather than 161 mrem/year.

While Table 6.37 summarizes doses to the entire U.S. population, Table 6.28 relates to the model region, where the assumed background dose commitments are significantly above the average values for the U.S. but representative of western milling regions. The details of the assumptions for the model region are given in Table 4.14 and are discussed in Appendix C. Most of the difference between the annual average lung dose of 174 mrem for the U.S. and 704 mrem for the model region is accounted for by the higher radon concentration that is assumed for the latter.

Comment: If the upper range of natural surface radon exhalation is 2 to 3 pCi/m^2-sec where the average is 0.65 (as stated in Appendix O), then the upper range of surface radon flux from tailings under the proposed 2 pCi/m^2-sec limit would be, if there is a proportional range, between approximately 6 and 9 pCi/m^2-sec. (74)

Response: The assumed proportionality does not exist. The proposed radon limit is 2 pCi/m^2-sec from the reclaimed tailings. It is independent of the natural background radon flux, whatever it might be; see Section 12.3.4.9.

Comment: The GEIS should make it clear that the proposed radon limit is about three times average background. It is misleading to imply that this rate (2 pCi/m^2-sec) is "reasonably near those of surrounding environs." (74)

Response: The staff considers the characterization of the radon limit as accurate and appropriate, given the low level of permissible incremental radon flux increase and the variability of natural radon exhalation rates from undisturbed soils. (See Section 12.3.4.2 and Appendix O.)

Comment: No basis is provided for the assumed boundary values of the radon diffusion constant in natural soil given in Appendix O of 0.01 to 0.05 cm^2/sec, or the assumed soil density of 1.6 g/cm^3. The radon diffusion constants for soils given in Table 9.10 indicate that lower values are appropriate since only one value comes close to 0.05 and several are less than 0.01; radon exhalation rates from natural soils may thus be overestimated. (74)

Response: The radon diffusion coefficients given in draft GEIS Table 9.10 serve as an adequate basis for the values stated in Appendix O. These diffusion constants were used in Appendix O only for illustrative purposes in discussing the relationship between radium in soil concentrations and radon flux measurements. As for the assumed soil density of 1.6 g/cm^3, that value is very commonly accepted and requires no reference.

4.2 Atmospheric Transport

Comment: The following information needed in order to evaluate the GEIS dose calculations was not included: heights of mixing levels used, and the assumed joint frequency distribution of the meteorological parameters for the model region. (26)

Response: The annual average height of the mixing layer used in the GEIS dispersion calculations was assumed to be 850 meters. The joint frequency distribution of wind speed, direction, and stability category assumed for the model region is now included in Appendix G-2.

Comment: It is noted that Figure G-4.15 was printed with a different orientation than other similar graphics, thereby resulting in confusion about compass direction. A discussion of these isopleths (Figures G-4.13 to 4.18) in the text would be helpful, especially in understanding the curves for radon. (26)

Response: Figures G-4.15 and 4.18 are now correctly oriented. Proper orientation relative to the wind rose makes these curves much more understandable.

Comment: The dispersion model used for the GEIS is not representative of the state-of-the-art and is inadequate when applied to conditions of low wind speed, rough terrain and localized conditions. (26, 37, 85)

Response: Currently in the U.S., the majority of theories used to predict dispersion of windborne materials are based on the Gaussian plume model originally proposed by Sutton[1] as early as 1932. A great deal of empirical work has been done to determine plume standard deviations (sigmas) for the atmospheric boundary layer under various meteorological conditions and to extend the basic formulation of this model and its range of applicability. The Gaussian plume model has achieved popularity because it is easy to apply, dispersion data are readily available and most measurement data fit the model reasonably well.[2] Recognizing that no model available at this time, nor probably in the foreseeable future, is free of serious limitations, a group of specialists has unanimously recommended the Gaussian model as the state-of-the-art choice for all point source evaluations.[3] For area sources, the GEIS model employs the basic Gaussian plume point source model to sum the contributions from individual small area sources.

The GEIS model is appropriate for estimation of the radiological impacts from facilities located in regions with level or gently-rolling terrain. The influence of complex terrain on dispersion of airborne pollutants is site-specific and difficult to evaluate. It has been concluded by a group of specialists that no single model exists which can be used to adequately treat all complex terrain situations.[3] In such cases, it is often necessary to make field measurements at each specific site.

The staff considers that the use of the generalized Gaussian plume diffusion model may somewhat overestimate or underestimate local airborne radioactivity concentrations. The evidence provided by Commenter 85 in support of additional dispersion credit under low wind speed conditions has relevance only with respect to the estimation of plume centerline concentrations, typically used in accident analyses. Annual average concentrations used in this document are based on sector-average concentrations involving crosswind integration. Such concentrations are thus independent of lateral dispersion, which is relatively enhanced under low wind speed conditions.

> Comment: The fact that plume depletion is complex and not thoroughly understood limits the validity of the GEIS. (46)

Response: With the exception of radon gas, all radioactive materials released from a uranium mill will be in a particulate form. These particles, even when they are unaffected by gravity (< 10 μm), deposit on surfaces in contact with the plume with resulting depletion. This deposition is not thoroughly understood but is thought to be due to surface impaction, electrostatic attraction, adsorption and chemical interaction. Chamberlain[4] defined the ratio of the deposition rate (W) to the immediate ground level air concentration (χ) as the deposition velocity, V_d, so that $W = V_d\chi$. The important feature of this formulation is that V_d can be evaluated by field or laboratory measurement of χ and W, and then can be applied to estimating deposition during atmospheric transport of particulates. Even though it in no way explains the physics of the deposition mechanism, it is a useful way of approximating deposition and plume depletion phenomena. The staff considers the inherent uncertainties to be unavoidable, but not of such a nature or magnitude to markedly impair the overall validity of this document.

> Comment: Models for estimation of deposition velocity, mixing height, plume depletion, gravitational setting, and plume trapping are inaccurate. (85)

Response: The deposition velocities used are average values derived from field measurements of deposition of particles on grass.[5] Although numerous models have been proposed for estimating deposition velocities, only limited comparisons of predictions of these models with observed data have been made. Therefore, they cannot be considered fully validated at this time.

The source depletion model used is based on the principle of conservation of mass. Horst has concluded that the difference between the surface depletion model and the source depletion model is dependent on the deposition velocity, wind speed, and stability class. For cases of low deposition, high wind speed, and unstable or neutral conditions, the difference in the air concentrations calculated by using these two models is negligible. Based on the assumed wind erosion mechanism and the annual average meteorological data for the model region, it is not expected that differences in the dose estimates from these two models would be significant.

The effect of gravitational settling on the dispersed plume from an elevated source generally is estimated by using the "downward tilted" model proposed by Van der Hoven. Following his recommendations, a correction to account for this sedimentation effect is applied only for particles with fall velocities, V_s, greater than 1 cm/sec. In analyzing the impact of the model mill, since large particles (V_s > 1 cm/sec) are released only from the tailings (which are assumed to be at ground level), no "tilted plume" factors were needed.

The annual average daytime mixing height is used to estimate the plume trapping effect. For neutral and stable meteorological conditions (stability classes D, E, F) the vertical standard deviations (σ_z's) are less than 500 meters at distances up to about 100 kilometers. Only stability classes A through C are normally affected by the presence of a stable layer (or lid). At night, an inversion extends down to the ground for E and F stabilities. Under these conditions, no treatment of plume trapping is necessary. In short, the daytime lid provides a reasonable bound for the conditions which are effected by a lid and does not disturb those which are not.

Computational experiments have shown that for a typical mixture of stability classes, the dose calculations are not sensitive to the variation of mixing height with stability. The algorithm used to account for plume trapping is based on the method proposed by Turner. As indicated by that author, his method is a good approximation of the more complex method derived by Bierly and Hewson.[6] Considering the uncertainties inherent in the dispersion model and assumed meteorological parameters, the staff believes that for long-term dispersion calculations, the differences between these two methods are negligible.

> Comment: No provision is made in the dispersion model to account for enhanced diffusion due to building wake effects. (85)

Response: Building wake effects on the dispersion of radioactivity from uranium milling operations are not significant because: (1) the majority of the radioactive materials are released from large area sources and near the ground level; and (2) such effects are significant only at very close-in locations on an hour-by-hour basis, with virtually no effect on annual average concentrations.

> Comment: The use of the Briggs dispersion coefficients for dispersion calculations is inappropriate, as these coefficients are inaccurate at large downwind distances. (85)

Response: The Briggs vertical dispersion coefficients agree with Pasquill-Gifford (P-G) curves in the range between 100 m to 10 km, except that the curves for A and B stability would approximate the "very unstable" and "unstable" curves recommended by Smith. Even though the Briggs dispersion coefficients are intended primarily for use in calculating ground level concentrations from elevated sources, these values better describe diffusion at greater downwind distances than those derived from the P-G curves. In general, the Briggs values give somewhat more conservative concentration estimates than those from the P-G curves.

Because few plume dispersion values have been reported for distances beyond 10 km, the assumed dispersion coefficients only provide "best-estimates" at long distances. However, since vertical diffusion ultimately extends through the entire boundary layer which is usually surmounted by a stable layer, this limits σ_z to the so-called "mixing height." Therefore, the actual effects of the uncertainty in these estimated dispersion coefficients at long distances are not significant.

4.3 Radiological Impact Evaluation Models

4.3.1 Uncertainty/Conservatism

> Comment: The total regional radiological impacts from operation of the model mill for 15 years should not be obtained by multiplying doses computed for the last year of operation by 15 because doses during earlier years are much less for most exposure pathways. (55)

Response: Radioactivity releases from the model mill are essentially constant over the duration of the 15-year operational lifetime. For any one year of operation the total regional radiological impacts are computed using the environmental dose commitment (EDC) concept, which, as explained in Appendix G-6, yields the total impacts due to releases occurring during that year. As releases are assumed constant for the 15-year operating lifetime, the total impacts are computed as 15 times the annual EDC values. This technique accounts for lower actual impacts during earlier years, as well as years beyond the end of the 15-year period.

> Comment: It is inappropriate and overly conservative to assume that all soil-deposited Ra-226 decays directly to Pb-210 since approximately 20 percent of the intermediate Rn-222 product will diffuse into the atmosphere. (55, 86)

Response: The staff acknowledges that this assumption is both conservative and inconsistent, and has been considering altering calculational methods to correct this problem. No change has been deemed necessary and none has been made because of the considerable calculational difficulties involved and because such a change would not produce any significant benefit with respect to increased precision or accuracy. Only a 20 percent reduction in the concentrations in soil of several relatively unimportant nuclides would be involved, at most, and this would be counteracted by the deposition of daughters of radon released from soil elsewhere. Of the various exposure pathways, the maximum dose reduction would occur with respect to external doses from contaminated soil which depends primarily on the abundance of short-lived gamma-emitting radon daughters. This reduction would also be limited to 20 percent and this particular pathway is not significant with respect to others for which dose reductions would be negligible.

> Comment: Use of the semi-infinite sphere model may overestimate external doses from airborne plumes by one or two orders of magnitude at short downwind distances. (85)

Response: The semi-infinite sphere model is employed as a matter of calculational convenience because doses from this pathway are relatively insignificant (especially with respect to inhalation doses which always co-exist), because doses that are calculated for this pathway are due primarily to short-lived gamma-emitting radon daughters and have no relevance with respect to 40 CFR 190 compliance, and because even at nearby locations the virtual point-source distances for the primary contributors (which are large area sources) yield large plume widths which substantially reduce the inherent level of conservatism to factors far below those quoted in the comment which pertain to point-source evaluations. The alternative, which is the implementation of a finite plume model involving three-dimensional time dependent integration accounting for ingrowth and decay, is very costly from monetary and man-hour perspectives, and ordinarily provides no special benefit other than enhanced calculational validity. This alternative could be implemented in the licensing review of any particular case, if necessary. This possibility is extremely remote because other exposure pathways contribute much greater doses at any location.

> Comment: Annual population and environmental dose commitments should be used only as relative measures of environmental impacts in the evaluation of alternatives. The levels of uncertainty and conservatism involved in their calculation are such that they should not be represented as accurate in an absolute sense. (85)

Response: The staff acknowledges the unavoidable presence of considerable uncertainty in such calculations. The nature and magnitude of the various uncertainties normally involved defies the calculation of specific error bars and makes it truly impossible to determine, in fact, whether the calculated results are higher or lower than the actual case. The considered judgment of the staff is that calculational results are more likely to be overestimates than underestimates. At times, such calculations must be used as the basis for decision-making, recognizing their uncertain nature. This occurs wherever decisions must be made and better guidance is not available.

> Comment: An alternative approach method for calculating vegetation concentrations has been described by Travis (1979). In a study conducted on radon dispersion and dosimetry, the GEIS model was compared to one referred to as a "market basket" approach. Market basket estimates of vegetation concentrations were found to be a factor of 10 less than those found using the GEIS approach. The authors of the study concluded that the market basket estimates were more realistic. It is recommended that the NRC consider incorporating transfer coefficients based on the market basket approach. (85)

Response: The "market basket" approach referred to was employed in NUREG/CR-0573 for estimating continent-wide ingestion of Pb-210 produced by decay of Rn-222. The market basket concentration factors for Pb-210 were developed by comparing and ratioing Pb-210 concentrations found in limited samples of food taken from New York City markets with an estimate of the average U.S. air concentration of Pb-210. As stated in the report, this market basket approach was used "because of the difficulty in determining the relative contribution of foliar deposition vs. root uptake "in determining first-year effects of a one-time release. The staff has considered adopting this approach but has not done so, for the following reasons:

a. ingestion pathway doses are dominated by Ra-226, which would not be affected by altering the Pb-210 concentration factor as suggested;

b. we are not compelled to use such an approach due to the difficulties experienced by the NUREG/CR-0573 authors;

c. while the market basket approach is considered appropriate for a continent-wide evaluation, which requires wholesale averaging, that approach is unnecessary in a localized region where air and ground concentrations resulting from particular sources can be adequately estimated on an explicit basis; and

d. the comparison of very limited data, with respect to Pb-210 concentrations in New York City food, with a single estimate of the U.S. continent-average Pb-210 air concentration, is far from definitive.

In brief, the staff does not believe such a model is appropriate for very localized evaluations and is not persuaded that it offers increased validity.

> Comment: The results of evaluations of compliance with 40 CFR 190 for the model mill should not be used to determine compliance for any real mill as such evaluations are highly site-specific. (59, 85)

Response: The staff concurs with this comment. All 40 CFR 190 compliance evaluations performed by the staff for actual facilities are performed on a site-specific basis. The GEIS radiological assessment of a model is meant to illustrate the kinds of control measures that will have to be taken at actual mills to meet 40 CFR 190.

> Comment: Various assumptions with respect to occupancy factors and exposure pathways for the fence post, trailer, and ranch locations should be justified or revised. An occupancy factor of much less than one percent, instead of 10 percent, would be more appropriate for the fence post location. The 50 percent occupancy assumption for the trailer location should be explained. The assumptions as to the presence of the vegetable ingestion pathway at the trailer and ranch, and the milk ingestion pathway at the ranch need to be justified or deleted. (85)

Response: As explained in the text (see Section 6.2.8.2.3) these locations are hypothetical; they are chosen to serve as reference locations for the evaluation of compliance with applicable radiation exposure limits and for the evaluation of the effectiveness of various effluent reduction alternatives. In this respect the occupancy factors and exposure pathways assumed are quite adequate and need not be revised. The milk pathway, however, has been deleted at the ranch location in order to reduce complexity and promote clarity; as stated previously in the draft GEIS, the milk pathway is not routinely present at nearby locations.

> Comment: In arid regions, beef cattle such as those assumed to exist at the ranch location must range over large areas to satisfy grazing needs. The equation used to calculate meat concentrations apparently does not take variations in distance from the mill into account. (85)

Response: The evaluation is based on concentrations evaluated at a single distance which averages out the effects of grazing at lesser or greater distances.

> Comment: Total individual and population dose estimates should be calculated on the basis of a 70-year lifetime exposure rather than a 15- or 20-year period of mill operation and reclamation. Reclamation in 5 years and reduction of radon emissions should not be assumed in the absence of enforced regulations requiring reclamation in that time or demonstration that such radon emission reductions can be achieved. The GEIS should reflect uncontrolled and long-residence effects. (56)

Response: Total population doses are computed using the concept of environmental dose commitment (EDC) with a 100-year integrating period. This technique, described in Appendix G-6, accounts for the impacts of all releases for a period of 100 years beyond the time of emission. Total doses to nearby individuals are estimated conservatively for the full 20-year pre-reclamation period by adding 15 years of annual impacts during operation (evaluated during the 15th year when such doses are greatest) and 5 years of annual impacts during pile-drying (evaluated during the 5th year of drying when those doses are greatest). The staff has evaluated persistent population doses from radon, both with and without effective reclamation, at varying levels of radon control (e.g., Ch. 12). Effective radon control and drying within 5 years are both feasible and achievable, although in some cases the required drying time may be longer. The staff's regulation changes effecting the conclusions of this document will make reclamation and radon control enforceable regulatory requirements.

> Comment: The total activity inventory in the tailings pile of U-235 and its radioactive daughters will be significant, will yield significant environmental impacts, and should be considered in the tailings stabilization plan. (26)

Response: As noted by the commenter, Section 6.2.8.2.2 explains that the U-235 chain members will constitute less than 5 percent of the total radioactivity in the tailings and have half-lives generally much shorter than those of comparable U-238 chain members. Also, the U-235 radium and radon decay products, which produce the primary impacts from the U-238 chain, have half-lives of only 11.4 days and 4.0 seconds, respectively, as opposed to 1,600 years and 3.8 days for the radium and radon decay products of U-238. For these reasons, stabilization plans and radiological impact analyses need not specifically consider U-235 or its daughters.

> Comment: Radon eventually emitted from the U-238 contained in the yellowcake effluents of the model mill will total 4.6×10^{11} curies and cause 1.8 million deaths. (97)

Response: The staff has explicitly not considered this radon source or its potential health effects because of the very long time delays before radon would be produced. These delays are so long as to indicate that the released U-238 would become well-mixed with several meters of earth or washed into the oceans prior to any significant radon production. Although some radon could potentially be emitted, it would be numerically insignificant even with respect to the very small radon releases anticipated to occur from the reclaimed tailings pile.

> Comment: The present radiological impact evaluation models contain excessive uncertainty and conservatism, are not representative of "best available technology" and should not be used as the basis for regulations prior to revisions to reduce the compounding of conservatism and achieve greater validity. (52, 85)

Response: The staff considers its evaluation models to be state-of-the-art and adequate for the purposes of providing a basis for regulation and performing routine compliance and impact evaluations. These models are subject to change, as appropriate, based on available site-specific information or based on new data and information of a generic nature. Since the performance of calculations published in the draft statement, the staff has rewritten, and made available to the public, the computer code used in the preparation of this Final GEIS. This code incorporates revisions to environmental transfer factors and inhalation dose conversion factors based on such new information. The staff will continue to modify its evaluation models as is necessary to reflect a growing data base. The far-field radon dispersion model used for calculating continental health effects was developed by the National Oceanographic and Atmospheric Administration (NOAA) specifically for the GEIS. This model is based on several years of actual climatologic data. This state-of-the-art model is described in NUREG/CR-0573.

> Comment: Uncertainties and conservatisms involved in computing dose estimates should be enumerated. Ranges of uncertainties should be assessed with respect to concentrations, doses, and health effects. In general, there is an overly detailed presentation of results which most likely cannot be justified by the precision and completeness of the associated data base. (26, 85, 92)

Response: Where appropriate, estimates of uncertainty have been included (see Appendices G-7 and S). In many stated results, considerable uncertainty exists and cannot be avoided or easily quantified. This is particularly true with respect to results which depend on the site-specific characteristics assumed for the hypothetical model mill. In such instances it is of very little benefit to attempt to quantify the involved uncertainties. The staff does not know of any instances where considerable conservatism exists and is of significant import with respect to the final results and conclusions of this document.

> Comment: In a number of instances in the GEIS certain effects are dismissed as being insignificant. These include radon releases from yellowcake, pass-through of radioactivity inhaled by livestock, the entire U-235 decay chain, and others. An analysis is needed to ascertain whether such effects would be significant on a combined basis. (74)

Response: The effects that were dismissed were disregarded because they were insignificant on a relative basis rather than an absolute basis, i.e., they were insignificant as compared to those that were considered. This justification is no less valid for cumulative effects of the types mentioned.

> Comment: The confidence that one can put on the results of computer models, relied upon extensively by the GEIS, depends upon how closely those models reproduce actual physical conditions. Verification of model results by field measurement should be presented in the document. (26)

Response: Limited verification of code predictions has been accomplished satisfactorily, i.e., reasonable agreement between field data and code predictions has been ascertained. Such verification efforts and results as have been reported at the present have been products of NRC-sponsored research efforts which are summarized in Appendix G-9.

> Comment: The results of the GEIS are unreliable because of the analytical approaches employed in risk and cost estimating, which continually compound errors caused by inaccurate or conservative assumptions. Also, a "worst case" or "conservative" approach to modeling and data interpretation is almost always used. These conditions create a major potential for error such that, when combined with other errors, the compounding effect grossly distorts what can be expected in the real world. (85)

Response: The staff emphatically disagrees with these statements. Throughout the GEIS, the staff has made strenuous efforts to employ models, data, assumptions, and equations such that the results obtained would be realistic and reasonable approximations of actuality. Because of the nature of the analyses performed, considerable uncertainty must be (and has been) explicitly acknowledged. However, the staff denies that these uncertainties have been dealt with by continually employing worst case or conservative models, assumptions, and data, and considers the results of this document to be reasonable "best estimate" of the actual risks, costs, and impacts. For critical decisionmaking matters, such as is the case with the development of radon flux limits, the full range of possible assumptions and parameter values are explicitly identified and considered. For example, see Section 12.3.4.

4.3.2 Specific Parameter Values

> Comment: The assumed yield densities (values of Y_v in Equation 8, Appendix G-3) for pasture grass and vegetable crops of 0.75 kg/m^2 and 2.0 kg/m^2, respectively, are much too high for arid western regions where most milling occurs and should be evaluated on a site specific basis. (55, 85, 86)

Response: The values selected and used by the staff for yield density derive from and are referenced in Regulatory Guide (RG) 1.109 (Rev. 1, October 1977), as is the assumed value of F_r, the fraction of deposited activity retained on plant surfaces. The value of F_r depends on the assumed plant yield density, since with lesser plant density, lesser retention is experienced. Therefore, Y_v cannot be lowered without redetermining the appropriate value for F_r. Lowering Y_v only would result in an artificial inflation of vegetable and forage concentrations.

> Comment: The assumed feed ingestion rate for beef and milk cattle of 50 kg/day is much too high for arid western regions where most milling occurs. (55, 85, 86)

Response: The assumed feed ingestion rate is based on an 80 percent moisture content and represents a dry-weight ingestion rate of 10 kg/day, much closer to values suggested by commenters as being appropriate for western regions where moisture contents are typically very low. The staff considers this value to be appropriate for generic applications such as this document, or in the absence of site-specific data.

> Comment: The environmental transfer factors given in Table G-3.2 differ substantially from those presented in Draft Regulatory Guide RH 802-4 (May 1979). (55, 86)

Response: The mentioned Draft Regulatory Guide includes environmental transfer factors for radium and lead which were updated on the basis of an analysis of the final version of NUREG/CR-0574 (March 1979). This data has been incorporated in this document and the environmental transfer factors used here are consistent with those given in Draft Regulatory Guide RH 802-4.

> Comment: The soil to plant transfer factor for thorium is given as 4.2×10^{-3} in Table G-3.2. No reference could be found for this value. This value exceeds the range estimated by Garten (1978) of 4.5×10^{-5} to 2.0×10^{-3} and indicates a more representative value should be adopted. (85)

Response: References for values provided in Table G-3.2 are provided in a footnote to the table. The value for thorium is considered appropriate.

> Comment: No reference was found for the uranium, thorium, and lead feed-to-meat transfer coefficients. The value for radium is less than that cited in NUREG/CR-0574 (March 1979). (85)

Response: References for values provided in Table G-3.2 are provided in a footnote to the table. The value selected for radium resulted from the staff's analysis of data presented in NUREG/CR-0574 and represents the staff's judgment as to the average of values tabulated in the open literature.

> Comment: The feed to milk transfer coefficient for uranium is given as 6.1×10^{-4} in Table G-3.2 and is not within the range given by Garten (1978) of 4.0×10^{-5} to 2.7×10^{-4} based on field studies. The value given for thorium is a maximum value given by Ng (1977). More representative values should be used. (85)

Response: The staff considers the values for the feed to milk transfer of uranium and thorium given in Table G-3.2 to be appropriate.

> Comment: The rationale for the assumed 50-year environmental loss half-life of U-238 series nuclides in soil should be given. Some data indicates weathering may increase availability for resuspension; downward movement in soil would increase root contact. (99) The value selected for this parameter, 50 years, seems very high compared to experimentally determined values for cesium and strontium isotopes. (85)

Response: The staff selected the value of 50 years as the time constant for environmental loss from soil of U-238 series nuclides so as to account for the long-term loss mechanisms known to operate. The selection of the particular value of 50 years accounts for such losses while not underestimating short-term soil concentrations or environmental impacts. The staff does not consider it appropriate to revise this value on the basis of other, very chemically dissimilar, nuclide studies.

> Comment: The initial and terminal values selected for the resuspension factor R entering into Equation 5 of Appendix G-3, 10^{-5} and 10^{-9}, respectively, are considered to be conservative choices from experimentally determined values which range from 10^{-2} to 10^{-13}. The uncertainty inherent in the resuspension model undermines confidence in doses predicted. (85)

Response: The staff considers the values selected for the resuspension factor to be appropriate and does not consider the resuspension model to be conservative or to reflect unnecessary uncertainty.

> Comment: Assuming 100 percent of foliar deposition to reach the edible portion of all aboveground vegetation is unreasonable because the cited reference indicates most values are 10 percent or less, and, for forage, only 2 to 15 percent of aboveground plant material is ingestible. (85, 86)

Response: The reference cited pertains only to grain and potatoes and is used as the basis for reducing E_v for below ground vegetables to 10 percent. The fraction of total aboveground vegetation which is ingestible is not relevent; it does not affect the concentrations computed (see Equation 8 in Appendix G-3).

> Comment: The assumed growing period exposure duration of 60 days represents an upper limit for garden vegetables. A weighted average site-specific value, based on growing periods for actually harvested crops of different types, would be more appropriate. (85)

Response: The assumed value is considered appropriate for generic applications or in the absence of appropriate site-specific data.

> Comment: The assumption that cattle will be able to satisfy 50 percent of their annual feed requirements by grazing is optimistic for the arid west. (85)

Response: The assumed value is considered appropriate for generic applications or in the absence of appropriate site-specific data.

> Comment: Since some existing mills are in far more densely populated regions than is assumed for the model mill, conversion factors should be provided to increase computed regional population doses to reflect increased population for the milling region. (74)

Response: The assumed population density, population distribution, and meteorological conditions all effect computed population doses, as do any number of other characteristics assigned to the model mill such as those affecting source terms. The assumed regional levels of agricultural and livestock productivity also effect computed population doses. The characteristics assumed for the model mill and the surrounding region were selected so as to provide a reasonably typical sounding board for evaluating various kinds of environmental impacts and alternatives for impact reduction. On an independent basis, a uniform increase in population density would yield a proportionate increase in computed population doses, as long as the regional population did not exceed that which could be adequately supported by the assumed regional agricultural productivity. However, this is only one determining factor and the staff considers it impractical to provide conversion factors for all possible variations. Such variations would not significantly impair the utility of the model mill and region as a mechanism for evaluating the need for, and the effectiveness of, the various impact control alternatives evaluated herein.

As stated repeatedly in the GEIS, such as in Sections 1.3, 12.3.10, environmental impact assessments must be conducted at each milling site given the variability that exists in conditions such as those referred to in this comment.

4.3.3 Dose Conversion Factor for Radon Inhalation

> Comment: The effects of differing dust levels, air turnover rates, fractions of unattached daughters, humidity, and seasonal influences should be discussed and accounted for, as well as type of construction and geographic location. (26, 54, 85)

Response: All of these factors will vary from place to place and/or time to time, and they do affect the delivered dose from ambient radon concentrations. It is, therefore, a virtual impossibility to take explicit account of all of these factors at any one location or any one of these factors at all locations of interest. Because it is nececessary to account for radon inhalation exposures over all ranges of these conditions, and over the entire North American continent, the staff has devised and employed a calculational model for computing radon inhalation exposures which essentially averages out potential variations of the kinds mentioned by commenters. The staff acknowledges that in any individual residence, the delivered radon dose per unit radon concentration could vary significantly from that predicted by the staff's model. However, the model and data used are considered to yield reasonably accurate estimates of collective population exposures over the ranges of time and location which must be considered. Very little benefit, if any, would be obtained from any attempt to discuss, or implement in predictive models, all possible variations in all the parameters affecting radon dosimetry.

> Comment: The radon dose conversion factor is based upon disputed assumptions which potentially underestimate risk. The validity of the GEIS is limited by an inability to translate radon concentrations into doses. (46)

Response: The present science of radon dosimetry is such that any derived dose conversion factor, no matter how accurate or reasonable, would be based on disputed assumptions. This does not obviate the need for having and using a dose conversion factor for radon inhalation exposure. The staff has employed a model which it considers reasonably accurate with respect to average conditions and would not consider it appropriate to use a model so conservative as to have no potential of yielding underestimates of risk. The staff's model, as described in Appendix G-5, does convert radon concentrations to doses. Calculations of health effects, however, are based on cumulative exposure in terms of working-level-months (WLM), as opposed to cumulative dose (see Appendix G-7).

> Comment: The staff's model for radon inhalation exposure is nonconservative with respect to EPA-520/9-73-003-B, which estimates 4 mrem/yr per pCi/m^3, and EPA-520/4-78-013 which estimates 27 WLM per year of exposure to concentration of one WL. (35, 36)

Response: The basis for the staff's radon dose conversion factor differs from that utilized by EPA. Actual health effects are estimated on the basis of total WLM exposures, not doses, and the staff's estimate of 25 WLM/WL-yr does not vary significantly from that estimated by EPA.

> Comment: Dose conversion factors for radon inhalation should be age dependent. NUREG-0172 indicates that the lung dose per pCi of radon inhaled by an infant may be five times that for an adult. (35)

Response: While the dose per pCi inhaled by an infant may be five times that for an adult, Table E-5 of Regulatory Guide 1.109 (Rev. 1, October 1977), indicates that the average adult inhales 5.7 times as much air. The actual dose to an infant, adjusted to reflect both of these differences, would be less than that to an adult. Therefore, the staff has not included age-dependence in the radon dose model.

> Comment: Other, higher estimates of dose per WLM have been published. What would be the effect on radon exposure health effect estimates if, for instance, the value of 2.8 rad/WLM as contained in FRC Report No. 8 had been used? (54)

Response: Radon exposure health effect estimates, as stated in Appendix G-7, are based on total WLM exposures, not doses. Use of a different value of dose per WLM would have no effect on radon exposure health effect estimates.

> Comment: The man-rem entries in Table G-8.1 of the GEIS are only 0.62 times those given in Table 2.1 of the cited reference. This should be explained. (97)

Response: The values in Table G-8.1 were corrected to reflect the staff's estimate of 0.625 mr/yr per pCi/m^3; the values in Table 2.1 of the cited reference were based on a slightly higher value of 1.0 mr/yr per pCi/m^3.

4.3.4 Dosimetry

> Comment: Organ sensitivity to alpha radiation should be discussed with respect to inhalation dose conversion factors, as well as critical organs with respect to cancer induction for each isotope. Critical lung tissue effects should be described for U-238 and each daughter. Account should be taken of the fact that uranium is a bone surface seeker rather than a bone volume seeker. (54, 92)

Response: Although these topics are not discussed within the text of the GEIS itself, the relevant information has been incorporated as appropriate. Commenters are referred to Appendices G-5 and G-7, and to the references cited by those sections, for a full discussion of the factors considered in the staff's analysis of dose conversion factors and health risk estimators, respectively.

> Comment: Inhalation dose conversion factors for occupational exposure differ significantly from those used otherwise, due to different assumptions with respect to solubility in human lung fluid. The solubility classes chosen for occupational exposure estimates are based upon a single study by one laboratory, have not received sufficient peer review, and may not be representative of typical industry conditions. (26, 55, 99)

Response: The subject study was reviewed by the staff in the context of other available information and data and considered appropriate for use. Samples from several mills were included in the study and the results are considered representative of typical industry conditions. Dose conversion factors for inhalation, for both occupational and environmental exposure, have been based on the results of the final report of this study, NUREG/CR-0530 (January 1979).

> Comment: The inhalation dose conversion factors used are not consistent with those contained in NUREG-0172 or the latest guidance of the International Commission on Radiological Protection (ICRP) as provided in ICRP-30. Values of the activity-median aerodynamic diameter (AMAD) should be provided to allow verification of the staff's dose conversion factors. (55)

Response: As explained in Appendix G-5, the staff has utilized the ICRP Task Group Lung Model (TGLM) as the basis for the calculation of inhalation dose conversion factors. Unlike the models employed in NUREG-0172, the TGLM allows variation with particle size and solubility class and is therefore more appropriate. ICRP-30 does not represent a significant departure from previous ICRP guidance with respect to implementation or use of the TGLM. AMAD values for the particle sizes and densities considered in this document are given in Table 1 of Draft Regulatory Guide RH 802-4 (May 1979).

> Comment: Age-dependent inhalation dose conversion factors can be as well-justified as ingestion dose conversion factors. (99)

Response: The staff has not elected to attempt the derivation and use of age-dependent dose conversion factors for inhalation because of the lack of data necessary to incorporate age-dependence into the TGLM. Because breathing rates of infants and children are lower than those of adults, age-dependent results would not markedly differ from those calculated for adults, even if the dose per unit of activity inhaled is somewhat higher for younger age groups.

4.3.5 Other Topics

> Comment: Groundwater transport, and surface runoff, of radioactive materials can yield considerable radiological impacts to nearby individuals and populations, can have significant consequences with respect to 40 CFR 190 compliance, and should be addressed in detail. All potential exposure pathways should be considered and the peak year of exposure, which could be 20 to 30 years after mill shutdown, should be stated. (26, 74, 92, 99)

Response: As with the draft statement, this Final GEIS does not attempt to offer any explicit evaluation of a generic nature for radiological impacts from water pathways. Such pathways are so intensely site-specific as to make any such generic analysis utterly useless. The staff recognizes that such impacts can be significant, particularly in cases of older facilities where appropriate protective features were not included in the original site selection or facility design. This is no longer the case; the NRC staff routinely performs in-depth analyses of potential groundwater transport mechanisms in each license evaluation. Applicants are required to site and/or design so as to minimize potential impacts via liquid pathways.

Regulations delineate stringent seepage control requirements which must be put into effect at each milling operation, and further call for preserving existing or potential water use in each case. This, for example, would assure that where a drinking water quality aquifer is near a milling operation it must remain so during and after operations.

> Comment: The UDAD code and the manual describing that code are presently unavailable for review. Several required input parameter values are not stated. (26)

Response: The code manual, NUREG/CR-0553, was published in May 1979 and the UDAD code was made available to the public at the same time. The staff has modified the UDAD code to produce a code called MILDOS, which is now used for staff radiological impact evaluations for uranium recovery facilities. The MILDOS code, which has been used for all regional radiological impact evaluations presented in this document, has also been made available to the public. All significant input parameter values are contained in this document.

> Comment: Radon releases yield substantial far-field inhalation doses but also yield ingestion doses due to deposition of particulate daughters like Pb-210 on the entire grain belt of the U.S. (36)

Response: Both far-field inhalation and ingestion doses from radon releases have been addressed in detail. Please refer to Appendix G-8 of this document, and NUREG/CR-0573.

> Comment: The transport and diffusion models used in NUREG/CR-0573 should be discussed at length in the GEIS. In particular, the validity of the models used over the ranges of consideration should be examined. (97, 99)

Response: The requested discussion is available in NUREG CR-0573. The staff considers the models employed to be appropriate for the ranges of consideration necessary. The staff's considered judgment is that the results of that model are likely within a factor of two of the actual case for radon inhalation exposure estimates, with somewhat greater uncertainty as to the precision of the estimated ingestion doses associated with deposition of particulate radon daughters.

The far-field models were developed specifically in support of the GEIS effort based on National Oceanographic and Atmospheric Administration (NOAA) data. The model was developed in a cooperative, interagency effort (EPA, NRC and NOAA) with the assistance of Oak Ridge National Laboratory. The model is largely and imperical model based on several years of actual climatological data stored on computer by NOAA. More information is presented in NUREG CR-0573.

> Comment: The different types and bases of dose results published in the GEIS should be clearly defined. Fewer parameters or better organization would be beneficial. (35)

Response: The staff has made strenuous efforts to provide clear concise statements as to the bases and definitions for the different types of dose results presented. As a highly complex technical issue, radiological science and radiological impact evaluation discussions are deserving of such attention.

> Comment: The GEIS should explain how the environmental dose commitment concept is applied to chronic release situations. (54)

Response: The environmental dose commitment concept is applied to estimate the total environmental impacts resulting from releases occurring over some fixed time interval and is explained in Appendix G-6.

> Comment: Doses to small mammals offsite could exceed those for man due to burrowing in contaminated soil or ingesting arthropods. Large numbers of species within a milling region could be attracted to the tailings pond as a water source, despite poor quality, if few other water sources are available. (26)

Response: The text of Section 6.2.8 has been appropriately revised.

> Comment: External dose estimates should include the direct gamma dose from the tailings pile, particularly for close-in receptors. (26)

Response: Direct gamma doses have not been included as they are considered to be insignificant compared to doses from other pathways, even at close-in locations.

> Comment: The impacts of emissions of radon and particulates from ore trucks or other vehicles hauling ore to the mill site should be included, since the mill has no utility independent of such ore movement. (74)

Response: The impacts of such emissions have not been considered in detail because they occur offsite, are considered part of the mining operation, and cannot be affected by NRC which has no jurisdiction over shipment of unbeneficiated ore. Analysis of such impacts by NRC would be fruitless since NRC has no authority to regulate such impacts.

The EPA is completing a study of uranium mining activities under a mandate by Congress [see Section 114(c) of the UMTRCA (P.L. 95-604)], and will be reporting recommendations on what programs should be initiated to control such impacts.

> Comment: The assumption stated in Appendix G-3 that daughter concentrations in food products are identical to those of the parent isotopes for which concentrations are calculated explicitly can lead to erroneous results because different transfer coefficients apply to different elements. (43)

Response: Only short-lived daughters are assumed to have concentrations equal to those of a parent that is not the same element. Except for Po-210, such short-lived daughters yield only negligible ingestion doses (due to their short half-lives). For the meat pathway, build-up in the animal occurs over a long enough time interval such that ingrowth of Po-210 from Pb-210 would be the primary contributor, as opposed to direct uptake of Po-210. For vegetation, which is assumed to have a 60-day growing period, disequilibrium of Po-210 could be a significant perturbation. Moore, et al.,[7] give values of the transfer coefficient for Po-210 from soil to plant of 2.6×10^{-4} for vegetables and grains, and 4.2×10^{-3} for grasses and forage. These are less than the values used here for lead and indicate the predominance of ingrowth, as opposed to direct uptake, as the primary mechanism for the development of Po-210 concentrations in vegetation.

> Comment: The figures for uranium mills in Table 6.41 (page 6-74) do not agree with those in Table 6.39 (page 6-72) in the total line for the years 1978-2000 and there seems to be no reason why they should not. The last sentence of 6.43 (on page 6-73) uses the figures from Table 6.41 and does not mention those in Table 6.39. Although the difference in the figures is small, there seems to be no reason why they should not be the same in all three places. (85)

Response: The slight differences result from the fact that one set of numbers includes only doses from radon, which is evident from the titles of the tables.

4.4 Radiation Health Risk Estimators

> Comment: The estimated number of potential health effects should be based on the (absolute or relative) analytical model only. Otherwise, the estimates will be excessively (high or low). Risk estimators used in the GEIS and how they were selected should be discussed. (32, 46, 54, 85, 92)

Response: The NAS BEIR-I Report[8] described and discussed two analytical risk models (absolute and relative) which might be used to estimate possible risks of cancer from exposures to radiation. The absolute risk model assumes a constant increase in incidence over a period of time whereas the relative risk model assumes a fractional increase in the normal incidence over a period of time. Since the normal incidence of most cancers increases with age, estimates based upon the relative risk model and an assumed lifetime "plateau" (or period of increased incidence) generally yield higher risk values. Knowledge of cancer and epidemiological data currently are incomplete; consequently, it is uncertain which of the two models might best predict the risk from exposure to effluents from uranium mills and precisely which parametric values should be selected.

Some authors have suggested that the relative risk models be used for estimating potential lung cancers from exposures to radon.[9,10] Others have chosen the absolute risk model[11] or combinations thereof.[12] The absolute risk model also has been more widely accepted among international authorities.[13]

The risk estimators used for estimating the potential number of health effects in the GEIS were selected by averaging the extremes of the range of values for premature deaths per lifetime for a population dose of 10^6 person-rem determined by evaluating the absolute risk model and the relative risk model for plateau durations of 30 years and remainder of life. The average was selected as the representative or central value for estimating risks.

The evaluations were performed in the manner suggested in the NAS BEIR-I Report (Tables 3-2, 3-4, and 3-5). In 1979, the NAS made available for review and comment a draft of the NAS BEIR-III Report[14] which updates and extends the BEIR-I Report. Changes in the evaluations as suggested in the BEIR-III draft would reduce the range of values and reduce the central value of the risk estimator for lung cancer used in the draft GEIS by about 30 percent.

It is not practicable to determine possible lower limits for risk estimators. Epidemiologic data currently available would not rule out a value of zero for the risk from incremental additional exposure of the very low levels expected for the general public from uranium milling operations, e.g., a practical threshold for inducing cancer might exist. Nor are the central value risk estimators used in the GEIS the maximum values that could be found, but they are considered representative of a likely range of nominal upper limits derived on the basis of a linear nonthreshold dose-response assumption.

Comment: 1. Calculations of the potential number of health effects presented in the GEIS are grossly in error (over or underestimates) for many reasons. (54, 85)

2. The selected risk estimator values are less than the maximum values found in some publications. (26, 46, 54, 74)

Response: An Environmental Impact Statement is intended to provide a realistic evaluation of the impact of proposed action and alternative actions. In order to quantify the potential risks of various operating modes at uranium mills, it was necessary (1) to estimate the potential individual and collective exposures to radiation, and (2) to estimate the potential number of serious health effects which might be postulated to result from such exposures. Substantial uncertainties are inherent in relating the low levels of exposure to the risks of realizing health effects. In developing the risk estimators used in the GEIS, the staff attempted to obtain values which are "realistically conservative." The selected values are not as high as some which can be found in the literature, but they are higher than the "best estimate" values proposed by some knowledgable authorities.

The calculated risks might overestimate or underestimate the actual impact--which cannot be determined. The staff believes that the calculated risks are likely to be somewhat overestimated; but not unduly so, considering the recognized levels of uncertainty involved.

Comment: The selected values of risk estimators for the GEIS, which are greater than those selected by ICRP (Publication 26) for both lung and whole body exposures, will result in overestimating the number of health effects. (50)

Response: As discussed above, the risk estimators selected for the GEIS reflect the results of both the absolute risk model and the relative risk model. The use of the relative risk model generally results in higher estimates of health effects than use of the absolute risk model. The ICRP, in Publication No. 26, uses an absolute risk model and perhaps somewhat less conservative parametric values; consequently, some differences between the risk estimators could be expected.

Comment: 1. Justify the use of latent periods of 0, 10, or 15 years when some radiation induced cancers are known to occur 20, 30, or more years after exposure. (54, 92)

2. Latent periods, at low-exposure levels, are different (longer or shorter) from those at high-exposure levels and this should be reflected in the GEIS evaluations. (54, 85)

3. In view of the long latent periods, loss of expected lifetime would be a better measure of risk than the estimated early cancer deaths. (85)

Response: If persons are exposed to sufficient radiation, biological effects such as cancer can be induced. The response typically would be manifested as an increase in incidence of the diseases above the normal incidence for the exposed group. The increased incidence can be seen only after some finite period of time and would persist for another period of time. The delay between the exposure and the increase in cancer incidence is the minimum latent period and the delay between the exposure and detection of the radiation induced cancers generally is the latent period. The duration of the increased incidence is known as the plateau duration and it may persist for some number of years or for the remainder of life. The minimum latent period used in the GEIS for evaluating risk models ranged from 0 to 15 years depending on the age at the time of exposure and the site or type of cancer.

A longer latent period might indeed be applicable for cancers as a consequence of exposures to low levels of radon; the data currently available are not adequate to conclude that the risks per unit of collective dose (person-rem) would be less than for exposures at higher levels rather than simply delayed in occurrence. In either case, loss of expected lifetime might also be an appropriate end-point or index, as well as early deaths from radiation-induced cancer.

Comment: 1. Explain the format used in presenting the risk estimators such as Table G-7.1 of Appendix G in the draft GEIS. (28)

2. Age-specific risk estimators should be used in the GEIS. The use of risk estimators for adults can underestimate health risks for children specifically and the population, generally, owing to the presence of more sensitive groups of people. (92)

Response: Table G-7.1 of Appendix G in the GEIS presents the central value of the risk estimator. As discussed above, it is the average of the extremes of the range of values derived from the absolute risk model and the relative risk model. The upper and lower values of the range are also presented in the table.

Age-specific parameters were used in the evaluations employing both the absolute risk model and the relative risk model. Thus, the risk estimators, which are dependent upon the evaluations, do reflect age-dependent risk considerations.

Comment: The adjustment of the absolute risk coefficient for lung, from 1.3 to 2.0 per 10^6 person-rem-year, based on data from U.S. miners, obtained since the BEIR-I Report, does not appear to be justified for several reasons:

1. The risk estimator value of 1.3 was an average of four incidence values from miners of four nations. As increase in the incidence of lung cancer among U.S. miners (which was substantially lower than other miners) would have little effect on the average of the four values. (85)

2. Details of how the new data were used to revise the estimators is not available for formal review by peers and alternative conclusions might be provided. (85)

3. The incidence of lung cancer for the four groups of miners should not be simply averaged because the number of workers in each group are not equal, the exposure conditions were not identical, and the quality of the data is not uniform. (85)

Response: The information available does not permit unambiguous interpretations or conclusions concerning the potential risk of lung cancer as a consequence of exposure to radiation. The NAS, after reviewing recent data, suggested an expression for estimating the risk of incidence of lung cancer per million person rem per year as 0.2 x (attained age over 35) with a risk of 0 to age 35, latent periods of 15 years for ages 20-34 at irradiation, and 10 years thereafter, except that a risk of 7.0 per million person rem per year is used for those irradiated at age 65 or older. A value of 2.26 was suggested for use when the irradiation group is representative of the general population (BEIR-III draft 1979). Consequently, the increase of the risk estimator from the value of 1.3 as given in BEIR-I, based on miner and other data, to 2.0, as suggested in the NAS Report (EPA 520/4-76-013), appears to be both consistent and representative.

It is indeed unfortunate that some work has been referenced prior to publication (e.g., in the NAS reports), since specific details of the epidemiological studies and rationale on statistical treatment are not available for review. However, from the information available, the values for risk estimators used in the GEIS appear to be reasonable.

> Comment: Uranium miners who smoke are known to have a much higher incidence of lung cancer than miners who do not smoke. Failure to recognize such carcinogen co-factors can lead to large errors in risk estimates for the general public. Other factors, such as race, socioeconomic conditions, and habits, can affect risk. (50, 85)

Response: The incidence of lung cancer is indeed higher for miners who smoked than for miners who did not smoke. This observation is also true for smokers and nonsmokers in the population generally. Recent reviews of the data (e.g., the draft BEIR-III Report) suggest that the risk of lung cancer from smoking is additive to the risk of lung cancer from irradiation.

Factors such as race, socioeconomic conditions, and other characteristics could affect the risk estimator values. Unfortunately, available data and analyses have not been adequate to provide the appropriate correction factors for such adjustments.

> Comment: Extrapolations of data from exposures to radon at high levels (miners) to the very low levels addressed in the GEIS, can lead to gross errors (over or underestimates) of the potential health effects. (32, 54, 85, 92, 96)
>
> 1. The ratio of induced lung cancer to normal incidence of lung cancer will not be the same for both groups; consequently, the relative risk estimators for miners cannot be expected to be valid for the general public since latent periods increase for lower-level exposures. (85)
>
> 2. The normal incidence of lung cancer in the 4-State area applied to miners is 40 to 50 percent lower than the average for the U.S. and this should be factored into risk estimates using relative risk models. (85)
>
> 3. In view of the increase in lung cancers caused by chemical carcinogens in the environment and the use of "normal incidence" values in making estimates, the "normal incidence" of the early 1900s should be used in the calculations. (85)

Response: Extrapolations of data from high to low exposure levels introduce potential errors. Indeed, there are substantial factors of uncertainty in the extrapolations as well as in the applications of the extrapolated data, as indicated by the comments. Incomplete knowledge prevents accurate quantification of the magnitude of the possible errors introduced by the confounding factors. Most authorities agree that linear extrapolations generally yield conservative results when it is assumed that there is no threshold of dose for increased incidence of cancer.

> Comments:
>
> 1. Epidemiological studies which have been completed in the vicinity of mills or among those who might otherwise have been exposed to greater than average concentrations of radon should be presented. (26, 92)
>
> 2. Discuss the Washington Post article which states that 177 excessive lung cancers have been found in Durango, Colorado, as a consequence of exposures to radon. (54)
>
> 3. Health effects other than cancers can be anticipated to occur as a consequence of exposures to radon (e.g., cerebral and coronary diseases) and should be discussed. (54, 92)
>
> 4. Studies which indicate that health effects will occur at very low levels should be presented. (92)

Response: Two studies attempted to determine whether the uranium mill tailings used as fill under dwellings in Grand Junction, Colorado, were having an effect on mortality there. Mason et al.[15] compared age adjusted cancer mortality rates among whites for all cancer and for leukemia and lung cancer for the 1951 to 1967 period and compared the findings to Colorado rates. No excesses were noted. In the second study, Cunningham[16] used a case-control method and investigated the observation that leukemia in Mesa County, Colorado, (Grand Junction is the county seat of Mesa County) had increased since the study by Mason et al. was made. He confirmed that the leukemia rate had increased since 1970, but he found no excess of leukemia cases associated with houses built on uranium mill tailings.

The article in the Washington Post which alleged that a substantial number of excessive lung cancers were found in Durango, Colorado, was based on a study made by a local physician. A follow-up study by the Colorado Health Department concluded that data and epidemiological methods had been improperly used and no excess of lung cancers existed for that region based on available data.

Lung cancer is the principal potential health effect which is of concern from exposure to radon. While there is some potential risk for other health effects, the risks of other effects are insignificantly small when compared to the risk of lung cancer.

We know of no data or studies which indicate definitively that health effects do or do not occur at the low levels of exposure that are anticipated to result from operation of uranium mills.

> Comment: The discussion of genetic risks where high LET (linear energy transfer) irradiation from radon is involved, should be expanded. (54)

Response: Exposures to radon and daughters produce nonuniform doses among the body organs. The highest dose from inhalation is to the bronchial epithelium of the lung and the lowest to muscle (soft tissue) which includes gonads. According to an EPA estimate, the soft tissue dose would be about 0.07% of the dose to the bronchial epithelium.[11] In terms of potential health effects, the risk of genetic effects from the gonad dose would be about 0.4% of the risk of death from lung cancer. Thus, the genetic risks are an insignificant fraction of the total risk.

> Comment: Many articles and reports indicate that the relative biological effectiveness (RBE) of high linear energy transfer (LET) radiation should be increased for applications at lower doses and dose rates. Since radon is a source of high-LET radiation, the RBE should be adjusted in extrapolating data from high exposures in uranium mines to the low levels anticipated beyond the boundaries of uranium mills. (32, 54, 92, 96)

Response: The number of biological effects found among a population exposed to low levels of gamma radiation generally are less than the number that would be predicted based on an assumed linear relationship between number of effects and dose and the observed number of effects from high levels of exposure. On the other hand, the number of biological effects found among a population exposed to low levels of exposure to neutron or alpha (high-LET) radiation are approximately equal to the number that would be predicted based on an assumed linear relationship between the number of effects and dose and the observed number of effects from high levels of exposure. The RBE is based on the magnitude of dose from one type of radiation required to yield an effect equal to that caused by a unit dose from gamma radiation. Thus, the RBE for high-LET radiation should be increased with decreasing dose values to compensate for the less than linear decrease noted for gamma irradiation. The NRC generally assumes, for radiation protection purposes, a linear non-threshold relationship between doses and biological effects for all radiation sources, including gamma radiation. This assumption is conservative for predicting effects from gamma radiation, but should provide reasonably good estimates of effects from high-LET radiation. Consequently, no correction would be required by NRC in making extrapolations from high to low levels of exposures of radon. Further, the risk estimators are not based only on exposure data from miners and subsequent extrapolations.

> Comment: Risk values associated with common activities should be provided so that laymen reading the GEIS might have a perspective for judgment. Also, the GEIS should provide a breakdown by site (including lung and bone) of the 9,900 total cancers from normal incidence. (85)

Response: The staff has been keenly aware of the need to provide perspective for judging the significance of the estimated radon releases and potential health effects from uranium milling. Radon releases and resultant radiological exposures, from natural and technologically enhanced sources of radon, such as plowing of agricultural lands, have been evaluated in detail. These studies are described in NUREG/CR-0573 and are summarized in Table 12.3.

Knowledge of risks associated with more familiar activities might indeed be helpful to readers in judging the significance of the values and issues presented in the GEIS. Lists of such risk values were provided by some commenters and publication as part of the GEIS might adequately serve such a purpose. Unfortunately, references or other bases for selection of the values were not uniformly provided and they have not been verified by the NRC staff.

Some readily available information on cancer statistics from the American Cancer Society may be helpful:[17]

- o Approximately 25 percent of the U.S. population can expect to have cancer during their lifetimes based on current incidence (not including nonmelanoma skin cancer, with an estimated incidence of 300,000 per year).
- o Of the deaths from all causes in the United States, about 20 percent are from cancer.
- o Fractional cancer incidence and mortality by site and sex estimated for 1979 are presented in Table A-2.1.

Table A-2.1 SUMMARY OF 1979 ESTIMATES OF U.S. CANCER INCIDENCE AND MORTALITY BY SITE AND SEX[17]

	Cancer Incidence by Site and Sex*		Cancer Deaths by Site and Sex	
	Male	Female	Male	Female
Skin	2%	2%	1%	1%
Oral	5%	2%	3%	1%
Breast	-	27%	-	19%
Lung	22%	8%	34%	14%
Colon & Rectum	14%	15%	12%	15%
Pancreas	3%	3%	5%	5%
Prostrate	17%	-	10%	-
Ovary	-	4%	-	6%
Uterus	-	13%	-	6%
Urinary	10%	4%	5%	3%
Leukemia & Lymphomas	8%	7%	9%	9%
All other	19%	15%	21%	21%

*Excluding nonmelanoma skin cancer and carcinoma in situ of uterine cervix.

4.5 Groundwater Impacts

Comment: The GEIS should emphasize that floodplains, shorelines, and groundwater recharge areas are not suitable locations for tailings ponds. (21, 25, 26)

Response: The selection of the proper site for a tailings pond is an important consideration in the licensing of a new mill. The staff has provided appropriate guidance on site selection in the regulation performance objectives. Careful examination of the proposed disposal location is a very major part of the evaluation of any license application.

The final regulations have been revised from their proposed form to emphasize more than was done in the proposed version the overriding importance of siting in developing tailings disposal programs. Furthermore, the regulations require positive seepage control measures be taken, if necessary, to assure tailings solutions do not contact groundwater. The regulations also require that tailings be sited where they cannot be disturbed or disrupted by natural forces, for example, in areas where there is only very limited upstream surface drainage. The staff considers these requirements to effectively rule out inappropriate siting in flood plains, recharge areas or in other areas where geohydrologic conditions which would lead to unacceptable groundwater or surface stream impacts. Also, see Section 12.3.5 concerning the unlikely occurrence of surface recharge and precipitation infiltration in semiarid western milling regions.

Being affected by site-specific conditions as much as it is, the problem of protecting groundwater must be evaluated, and optimum mitigating siting and design measures worked out, on a case-by-case basis. This is one of the major reasons for the staff's conclusion in the GEIS (Sections 12.3.10 and 1.3) that site-specific, documented environmental assessments should be prepared for public review and comment by the NRC and Agreement States in connection with licensing actions. The regulations identify the concerns that must be addressed initially by applicants and licensees and independently by the regulatory agency in such assessments.

> Comment: The transport of water-soluble ions, such as those of uranium, molybdenum, etc., by groundwater should have been more completely treated since they represent hazards to human health. (26, 51, 74, 85, 92, 99, 138)

Response: The GEIS (in Appendix E and Chapter 6) analyzes, for illustrative purposes, the transport of several common tailings solution contaminants and indicates repeatedly that the specific contaminants and concentration levels vary significantly from site to site. In general, however, it shows that potentially significant impacts to groundwater is likely, without controls of seepage. On the basis of this, regulations are being established which require strict control of seepage and other measures to assure preservation of current or potential groundwater uses. Specific seepage control measures are delineated in the regulations (see Section 12.3.5). By taking such measures, groundwater protection objectives should be accomplished.

In some cases (primarily where an alkaline leach is employed), uranium and molybdenum can form relatively mobile chemical species which, without seepage control, can cause problems. As stated repeatedly in this document (for example, Sections 1.3, 12.3.5, and 12.3.10), because the problems of tailings disposal are so site-specific, the problems and the exact methods of dealing with them must be worked out on a case-by-case basis. New legislation (P.L. 95-604) and the regulations assure that a full, independent environmental assessment will be conducted of unique site-specific problems (such as uranium and molybdenum contamination of groundwater it these were to be a problem) at each mill.

> Comment: It should be pointed out that the potential period of contamination is much longer than 15 years. (37, 74).

Response: As discussed in more detail in Sections 9.3.4.2 and 12.3.5 and Appendix E-3-Section 3, ongoing seepage from mill tailings impoundments after the end of mill operation is not expected to occur given the arid and semi-arid conditions in the Western U.S. milling regions and seepage control measures specific in regulations. The period of concern is primarily during mill operations when very large quantities of solutions are discharged continuously (about 1800 MT per day on average, Section 5.2).

> Comment: Fracture flow of contaminated water should be analyzed as a mechanism whereby undiluted toxicants may move large distances fairly rapidly. (37)

Response: Fracture flow has clearly been shown by experience to be one of the most important mechanisms of contaminant transport. This has been observed in at least one operating mill. The GEIS and regulations have been revised to emphasize the need to identify and take actions to preclude channelized transport of contaminants through fractures, fissures and other zones of high hydraulic conductivity.

> Comment: A more detailed evaluation of long-term seepage is warranted. (38, 54, 74, 99)

Response: Appendix E-3-Section 3, and Sections 6.2.4.2, 9.3.4.2 and 12.3.5 have been amplified to discuss the matter of long-term seepage. In general, the conclusion is that in semi-arid regions seepage after the cessation of mill operations will not be a significant problem. Existing and potential groundwater uses can be preserved.

> Comment: The discussion of groundwater flow in App. E should be expanded to include: (1) effects of solution mining; (2) characteristics of groundwater at existing sites; (3) filtration and adsorbing properties of soil; (4) chemical reactions between groundwater and soil; and (5) the fact that groundwaters in uranium mining areas are "naturally" contaminated with radioactive elements. (53, 54, 92, 99).

Response: (1) The NRC has sponsored a study of the general effects of solution mining (NUREG CR-0311, Aug. 1978), will continue to support research into various aspects of this technology, and will publish an environmental assessment when specific licensing action is undertaken. Detailed evaluation of solution mining is not intended for coverage by this statement. This document is limited to detailed assessment of the impacts of "conventional milling" as stated in Sec. 1.2 of Chapter 1.

(2) Such properties have been and will be considered in individual environmental impact statements dealing with specific sites; detailed discussion of specific sites is not the purpose of this generic study. See Sections 1.3, 12.3.5 and 12.3.10 concerning how highly variable and site-specific matters as groundwater protection must be handled.

(3, 4) Sections 1.3 and 2 of Appendix E-3 discuss and illustrate in general terms the process of impedence and removal of contaminants in groundwater by filtration, sorption and chemical reaction in underlying strata. These matters are developed in sufficient detail for the purposes of this generic statement which is to support the regulations being promulgated. These processes occur in varying ways and to varying extent; regulations establish requirements that will account for them and assure groundwater protection at each site through seepage control measures.

(5) The stringent seepage control measures specified in regulations being promulated should assure that uranium for tailings impoundments will not become a groundwater contaminant of concern.

> Comment: The effects on groundwater are different in the operating and nonoperating phases of milling. (53)

Response: There is clearly a difference in the potential impact that is posed during the operational and post-operational periods. These are discussed in Sections 6.2.4.2, 9.3.4.2, and 12.3.5 and in Appendix E-3. After milling operations cease, there should be no continuing seepage from impoundments in semi-arid and arid western U.S. milling regions. The matter of long-term seepage has been discussed more completely in the final GEIS than in the draft version.

> Comment: The severity of the environmental effects of nitric acid leaching is understated in Sec. 9.3.4.2.1 because of the fact that the nitric acid standard is primary (i.e., based on health effects) whereas the sulfuric acid standard is secondary (i.e., esthetic).

Response: The staff agrees. This point was maae in evaluation of the costs and benefits of the nitric acid leaching alternative in the draft GEIS, Section 12.3.3.3. However, this has been emphasized by an appropriate text change in Sections referred to in the comment.

> Comment: A discussion of the relative magnitudes of groundwater withdrawal and recharge rates should have been included. (74, 99)

Response: Relative groundwater withdrawal rates and recharge rates are discussed for the severe case of 12 model mills, with associated mining, in the model region in Sec. 6.3.4.2. The recharge rate assumed for the model region is adequate to support all withdrawals. It is noted, however, that this may be a serious problem in some areas (see second paragraph of section entitled "Water Use"). A more detailed assessment of this site-specific problem is beyond the scope of this generic statement, however an estimate of water resources lost by evaporation as a result of all conventional uranium milling activities (including associated mining) is given in Chapter 15. As repeated throughout the document (Sections 1.3 and 12.3.10, for example), these matters must be evaluated on a case-by-case basis.

Also, in this connection, regulations effectively call for minimizing consumption of water in the mill (Criterion 5).

> Comment: Surface disturbance and construction activity can, if they take place in an aquifer recharge zone, affect the quality of underground water. (74)

Response: The staff agrees that, although very unlikely, there is some potential for this. The possibility can only, and will be, assessed in a site-specific licensing evaluation. (See Sections 1.3 and 12.3.10.)

> Comment: The GEIS does not address the potential water use impacts of finding alternative sources of water when supplies become contaminated. (74)

Response: The purpose of the GEIS is to consider impacts of the disposal of uranium mill wastes on groundwater and other resources. The problem of finding alternative sources of water when otherwise available supplies become contaminated is so site-specific that it would be fruitless to conduct and present a generalized analysis of the problem. The staff believes that such an analysis would not add substantially to, nor be consistent with, the objectives of this generic statement.

The regulations being promulgated should assure that existing or potential water uses (such as, drinking water use) are preserved.

Comment: There were numerous comments on specific aspects of the quantitative seepage and groundwater contaminant transport analyses performed by the staff for illustrative purposes in Appendix E, Chapters 6 and 9. While each may be directed at separate and distinct aspects of the analysis, a general response concerning the purpose of the GEIS groundwater modeling effort is appropriate regarding these comments collectively. The comments are first listed, the general response is then given, and then, as required, additional responses are given to specific comments where the general response may not be sufficient by itself. Specific comments are as follows:

1. A more complex analysis using finite-element techniques should have been used to model the dispersion of the seepage. (85, 99)

2. State-of-the-art calculations using site-specific information are being performed to elucidate impacts on groundwater. These studies are not included in the references, which thus present a distorted view of the situation. (85)

3. The breakthrough analysis is said to be conservative because it did not consider lateral dispersion, adsorption, precipitation, or ion exchange. These phenomena must be considered to provide a realistic estimate of contaminant movement. (85)

4. Some of the values assumed for permeabilities are unrealistic, anisotropies in permeability are not considered, and the possibility of changes in permeability caused by acid seepage water should be considered. (38, 99)

5. The important parameters varied in the sensitivity analysis should be defined and their selection justified. (85)

6. Vertical dispersion was not considered in the model calculation; therefore, the breakthrough curves are too conservative. (85)

7. The breakthrough curve for iron cannot be used for all contaminants; it is applicable only to species that behave geochemically as does iron. (85)

8. Precipitation reactions, resulting from supersaturation as the tailings liquid evaporates, should have been considered in the staff's analysis. (85, 92)

9. An estimate of the length of the 2,000 meter wide belt of contaminate water should be made, and the lateral dispersion of the belt should be addressed. (74, 99)

10. The limits of the area in which groundwater contamination would exceed drinking water standards should be stated. (74)

11. The discussion of the movement of contaminants in seepage water is inadequate because the downgradient concentrations of various ions are not given specifically. (74, 99)

12. Under the discussion of radium and thorium, the staff elected a conservative value for the distribution coefficient of radium in nearly neutral water at 10 milliliters per gram. In a study at the Split Rock Mill, a distribution coefficient of 100 milliliters per gram for a neutral solution was used. (85, 99)

13. Under the discussion of selenium, a concentration of 32 milligrams per liter in the tailings pond water at a pH of 2 is assumed, with no reduction due to changing pH or ion exchange. At the Split Rock Mill, the tailings pond water contained 1.8 milligrams per liter of selenium at a pH of 1.95; the concentration of selenium changed by approximately an order of magnitude as the tailings pond water seeped through natural soils. (85)

14. The discussion on manganese suggests that in natural waters the concentration of manganese is typically less than one-half that of iron. At the Split Rock Mill in Wyoming manganese was present in far less than half the concentration of iron at specific points of measurement. (85)

15. The transport of water-soluble ions, such as those of uranium, molybdenum, etc., by groundwater should have been more completely treated since they represent hazards to human health (26, 51, 74, 85, 92, 99, 138).

16. Tables 6.3 and 6.4 should be expanded to include all of the elements listed in Table E-3.1. At a minimum, it should include molybdenum and uranium. (74)

17. The seepage discharge calculations are overconservative because neutralization of acidic seepage by basic soils and its impact on permeability is not taken into consideration. (85)

18. Various geochemical reactions could impede the movement of contaminants so that some of the conclusions about groundwater contamination may be overstated in the GEIS. In any event, this is a site-specific phenomenon. (85)

19. The statement that seepage of tailings solution could adversely affect groundwater quality is inappropriate in view of the site-specific nature of the problem. (85)

20. The site-specific nature of groundwater impacts renders general statements useless. (85)

21. Under the discussion of other possible contaminants, it is suggested that arsenic would not be affected by pH and could be expected to follow concentration curves shown in Figure E-3.1. At the Split Rock Mill, arsenic is affected by pH and various adsorption/ coprecipitation reactions. This is especially true when iron and manganese oxides precipitate in the interstices of natural soils. These oxides are a highly adsorbent material. (54, 85, 99)

22. In the conclusions to Appendix E, it is stated that no contamination of groundwater with radioactive material will occur because of seepage from the model mill tailings pond, but that contamination from sulfate, iron, manganese, selenium, and possibly other trace elements will occur. These predictions for iron, manganese, selenium, and arsenic are grossly overconservative and do not accurately reflect retardation by natural phenomena. (85)

Response: As repeatedly stated in the draft statement (for example, Sections 1.3, 6.2.4.2, 12.3.5 and 12.3.10, and Appendix E-Introduction), the geologic, hydrologic and geochemical factors and processes which control contaminant movement are extremely complex, variable and site-specific. Given this, the staff appropriately attempted in the GEIS only to generally characterize the nature and extent of potential tailings impoundment seepage impacts--(1) typical seepage chemistry is characterized; (2) mechanisms which control seepage and velocity of solutions in saturated and unsaturated zones are discussed; (3) physical and geochemical mechanisms which retard, disperse and generally work to reduce contaminant concentrations are discussed; and (4) numerical examples are given. With these discussions as background, alternatives for controlling seepage and contaminant transport are examined.

With regard to numerical examples, simple geometric models and simplifying assumptions were used. More complicated and sophisticated models are available and are most appropriately used where site specific data is available to support their use, and where indeed the increased capability of depicting complex spatial variations is needed. To apply them for the purposes of a generic study such as this is certainly not necessary. In fact, to carry out a complicated modeling effort for this generic study was considered to be inappropriate and unrealistic. Where simplifying assumptions have been made, such as ignoring vertical and horizontal dispersion in numerical examples, they are clearly identified and the general effect of the assumption is explained. In most cases, these assumptions were somewhat conservative in the sense that predicted impacts were maximized. Recognizing the variable nature of the problem, a parameter study was presented in Section 6.2.4.2.4 to illustrate the effect of varying assumptions concerning the factors which determine the extent to which impacts will occur.

The staff believes the range of values examined is reasonably representative of variation which will actually be observed from site to site for the factors considered. Notwithstanding this, however, the fact that commenters pointed to observations of values for parameters which in some cases are different from those contained in illustrative cases and general discussions in the GEIS is not surprising but is expected.

The fundamental conclusions of the GEIS regarding groundwater protection, which are fully supported by the analyses in Chapters 6, 9 and 12 in Appendix E, are simply that:

- significant detrimental impacts can occur to groundwater resources from the seepage from tailings impoundments;
- the precise extent to which these occur and the specific measures which should be employed to preclude them must be worked out on a site-specific basis;
- the most effective way to avoid problems is to control seepage to groundwater.

Appropriately, regulations are cast primarily in the form of performance objectives. Methods which must be considered in specific cases which assure seepage to groundwater is controlled to the maximum extent reasonably achievable are identified, the major objective being to assure that current or potential groundwater uses are preserved. The need for development of specific methods of tailings disposal on a site-specific basis is repeatedly made in the document; for example, see Sections 1.3, 12.3.1, 12.3.5, and 12.3.10. The points in the regulation related to groundwater do not hinge upon the precise value of any parameter or assumption in the numerical, illustrative cases presented in the GEIS. They are based on the broad analysis of the various aspects of the groundwater protection problem presented throughout the document and summarized in Chapter 12.

The following additional points are made in response to individual comments:

Comment 4: The staff recognizes the potential for deterioration of clay minerals under exposure to acid tailings solutions. See Section 9.3.4.2.1 discussion on research sponsored by NRC and others on this matter. Regulations (Criterion 5) specify that tests shall be conducted to confirm that clay liners, if proposed, will not be degraded by acid contact.

Comment 7: The discussion on iron recognizes geochemical processes will tend to reduce iron to very low levels (as low as 1 mg/L).

Comment 15 and 16: Both molybdenum and uranium to some extent can form mobile, anionic species which can be of concern. A text change has been made to discuss the geochemistry of uranium. The draft GEIS, p. E-20, adequately recognized molybdenum as a potential significant contaminant.

Comment 17: Tailings solution - soil interactions cannot be readily quantified in general terms. As described in Section 9.3.4.2.1, acid contact wtih soils can apparently result in either increase or decrease in permeability properties.

Comment 21: The staff recognizes that by adsorption, coprecipitation or other geochemical process, arsenic concentration will diminish in the neutral pH range to some extent. These processes do not appear to be nearly as strong for arsenic as for other elements discussed (see for example NUREG/CR 1494, June, 1980), however.

4.6 Other Nonradiological Environmental Impacts

> Comment: How can seed production (1.2×10^{10} J/ha) exceed primary production (5.2×10^{9} J/ha)? (26)

Response: This error has been corrected.

Comment: Impacts to herbivores through uptake of toxic elements by vegetation is discussed, but fails to mention the equally important uptake mode via windblown adsorption of particulates onto the outer surfaces of plants during the operational mode of the model mill. (26)

Response: An appropriate text change has been made.

Comment: The basis for the conclusion that the impacts from 12 mills on terrestrial and aquatic biota will reach an ultimate magnitude of 12 times the impact from a single mill should be given. (26)

Response: In the absence of data that would indicate some relationship between magnitude of impact and number of mills, the staff made the simplest, most reasonable assumption, i.e., that the relationship is linear.

Comment: This document contains few data that would enable us to judge impacts of mill construction on wildlife resources. It would appear that there have already been enough mills constructed so that NRC should be able to tell us in this document exactly what will happen to pronghorn and other groups of animal on a mill site. (40)

Response: Environmental impact assessment, even for real facilities, is not an exact science. Impacts to wildlife from construction are highly site-specific. Therefore, the staff sees little value in addressing such impacts in great detail in a generic assessment such as this.

Comment: The prairie falcon is not now, nor has it ever been, endangered as indicated in the document. (40)

Response: An appropriate change has been made in the text.

Comment: Twelve mills, if considered for Wyoming, would impact more than the 36-60 pronghorn estimated. These animals are not going to simply be displaced. It is more likely herd numbers will be reduced to accommodate the loss in habitat. (40)

Response: The text has been changed as appropriate.

Comment: There is no attempt to state in 6.2.6.1.4 the extent of the area over which forage would be contaminated by toxic elements. (74, 99)

Response: Using the assumptions for seepage at the model mill tailings pond site (see Appendix E), the area in which vegetation may be contaminated with potentially toxic elements is approximately 1.3 ha. This figure is based on the assumption that there will be a small surface seep (see Figure E-2.1) on the order of 0.1 L/sec. Surface seeps greater than this will result in larger areas of contamination. Contamination of foliage by wind-blown tailings will occur over the same area indicated for radioactive contaminants (see Appendix G).

Comment: There is inadequate consideration of effects on wildlife in general. Over what area would the maxima stated in Table 6.7 be likely to be exceeded? (74)

Response: The elements of concern in Table 6.7 would be arsenic, molybdenum, and selenium. Using assumptions for the model mill surface seepage, an area of 1.3 ha may be affected. However, as indicated in the footnote to Table 6.7, concentrations of these elements in the vegetation are dependent on many factors, including quantity of seepage.

Comment: In view of the fact that blowing tailings will continue to be a problem into the indefinite future, and the area impacted by blown tailings will expand, the potential for irretrievable commitment of large areas of land exists, with the concomitant irretrievable commitment of forage and wildlife resources. (74)

Response: Final regulation changes to be promulgated on the basis of this study will assure that blowing of tailings will not be a continuing problem. Furthermore, mandatory decontamination prior to facility decommissioning and license termination will be as necessary to return all areas except the tailings disposal site(s) back to unrestricted use. Dusting rates during operation will also be controlled to levels as low as reasonably achievable.

Comment: The increase in vehicular traffic resulting from employee travel to the mill may have significant adverse impacts on wildlife. Consideration should be given to requiring mill operators to bus workers to and from the mill, either from population centers or some convenient collection point, to mitigate such wildlife impacts. (74)

Response: The staff does not agree that bussing of employees should be considered as a generic requirement; impacts to wildlife from employee transportation to and from mills are often very minor and are always intensely site-specific. Such impacts, and measures to mitigate them, are considered as appropriate in the course of individual licensing reviews.

Comment: There are several errors in Table 4.8. Regional ecosystem characteristics can be better defined using a range of biomass, production and consumption values which are related to rainfall and/or temperature regimes. (86)

Response: Errors in Table 4.8 have been corrected. The data chosen are used merely as an illustration. Actual regional characteristics should be used, of course, at actual specific sites. Some details of the regions of interest are described in NUREG/CR-0597, a supplement to the GEIS.

Comment: There is some question that nonradiological impacts will be acceptable near mining and milling activities. Sufficient data is not available to confirm these statements. Theoretical studies do indicate that over a long period of time, unacceptable levels can occur. (99)

Response: As indicated in the summary, the staff expects no unacceptable nonradiological impacts under the conditions typified by the model mill, provided reasonable efforts are made to control tailings erosion and other potential sources of impacts discussed in the text. The staff agrees that under certain conditions, unacceptable impacts could occur, if not properly controlled.

Comment: Water degradation resulting from runoff carrying contaminants deposited on the land surface by wind, seepage and evaporation processes could occur. (26)

Response: An appropriate text change has been made.

Comment: Given the great uncertainties in assessing impacts to an ecosystem from uranium mining and milling activities, it was unexpected to read that there would be "no impacts to aquatic biota during the construction or postoperational phases." (26)

Response: The text has been revised to reflect a slight possibility for such impacts.

Comment: There are at least three mills obtaining process waters from rivers. This alternative and associated impact should be considered. (99)

Response: The detailed discussion is limited to the hypothetical model site which is assumed to have only ephemeral streams within the immediate area. Therefore, the mentioned alternative (use of rivers for process waters) has not been explicitly considered. Such a condition is rather atypical and is not considered appropriate for stipulation within the context of this generic assessment.

Comment: The socioeconomic impacts created by the influx of workers required to construct and operate a uranium mill are extremely site-specific, as well as being very difficult to evaluate. Such impacts could well make the envisioned 12-mill complex a very unrealistic illusion. (86)

Response: Information included herein is that which is necessary for the development of a sociocultural model for the analysis of potential impacts that might be regionally specific. Such a model does not reflect the reality expected in any given site-specific situation. Because the objectives of this generic study are so broad, the theoretical model that is employed does not reflect highly variable factors related to very localized areas.

Comment: Explanations as to why the base-to-service multiplier increases with operation of the uranium mill, and how the milling operation is expected to affect the region's economy should be provided. (99)

Response: Appendix F has been suitably amended.

> Comment: Describe the impacts expected from increasing urbanization connected with land loss due to mining and milling as they pertain to increased population and greater demands for social services. (110)

Response: Sociocultural changes that occur as population size and density increase, with associated alterations in the local settlement system, are complex. The particular manifestations that a changing social system may reflect are very site-specific and, thus, could not be very realistically addressed in this assessment. Detailed assessments of such impacts are appropriately reserved for site-specific evaluations. The staff considers, however, that urbanization in rural and undeveloped areas could potentially produce severe sociocultural impacts.

> Comment: Much more information on the affects on minority communities should be provided. (44, 138)

Response: In response to this comment, an addition has been made to Appendix F. However, it should be pointed out that the issue of minorities, particularly Native Americans, is considered in Section 6.3.7. The staff agrees that impacts to minority groups could be severe in site-specific situations. Some smaller sociocultural groups could be dispersed with a loss of cultural identity for group members, and a loss of cultural diversity for the general region.

4.7 Accidents and Consequences

> Comment: In the discussion of accidents in which contaminants reach a body of water, credit is taken for dilution without discussion of the increased human and animal populations put at risk. (74)

Response: A clarification has been made to the text.

> Comment: There is a discrepancy between NUREG-0511 and NUREG-0525 as to significance of the exposure(s) resulting from a worst case spill of yellowcake. (26)

Response: The impression that a "discrepancy" exists is apparently due to differences in the cited discussions concerning individual exposure and population exposure. Individual exposures, as stated in NUREG-0525, will not be so large as to produce a significant radiological effect. As stated in Summary Section 3.5 (page 9 of the Draft GEIS) population exposures from a worst-case spill in a relatively populated area could amount to as much as 10 times those occurring from routine mill releases.

> Comment: On page 2-4 of the draft GEIS it states "In no case examined was evidence obtained indicating contamination above EPA Drinking Water Standards." I am certain this is not true because following the Church Rock spill the licensee was supplying water to local Indians from 70 miles away. (28)

Response: The statement mentioned refers only to streams examined as part of the Phase I studies of inactive mill sites, in which Church Rock was not included.

> Comment: Some explanation should be given for the value of 6 cm for the highest monthly precipitation of the model site, for in the NURE regions, the range is from 9 to 52 cm. The maximum 24-hour precipitation of 1.5 cm is small compared to expected releases from heavy thunderstorms in the Southwest. (37, 74, 99)

Response: The 6 cm figure has been corrected to 12.3 cm, which is considered appropriate for the assumed semi-arid model region. The maximum 24-hour precipitation has been changed to one-half the monthly maximum, or 6 cm.

> Comment: Scrubbers in most modern mills operate under a variety of fail-safe controls. This reduces the probability of a total release, of the magnitude estimated, to the environment. (59, 85, 86)

Response: In the discussion, it is stated that the assumed accident is highly unlikely. This "worst case" was analyzed to assess what the maximum consequences could be; they are determined to be relatively inconsequential.

> Comment: The assumption that all of the yellowcake released in an air cleaning system failure or other accidents is in the respirable range is not borne out by experience. (59, 85, 86)

Response: The staff considers this conservative assumption to be appropriate for the purposes of evaluating potential consequences.

> Comment: The assumption that two days inventory of dry, unpackaged yellowcake would be on hand during a tornado event, and other associated assumptions, is highly unrealistic. (59)

Response: The staff considers such assumptions to be appropriate for the purposes of accident analysis, even though they represent uncommon conditions.

> Comment: A 24-hour duration of release following a yellowcake transportation spill is unrealistic because the spill would be covered with plastic sheeting within about 30 minutes. (59, 86)

Response: A purposefully conservative scenario is analyzed to ascertain maximum potential consequences. The staff does not consider a 24-hour release interval beyond the realm of possibility, particularly if truck personnel are disabled as a result of the accident.

> Comment: The discussion of potential release of tailings is based on the impoundment being located on a small ephemeral stream, far from a major free-flowing watercourse, with a convenient reservoir to impound escaping tailings liquids. Such a coincidence of safety factors does not occur in Colorado. A true worst case should be evaluated. (74, 92)

Response: The analysis was carried out on the basis of the assumed model site; however, a qualitative discussion was given for the actual uranium milling regions (Sec. 7.1.6.3.2). Impacts could, of course, be much more severe under other conditions. The potential for such impacts is routinely addressed in detail in individual licensing reviews conducted by the NRC, on a site-specific basis. Under the provisions of the UMTRCA and the Commission regulation changes implementing the conclusions of this document, such reviews will also be required in Agreement States. (See Section 12.3.10)

> Comment: Although NRC may "expect" that the consequences of a slurry transport accident would be less severe than the consequences of a yellowcake transport accident, NRC has not demonstrated this. (85)

Response: The staff concurs with this comment. Indeed, certain conditions could be assumed which would lead to the conclusion that a slurry spill would have worse consequences. However, our considered judgment is that consequences of a dry spill, per pound of yellowcake, would likely be worse.

> Comment: It is inappropriate to use the maximum hypothetical accident for each potential accident analyzed involving milling operations. (86)

Response: The purpose of such evaluations is to assess maximum potential consequences; therefore, the staff considers such analyses to be appropriate.

> Comment: Because operating and cost consequences of a fire in the solvent extraction circuit are so severe, all mills are fitted with fire suppression apparatus that is carefully and continuously checked; occurrence frequency is less than one per 100 years. (86)

Response: The expected frequency of occurrence is given as 4 per 10,000 years (based on chemical industry data). The historical frequency for the uranium milling industry is, as suggested, less than one per 100 years of mill operation.

> Comment: According to Table 7.2, the sulfate concentration would have to be diluted by more than a factor of 100 in the reservoir to meet water quality standards for livestock. (92)

Response: The dilution factor in the reservoir would be approximately 1,000.

> Comment: The only costs quoted for cleaning up a spill are those for scraping the reservoir; this does not seem to be a complete response to a potentially serious threat. (92, 99)

Response: The cost estimates given are for scraping the reservoir ($470,000) and transporting the tailings back to the impoundment ($480,000). These estimates are based on costs computed for moving the Vitro pile in Salt Lake City. Because of the urban environment, the Vitro costs are likely to be higher than for a less populated area. Inasmuch as the reservoir should be returned nearly to its original condition, the postulated action appears to be adequate. Although these cost estimates are considered reasonable, based on the site characteristics and other conditions assumed, preliminary data from the cleanup necessitated by the Church Rock dam failure indicate costs could indeed be higher.

> Comment: The impacts of major unexpected tailings slurry releases should be shown more adequately in Chapter 7. (92)

Response: The staff considers the scope and level of detail of the discussion in Chapter 7 to be appropriate, given the highly site-specific nature of such impacts. As indicated above, such impacts are duly considered on a site-specific basis in the course of individual licensing reviews. (See Section 12.3.10.)

> Comment: In Section 7.1.5.1, the increased relative frequency of transportation accidents on bridges should be incorporated and more recent data should be used to estimate the length of roadway under federal control. (97)

Response: For reasons stated in Section 7.1.5.1, the staff does not consider it appropriate to assign an increased accident frequency to travel over bridges (i.e., most deep water bridges are heavily protected, and they are the only ones of concern with respect to substantial product immersion following a yellowcake transportation accident). Newer data would not likely indicate a significant revision to the estimated ratio of total bridge and highway miles.

> Comment: The statement that most failures in tailings distribution piping would result in release of the slurry to the tailings pond is inconsistent with Table 7.1, which shows that six out of seven pipeline failures resulted in release to a watercourse. (99)

Response: Those failures which resulted in a release to the tailings pond are not listed in Table 7.1.

> Comment: Reuseable containers smaller and stronger than 55-gallon drums should be considered for mitigating the increasing potential for yellowcake dispersal in transportation accidents. (99)

Response: The staffs of the NRC and the U.S. Dept. of Transportation have recently published, in a separate action, a comprehensive review and assessment of yellowcake packaging requirements (see NUREG-0535). The general conclusion of this study was that present requirements could not be cost-effectively strengthened.

> Comment: Dose commitments from yellowcake truck accidents in urban areas should be considered. (99)

Response: The consequences of an urban area yellowcake accident are provided in Section 7.1.6.5.1.

> Comment: The GEIS does not consider the potential effects of a hurricane on an operating mill and its associated tailings impoundment. (135)

Response: Hurricanes are not considered explicitly in this generic statement because they are experienced only in NURE Region C, whereas tornadoes occur in all regions. Hurricane impacts would be similar to those otherwise evaluated as potential results of flooding, tornadoes, dam failure, etc.

5.0 ALTERNATIVES EVALUATIONS

5.1 Definition of Alternatives

> Comment: The liquid portion of the tailings slurry could be disposed by deep brine well injection. (21)

Response: Although this method would be acceptable to the staff under appropriate conditions, and is current practice for some solution mining operations, it has not been utilized to date with respect to conventional milling operations. Acceptability of this approach is highly site-specific, which is why it is not explicitly treated in the context of this generic statement. The matter can be adequately addressed on a site-specific basis in the manner discussed in Section 12.3.10. Also, the staff is not so much concerned with establishing acceptable methods for disposal of the liquid fraction of the tailings slurry as with the solids, since liquids are readily disposed by natural evaporation in most instances.

> Comment: A preferable alternate disposal location would be at the top of a shallow canyon where a downstream dam would be easy to construct and wind factors could be minimized. (21)

Response: The staff agrees with this comment to the extent that it recognizes the benefits of minimizing upstream drainage area and maximizing natural wind protection, which are addressed explicitly in the staff's proposed and final regulations.

> Comment: With regard to the option of lining before backfilling the pit as in Alternative 2, it is doubtful that a clay liner could be applied to pit walls below the water table. If this were feasible, the integrity of the liner probably could not be maintained once the groundwater gradient was reestablished. (43)

Response: The staff agrees that groundwater problems could make lining before backfilling inappropriate. The other option, that of backfilling before lining, might then be appropriate.

> Comment: The draft statement fails to evaluate the full range of reasonable alternatives that would allow greater utilization of the preferred option of below-grade disposal. In particular, the draft GEIS omits serious consideration of the following two categories of alternatives: (1) transporting dried tailings to other individual sites or to a regional repository for several mills, and (2) siting new mills only where the prime option can be utilized. (47)

Response: In general, the staff does not consider that detailed appraisal is warranted with respect to alternatives involving transportation of huge volumes of tailings over large distances. Such alternatives involve very large and avoidable environmental and economic impacts. Also, the staff has specified in the final regulations those minimum performance standards which are necessary to avoid significant adverse environmental impacts, whether applied to individual sites, regional repositories, or above grade or below grade disposal schemes. The staff considers that compliance with these standards will assure appropriate protection of the public health, safety, and the environment without unduly limiting the ability of the industry to operate in a manner which is both environmentally and economically sound. In this respect, the staff's regulations have been purposefully stated so as to allow licensees flexibility with regard to the specific details of their tailings management programs, so long as the staff's minimum performance objectives are met. The final regulations have been clarified to further emphasize the paramount importance of siting and the need to seriously examine sites amenable to below grade burial (see Sections 12.3.2 and 12.3.3).

> Comment: A windbreak could be constructed around the ore unloading area but without special design its wake effect could create more of a dust problem than originally existed. It would also serve as a snow fence and would cause deep drifting of snow across the entire ore pad. (59, 86)

Response: There are many ways in which fences can be used to control wind-blown particulate matter. Careful design may be necessary to insure wake effects would not be substantial. Snow drifting would not be a problem where annual snowfall is negligible, as is the case in most of the southwest uranium processing areas.

> Comment: An enclosed ore warehouse would be unacceptable because of the lack of natural atmospheric dilution provided for radon and uranium dusts, in addition to excessive costs. (59, 86)

Response: The staff concurs; as previously stated in the draft GEIS, sprinkling or chemical stabilization are considered preferable means of controlling dusting of uranium ore.

> Comment: The ore crushing and grinding circuit is more site-specific than is indicated in the GEIS. Not all ores can be ground efficiently in a semiautogenous (SAG) mill. Where SAG grinding is effective, industrial hygiene is improved. (59, 86)

Response: The staff recognizes that the effectiveness of SAG grinding is dependent on the properties of the ore; because of this, the staff concluded in the draft GEIS that the practicability of SAG grinding should be evaluated but not necessarily required in all cases (see Section 12.2.1). Most ores, however, are very readily processed via SAG grinding.

> Comment: Consideration should be given to the use of the large amounts of open pit mine waste available to create an above-grade basin consistent with Figure 8.9 and the elements of this alternative. It may not be necessary to locate a suitable "natural" topographic feature as there may be sufficient waste to create one. (59)

Response: Under appropriate site-specific conditions, the staff would agree. It is for this reason that the staff has not proposed a complete prohibition of above grade disposal.

> Comment: An evaluation of the total impact of ore transportation versus the impact of mill proliferation is needed so that regulatory agencies would have a basis for deciding whether or not to encourage the construction of a few large mills versus a multitude of smaller ones. (84)

Response: Such a study might be useful, on a regional basis, for the reason stated. However, regulatory agencies are not in a position to directly influence the capacity of uranium milling facilities proposed by private industry. Authority is limited to approval or denial of proposals offered, on the basis of compliance with applicable regulations, standards, guidelines, and staff policies.

> Comment: An aboveground tailings pile provided with ten feet of cover and revegetated, as in Alternative 1, will not necessarily be so susceptible to erosion that it will rapidly deteriorate. If the vegetative cover is adequate, this is unlikely to be the case. Furthermore, riprap could be applied to control erosion, if necessary. (85, 86)

Response: The staff's rejection of Alternative 1 is based on the conclusion that satisfactory long-term stability would not, in that case, be provided. In other situations, where satisfactory long-term surface erosion protection could be provided, by vegetation, rock cover, or other means, a different conclusion might be reached. Alternative 6, for example, represents a case where siting features and design measures indicate that an above grade disposal program would be acceptable.

> Comment: The cost of covering the tailings from the nitric acid leach mill are based on 1.50 meters of cover, costing $1.25 million dollars. This is inconsistent with 1) the proposed minimum cover thickness of 3 meters (thus, costs of this alternative could be more than double those presented; and 2) statements throughout the GEIS that the 3-meter minimum cover thickness was not determined by radiological effects, but to prevent accidental intrusion (burrowing animals, root intrusion, erosion). (86)

Response: In comparing the costs of the alternatives, only those costs required to reduce the radon flux to acceptable levels were considered. In the case of Alternative 9, the omitted incremental cost to implace a full 3-meter cover is about $2.1 million (at $1.75 per cubic meter of earth cover). This additional cost is relatively small compared to total costs for this alternative. The costs of meeting the three meter requirement are discussed in App. K-6. A less than 3-meter cover thickness was specified due to the marked overall reduction in the hazards of nitric acid leach tailings.

> Comment: The amount of radon released during the milling process is so small a percentage of that released in the total operation as to make charcoal adsorber delay traps for radon control unnecessary, especially since occupational exposures already are well within the specified limits. (86)

Response: The staff agrees with the thrust of this comment and has clearly indicated this in both the draft and final versions of this document (see Section 8.2.1).

> Comment: Pricing of the yellowcake scrubbers is given at $38,000 - $67,000 based upon a 1,700 M^3/minute scrubber. This is a gross oversizing, with a volume more than 60,000 cfm. A typical dryer should require about 4,000 cfm and the yellowcake dryer enclosure

and packaging area would require an additional 10,000 acfm of ventilation. (86)

Response: The required size of a ventilating system is very dependent on the air-tightness of the ventilated area enclosure. The staff considers this comment to be valid, assuming the drying and packaging areas are tightly enclosed. However, most mill structures are not very tightly enclosed.

Comment: A complete cost/benefit analysis showing the costs of deep burial and/or encasement of milling wastes must be added to the final GEIS. Furthermore, the staff must show that all potential mill tailings disposal techniques will not cause violation of the Resource Conservation and Recover Act (RCRA). (96)

Response: The staff considers that the presented evaluations of deep disposal and fixation options need no further expansion. As stated in Section 13.5.2, staff disposal requirements must only be consistent, to the maximum extent practicable, with RCRA requirements for other hazardous wastes. The staff has confirmed that its requirements are consistent, as appropriate, through consultation with EPA.

Comment: Alternative 7 should be enlarged to consider the possibility of using coal for heat and the resulting ash for cement. (97)

Response: The staff does not consider this permutation of sufficient practicality or import as to merit explicit evaluation, given the staff's overall conclusions about Alternative 7 in relation to the other alternatives.

Comment: With respect to Figure 5.2, other alternatives such as the Eluex process should also be presented. (99)

Response: Other process alternatives, including the Eluex process, are described in Appendix B.

Comment: Evaporation of clarified solutions in small, shallow and lined evaporation ponds should be addressed. Treatment of tailings water to remove interferences to increase water recycle should also be addressed in this section. A good reference for these processes is the EPA environmental study on uranium mills prepared by TRW. (99)

Response: The suggested reference has been included in this document. Also, the need for maximizing recycle of solutions is clearly addressed in the final regulations.

Comment: Large open pits due to copper mining are near some uranium mining and milling areas. (99)

Response: Although this may indeed be the case, the comments made in Section 8.3.5.1 remain valid. Because of the generic nature of this assessment, individual site-specific cases have not been examined.

Comment: Old open pit mines still have to be filled. Reprocessing of old tailings is also possible. In regard to the acceptance of the repository by nearby communities, a similar concern for tailings piles placed aboveground or at shallow depths can also arise. Most mines are quite isolated, however. (99)

Response: Despite the validity of these comments, the staff remains convinced that disposal in existing deep open pit mines, as discussed in Section 8.3.5.1, is not appropriate for inclusion in this document as a generically available alternative.

Comment: It should be noted that disposal of tailings in a deep mine would eliminate future recovery of metal values in the tailings. (99)

Response: The staff considers loss of economic reprocessing to be an obvious aspect of deep mine disposal, and a high-probability result of any final tailings disposal program. This was stated in Section 9.3.3.

Comment: There is no consideration of the alternative where tailings are dewatered and the solid and liquid fractions are handled separately, nor is the percent recycle of process water given. There is also no mention of more efficient water use within the mill. A recent survey by TRW for EPA Effluent Guidelines Division shows a wide variation in the volume of water used per ton of ore. This variation and its implications are not discussed in this document. (99)

Response: As clearly stated in Section 12.3.5, the issue of water conservation is important from both the points of view of minimizing consumptive use of water and of reducing tailings liquor seepage potential. As indicated by the EPA survey mentioned, methods for conservation are varied and site-specific. Detailed evaluation of them was beyond the scope of the GEIS; however, as discussed in Section 12.2, regulations require that methods for recycle of solutions and conservation of water must be evaluated at each site.

Comment: The sands washing proposed in both Alternatives 7 and 8 is not worthwhile, since it would not result in a significant decrease in the radioactivity contamination of sands prior to final placement. (118)

Response: The staff considers disposal of washed sands to be appropriate in Alternatives 7 and 8 for purposes other than radiation protection. However, the staff has determined that these are not viable alternatives (see Sec. 12.3.3.3). Before any tailings could be placed in contact with groundwater, it would have to be demonstrated that no degradation of actual or potential uses would result.

Comment: Returning tailings to the ore mine should be considered in conjunction with tailings decontamination via nitric acid leaching, especially in places like the Grants Mineral Belt where clay will have to be shipped in. (133)

Response: The possibility of employing this combination of alternatives is present. However, the staff is unable to give detailed consideration to all possible permutations and combinations of alternatives for the reasons stated in Section 8.4.1. Also, nitric acid leaching has been determined to be prohibitively expensive for routine commercial applications, as well as suffer from other drawbacks as discussed in Section 12.3.3.3.

Comment: Deep well injection of tailings slurry may be worth further study. (133)

Response: Under proper circumstances, disposal via this method may be environmentally acceptable. This method of disposal has been approved for some in situ uranium extraction facilities. Further study of a developmental nature, as suggested, would be appropriately performed by private industry or by the U.S. Department of Energy.

5.2 Cost Estimates

Comment: The unit costs given in Table K-4.1 of the GEIS and elsewhere, are too low. (52, 55, 59, 85, 86, 99)

Response: The staff believes that the unit costs given in the draft GEIS represent realistic cost estimates of the unit operations described. However, due to the rapidly escalating prices of petroleum products and construction costs since the preparation of the draft (1978), the staff has updated and revised almost all cost estimates by re-evaluating the fundamental cost elements for each unit operation. The new unit costs appear to be basically compatible with the prior estimates given in the draft, based on applicant submittals, when escalations in costs are applied to the 1978 values. The revised costs are presented in Chapter 11 and Appendix K. The source and derivation of the cost estimates are given in Appendix K-8, "Cost Bases."

Comment: The costs of various emission control equipment have been underestimated. (59, 77, 85, 86)

Response: The staff considers the cost estimates for these items to be reasonable, although such estimates would appear to be low due to the recently high rates of inflation. Costs for these items, as well as others, have been updated to account for inflation since 1978. Generally, these updated costs agree with data obtained through a survey of the industry (conducted by Commenter 86). (Also see Appendix K-8.)

Comment: The costs of implementing the alternatives are underestimated. (47, 59, 85, 86, 90)

Response: The staff believes that the cost estimates given in the draft GEIS reflect representative costs for the alternatives examined, based on the specific unit operations described. Costs may vary for each alternative depending on which unit operations are included and how such operations are performed, and on the accuracy of the particular unit costs for each operation. The staff has attempted to identify representative and consistent unit operations for each alternative, while recognizing that other possibilities exist for implementing disposal operations. In revising the draft GEIS, the staff has reviewed the alternatives in depth to assure that reasonable unit operations have been adequately considered. Furthermore, costs for the individual unit operations have been updated to account for the rapidly escalating costs for energy and petroleum products. Costs for implementing the alternatives have, therefore, been revised, both to reflect updated unit costs and reasonable combinations of unit operations. (Also see Appendix K-8.)

> Comment: The cost of the model mill itself is underestimated. (59, 86)

Response: As was stated in Appendix K of the draft GEIS (page K-4), \$7.1 million (now \$8.6 million) is the cost of the mill equipment. Entire mill costs (1800 MT/day capacity), as given in Ref. 1 of this section, are: \$21.38 million (Texas), \$24.09 million (New Mexico), and \$26.47 million (Wyoming); 1980 costs would be about \$25, \$28, and \$31 million, respectively. The staff believes these costs have been adequately evaluated.

> Comment: The costs of decommissioning a uranium mill are understated. The GEIS assumption that buildings and machinery can be removed at no cost to the operator is incorrect, and the costs of the operations involved in decommissioning are underestimated. (59, 70, 85, 86)

Response: With respect to the first point, it appears that this assumption may be valid in some cases, invalid in others. With respect to the second, decommissioning costs are consistent with those provided by applicants for licensing purposes. While these costs have not been completely reevaluated, as were alternative tailings disposal costs, the staff believes these cost estimates are indicative of the relative magnitude of decommissioning costs. The general costs given in Table 11.13 have been inflation-escalated to 1980.

5.3 Costs Not Included

> Comment: Various costs incurred in controlling emissions were neglected. The neglected costs are those that would have to be incurred if other equipment than that assumed in the GEIS were used for control, such as: (1) "sprinkling" would have to be done with "water cannons," (2) industrial hygiene in dry grinding areas requires more equipment, and (3) "demisters" should be used in place of HEPA filters to recover U_3O_8 dust. (86)

Response: In assessing the costs of operations for controlling emissions, the staff considered equipment that could be utilized under representative situations. The staff acknowledges that a mill operator may, for many reasons, choose equipment other than that postulated in the GEIS. Use of a demister, for example, appears to be advantageous from many viewpoints. In general, cost estimates for emission control are considered to be representative of what would be experienced regardless of specific controls used.

> Comment: Costs of various operations involved in implementation of tailings management alternatives were neglected. (59, 77, 85, 86)

Response: The reasonably good agreement between the updated staff estimates and industry estimates provided by Commenter 86 indicates that most of the operations required have been adequately costed.

> Comment: The cost of money is not considered with the GEIS. (55, 85)

Response: There are two aspects of this: (1) escalation of costs (inflation), and (2) interest costs. Cost escalation is treated in the GEIS and costs have been updated to early 1980. The staff realizes that costs will continue to escalate (as is stated in several places in the GEIS) but does not speculate as to the future rate of escalation. Interest charges are real costs, but vary so from operation to operation that the staff sees no sound way to treat these costs realistically on a generic basis. Cost estimates, as presented without interest and inflation, are adequate for the cost-benefit evaluations of alternatives which are treated on a common basis.

> Comment: The administrative and other costs of abiding by various regulatory programs are not considered in the GEIS. (85)

Response: This is correct in most cases (it is included in basic mill construction costs), as the staff considers such costs to be unavoidable.

> Comment: Contingency costs are not included, as is usual and appropriate. (55, 85, 86)

Response: Contingency costs (in the range of 15-20% of the quoted total costs) may be explicitly added, where appropriate, to estimated costs. Appendix K-8 describes the bases used by the staff in estimating costs.

> Comment: The increasing cost of energy is neglected in costing out the alternatives. (85)

Response: This cost is recognized and is a major component in the escalation of costs from 1978 to 1980.

> Comment: The cost, in energy, of implementing the tailings management alternatives is neglected. (85)

Response: This cost is explicitly stated only in terms of the dollars required to purchase the energy, but the staff is aware that energy will be expended to implement the alternatives. The staff is also aware that such expenditure is a small fraction of the total energy expended in extracting uranium from the ore deposit.

5.4 Estimated Impacts of Alternatives

> Comment: The discussion in the draft GEIS (page 12-8) mentions, without elaboration, that the nitrates resulting from nitric acid leaching pose a more severe environmental problem than anion species formed from conventional processes. The draft GEIS should have presented a more detailed analysis of this problem. (47)

Response: References 12 and 13, annotated in the list of references for Chapter 8 of the draft GEIS, discuss the problems to which the comment refers. The staff considers that the presence of nitrates in the tailings solution resulting from nitric acid leaching precludes any conventional approach to their disposal.

> Comment: There is no mention of the extent to which the alternative of wetting tailings surfaces to provide dust control may also contribute to groundwater contamination problems. (74, 84, 86)

Response: Sufficient water to moisten dry tailings surfaces is all that is required. It is not necessary to drench exposed tailings surfaces. Thus, with proper application, it is unlikely that any significant amount of water used in dust suppression would reach the saturation zone before evaporating.

> Comment: Since there is no discussion either here or in Table 6.3 to which this discussion refers, of groundwater contamination from (1) uranium, (b) molybdenum, or (c) many of the other substances listed in Table E-3.1, this discussion is clearly inadequate. The movement of radioactive contaminants, i.e., uranium, would be more than the 0.26 m stated for radium by two orders of magnitude. (74)

Response: The staff recognizes the fact that under certain conditions, uranium and molybdenum can be mobile. See response to this same issue in the section on groundwater impacts above, Section 4.5.

> Comment: The conclusion in 9.3.4.2.4 is not supported. At 9-17, it is stated: "...the concentration of all substances in groundwater is expected to be roughly the same as shown in Table 6.3, except for selenium, sulfate, arsenic, and other anions not affected by pH." Selenium, sulfate, arsenic, etc., would increase the concentrations shown in column B of Table E-3.1 by a factor of 3.6. Thus, we find:

	Tailings Liquid	Maximum Permissible Concentration
Selenium	106.8 mg/L	0.01 mg/L
Molybdenum	576 mg/L	None
U-nat	31,104 pCi/L	550 pCi/L

If we use the same assumption used in earlier parts of the GEIS, the water in the well 2 km from the mill site will be contaminated with, for example, 10,000 times the maximum permissible concentration of selenium. Using the same assumption, very high uranium values will be found at that location relatively soon, since it moves "at about the same velocity as water." There is no reason given for a belief that it will be significantly dispersed or diluted. (74)

Response: While under some conditions these elements will form anionic species which are very mobile, laboratory tests and empirical observations at existing sites indicate that they will be attenuated when seepage is neutralized by underlying soils. Actual concentrations will be significantly less than those referred to in the comment. They will remain more mobile than other elements such as radium and thorium which readily sorb into underlying soil. Thus, there is need for the seepage control measures and comprehensive geohydrologic data gathering and analyses called for by regulation.

Comment: Water sprinklers would have to be drained and protected from freezing in the fall, and would be inoperable until spring. The excess moisture would be a severe operational problem in the winter because the ore stockpiles would freeze into a solid mass. (86)

Response: Water spraying can be an effective way to control dusting from ore pads, if used properly. Only surface moisture need be maintained, which can be accomplished without bulk saturation. It is not the only available control method, and will not always be the most effective. The staff's final regulations recognize this.

Comment: Dry fabric filters offer little operating cost advantage compared to wet filters. They are troublesome in moist or wet climates, and can cause great problems when it is necessary to do maintenance work in replacing the bags. They might offer some advantages in severely cold climates. (86)

Response: If properly designed, installed, and operated, dry fabric filters are among the most effective of particulate control methods, but are not always the most cost-effective. Proper bag maintenance is critical to effective use.

Comment: The draft GEIS says, "In areas where acid solutions are handled, uranium and its decay products have penetrated concrete foundations and the earth below to a depth of a few meters. The contaminated foundations and dirt must be removed regardless of whether the entire building is to be reused or removed."

This approach effectively prohibits future reuse of mill buildings. With all this extra excavation, there will be a significant quantity of additional material to place in the tailings pond or other disposal sites. Also, no cost allowance was included for finding, developing, and reclaiming a source for the borrow material needed to fill onsite excavations. (86)

Response: If the problem of decommissioning is recognized at the time of construction, mill buildings could be designed so as to be removed from potentially contaminated foundations. The foundations could then be covered, and buildings re-erected on new foundations. Also, recognition of the problem at the outset would facilitate the accumulation of appropriate fill and topsoil over the mill lifetime.

Comment: In the assessment of the environmental impact, far too little attention has been paid to potential accidents. On page 9-38, intrusions into mill tailings by people digging basements or wells have been briefly mentioned and discounted, since "they do not lend themselves to prediction." This is clearly not an argument

> to be used in an impact statement, in particular since scenarios of this kind can very likely lead to serious health risks. A far more thorough discussion of these scenarios is required. (90)

Response: The questioned statement is a matter of fact, not an argument. Potential intrusion scenarios are discussed more for perspective than as a basis for quantitative risk evaluation, and also to support a 3-meter minimum cover thickness to provide adequate long-term physical isolation. Also, Section 12.3.4.3 assessed this in connection with individual risk. Worst case intrusion dose estimates are given in Section 9.4.2 ("Type 2 land use scenario").

5.5 Alternatives Impacts Not Included

> Comment: The alternative of switching from the current disposal area to a new location will require a reclamation plan with associated controls to be implemented at each location. (21)

Response: The staff agrees that dual reclamation plans and controls would be required if tailings were moved from one site to another. To be meaningful, the plans and controls would have to be site-specific (for both sites) and would be very difficult, if not impossible, to treat in a generic statement. Transportation problems alone would be so route and method specific that treatment of them, generically, would be impossible. Applicability of the final regulations to existing sites is addressed in Section 12.4 and in Appendix K-9.

> Comment: The document should explicitly state the potential long-term health effects of leaving mill tailings unprotected. One suggested method for dealing with the uncertainties of making such an estimate would be to construct scenarios which allow for possible future events, both human and natural. The results should be a range of estimates which would give a more complete understanding of the risk involved. (34)

Response: In Chapter 6 far-field continental radon dose commitments and health effects are estimated. Section 6.4 is titled "Continental Radiological Impacts." This information, and other information pertaining to base case long-term groundwater impacts adequately characterize the potential long-term impacts of unprotected tailings. Section 9.4.2 explicitly evaluates consequences of intrusion. Section 12.6 also discusses consequence of failures over the long term.

> Comment: What risks are associated with potential human activities at or near the site? (34)

Response: Near-field (within 50 km) environmental impacts are discussed in Section 6.2 of the GEIS. The environmental effects of accidents are discussed in Chapter 7. Also see Section 9.4.2 (and 12.3.4.3) where worst-case intrusion events are evaluated.

> Comment: Alternative 7 (fixing tails with cement or asphalt) and Alternative 9 (nitric acid leaching) were unfairly rejected in the GEIS. These two methods have the greatest potential for reducing environmental effects from tailings. (47)

Response: In Chapter 12, the staff pointed out the differences between Alternatives 7 and 9 and the other alternatives. The staff does not consider that a rejection of Alternatives 7 and 9 was implied; the statement was made "...that the industry cannot reasonably be required to adopt (these) alternatives...". (In particular, see Section 12.3.3.3.)

> Comment: There is much practical adverse experience with disposal problems of tailings located at the surface. This experience further indicates that Alternatives 7 and 9 are advantageous. (47)

Response: The staff examined work done on old tailings piles to determine their status in 1978. This work is briefly reported in Chapter 2. Twenty-two old inactive sites were examined; at all of those sites, there were some signs of wind and water erosion. This adverse experience indicates the general necessity of providing adequate physical isolation. In the staff's view, this protection can be provided by any of a wide range of final disposal options, including Alternatives 7 and 9, if sufficient care is taken in siting, design and implementation. The type of reclamation found acceptable by the staff, and required by the final regulations associated with this document, basically consists of a class of schemes resulting in a passive monitoring mode, which is a marked departure from past practice (see Sections 9.4.1 and 12.3.3).

> Comment: Separated slimes pose greater containment and reclamation problems than do ordinary tailings. Both the advantages and disadvantages of slime-sand separation should be discussed in the final GEIS. (59)

Response: Reference 2 to draft GEIS Chapter 8 (Sears, et al.) discusses the relative merits of sand-slime separation in some detail. The staff agrees with the comment, to the extent that containment can be more problematical if sands and slimes are separated, if improperly controlled. If special treatment, such as described in Alternatives 7 and 8, was given slimes (which contain hazardous elements in the greatest concentration), overall containment of tailings might be improved.

> Comment: The GEIS assumes that mine waste and overburden will be appropriate as tailings cover material. However, mechanical characteristics and radionuclide content of some mine wastes will preclude its use as cover material, obliging the operator to resort to a borrow pit. The environmental impacts and reclamation costs associated with stripping tremendous volumes of earth (over 3 million cubic meters for the model mill) are not addressed anywhere in the GEIS. (59, 60, 84, 86)

Response: For those mills that are associated with surface mines, the staff believes that there would indeed be ample opportunity over the lifetime of the mill to accumulate sufficient cover material (about 3×10^6 m^3 for the model mill). A 0.5 x 0.5 x 0.01-mile open pit involves the excavation of about 10×10^6 m^3 of material. In the case of underground mines, where tails are not returned to the mine (return is rare), a borrow area would indeed be required (unless tailings were disposed below grade and pit or other excavation produced sufficient material). The potential environmental impacts of stripping a borrow pit are addressed in Sec. 9.3.8.4. In considering alternatives that might require a borrow pit, the staff recognized that such a pit would have to be reclaimed so that there are no significant continuing environmental effects, such as continuing loss of soil, although there would be temporary effects during stripping operations. The monetary costs of obtaining cover material from a borrow pit, and reclaiming the pit, are taken into account in computing costs for alternatives (Appendix K).

> Comment: Cover material acquisition may require the transport of material from distant locations depending on local availability, and the interpretation of "elevated levels of radium." The impacts of this option are not considered in the draft GEIS. (73, 84, 86)

Response: Relative proximity of mine and mill is a typical condition and represents an appropriate assumption to make in a generic statement such as this. Cover acquisition at large distances from the tailings would indeed change the costs, and increase the impacts, of obtaining and placing adequate cover materials over tailings. One of the reasons for presenting the impacts (environmental and economic) in the way they were presented, in terms of unit costs (see App. K), is to allow calculation of costs as desired by the reader, since the staff could not conceivably address in detail all possible permutations. The staff considers that adequate protection must be afforded as practicable, regardless of total cost, as mandated by the Uranium Mill Tailings Radiation Control Act of 1978 (PL 95-604), as amended. Environmental impacts associated with obtaining cover material, from an offsite borrow area 10 miles away, are evaluated in Section 9.3.8.4.

> Comment: Section 9.3.4.2.3 does not address the potential water-use impacts of finding an alternative source of supply for users of underground water whose supplies will become contaminated, as described in the GEIS, (e.g., Table 6.3, with respect to selenium). The irretrievable commitment of resources caused by groundwater contamination should be disclosed. There is an irretrievable commitment (a) of valuable subsurface waters; (b) of surface waters, which will be contaminated by subsurface waters; and (c) land, because the cost of importing water into this large contaminated area may be prohibitively expensive. (74)

Response: The staff has pointed out the variability associated with estimation of hydrogeologic movements of ions in Chapter 6 and App. E. Such predictions are uncertain, particularly over large time spans. Selenium is indeed indicated to be over EPA standards in the base case. Moreover, the potential for such unacceptable contamination and the resulting impacts are clearly indicated in Chapter 6, as are the estimated times for arrival of selenium at various distances downstream (see Table 6.3). It is partly with these uncertainties in mind that seepage control is called for in Section 12.3.5. Seepage can be greatly reduced by implementation of any of the methods identified in Section 12.2.1, which include the use of bottom liners or other means to control seepage to acceptably low levels, as required by the staff's final regulations.

> Comment: Lime neutralization would help in retaining the clay seal. Complete precipitation of the metals listed would not be assured by raising the pH to 7. A ph of 10 may be necessary. The potential for long-term containment of seepage thus would be much greater and the potential impacts of overflows or spills would be less. A two-stage process would be recommended with the first stage raising the pH to 4.5 with limestone followed by aeration and settling. The pH can then be raised to a pH of 10 by addition of lime. (99)

Response: The staff generally agrees with these comments and has incorporated an expanded discussion and treatment of the process of neutralization in this final GEIS. See Chapter 8, Appendix B, and Appendix K. Also see Sec. 12.3.5 which further discusses the issue of neutralization.

> Comment: Net evaporation rates in Ambrosia Lake, New Mexico are as high as 48 inches per year. (99)

Response: The staff appreciates the relevance of this comment as related to its discussion of evaporation rates in Chapters 8 and 9 of the GEIS.

> Comment: Minimizing seepage through the use of bottom liners increases the risks and impacts of potential impoundment failure, and greatly increases the required drying time and difficulties associated with reclamation. The real objective should be to minimize the migration of contaminants into usable groundwater, rather than just minimizing seepage in all cases. (59)

Response: The relative merits and disadvantages of synthetic and natural liners are discussed in Chapters 11 and 12 of the GEIS, and also in Appendix K. The staff considers that there is no acceptable and reliable substitute for the barrier approach in restricting contaminant migration from conventionally managed tailings piles. Physical and mechancial problems associated with reclamation can be obviated by in-place dewatering, and impoundment strength can be engineered as required.

> Comment: Kerr-McGee, and other mill operators in similar circumstances, will have to overcome great difficulties and incur enormous expenses in providing a 3-meter thick earth cover as required by proposed regulations, since ore feed is predominantly from underground mines and the surrounding environs do not offer plentiful supplies of appropriate cover materials. (118)

Response: The staff appreciates the difficulties and costs involved in obtaining sufficient earth cover, as well as the potential environmental impacts of stripping cover material layers from large areas of undisturbed land. However, the staff sees no alternative to requiring reclamation in such a way as to provide adequate long-term physical isolation of the noxious chemicals and massive quantities of radioactive materials present in uranium mill tailings. The staff considers the impacts of cover material procurement, even in a worst-case situation, to be far less than those arising from large unstabilized tailings piles. This matter is evaluated in Section 9.3.8.4.

5.6 Long-Term Impacts*

> Comment: Because the GEIS fails to seriously address or consider the need for isolation over the long-term, and because constant environmental conditions are assumed, the analysis of long-term groundwater impacts is grossly inadequate. The GEIS fails to assess measures needed to prevent long-term groundwater seepage and fails to address long-term migration in groundwater of toxic and/or radioactive materials. (47, 90)

Response: Regarding the potential for long-term groundwater impacts, see Sections 9.3.4.2.2 and 12.3.5, and Summary Section 9, "Groundwater Protection." Regulations being promulgated call for steps to be taken to minimize or eliminate seepage to groundwater, and to preserve groundwater uses. These steps include dewatering of tailings, lining of tailings impoundments with low permeability clay or synthetic materials, and neutralization. The staff considers that continued

*For a general overview of the major issues raised on this matter see Summary Section 9, "Period of Long-Term Concern"; see also Sections 9.4, 12.3.4.6, 12.3.11 and 12.6.

postoperational seepage will not likely be problematic at disposal sites, because of these seepage control measures, and due to the fact that annual evaporation generally far exceeds annual precipitation (see Section 9.3.4.2.2) in western mill regions. Potential changes in climate could either degrade or enhance long-term isolation performance. Precise prediction of such indefinite, far distant events is not possible, and attempting to do so is nonproductive.

> Comment: The reason for assessing a historical period of 100,000 years in Section 9.4.1 should be stated. (74)

Response: The staff considers such a time frame to be appropriate for assessing the degree, likelihood, and potential effects of very long-term changes in geological, climatic and other environmental conditions.

> Comment: The length of time during which control, monitoring, and remedial actions will be required should be stated. (96)

Response: The staff considers that periodic surveillance will be required for an indefinite period of time. The regulations specify that no active maintenance be required at disposal sites, however. (See Sections 10.3 and 12.3.11.)

> Comment: Based on the many large uncertainties involved, and the potential for development of a cure for lung cancer, a 100-year period seems appropriate for evaluating the need for, and cost-effectiveness of, radon control. (85)

Response: There are indeed large uncertainties involved in assessing the impacts of radon emissions, and it may be possible that a cure could be developed for lung cancer in 100 years. However, the staff does not believe that these circumstances justify the use of a limited 100-year integration period for evaluating the impacts of radon releases which are likely to continue indefinitely.

> Comment: The full period of toxicity must be explicitly addressed:
>
> (a) to properly assess the need for, and the value of long-term isolation, particularly with respect to the evaluation of tailings management Alternatives 7, 8 and 9. (34, 47, 56, 97)
>
> (b) to realize that annual postreclamation surveillance requirements are useless. (90)
>
> (c) to account for the long-term societal and economic impacts of future human suffering. (96)
>
> (d) to recognize the unreasonableness of assuming constant, uniform environmental conditions, and of assuming that above-grade tailings impoundment embankments and covers can last indefinitely. (47)
>
> (e) to recognize the tremendous long-term uncertainties, grossly oversimplified analysis, and unconservative GEIS criteria. (47, 56)
>
> (f) to account for all radon to be eventually released and the associated cumulative health effects. (25, 32, 34, 54, 92, 96, 97, 98)
>
> (g) because the 1000 year period evaluated is only 1/80th of the half-life of Th-230 and will lead to regulatory requirements and designs only providing for 1000 years of isolation. (34)

Response: As described in Section 12.3.3, the staff has developed regulations which account for the extremely long-lived hazards associated with mill tailings. Disposal methods which will return sites to conditions virtually the same as surrounding environs, for many thousands of years, without the need for continuing active maintenance, are identified. The staff concluded, after evaluating a full range of tailings disposal alternatives, that there is no practicable way, nor a need, to provide absolute assurance of eternal containment of the very high volume, low specific activity wastes that are mill tailings. Uncertainties associated with any evaluation beyond several thousand years are so large and all encompassing as to render detailed evaluation essentially meaningless. In developing criteria, the staff evaluated failures that could occur over geologic time periods, such as 100,000 years, to provide a clear perspective on potential long-term impacts and to identify the kinds of steps which should be taken to eliminate or reduce to acceptable levels the potential for failure. (See Sections 9.4, 12.3.4.6, 12.3.11, and 12.6, and Summary Section 9, "Period of Long-Term Concern.")

Chapters 6 and 9 present total potential health effects from various levels of tailings radon release rates for 1000 years. Because of the vast uncertainties beyond this time, the staff did not routinely present integrated health effects for periods beyond 1000 years. Information is provided, however, to permit readers to readily compute longer term effects based on whatever long-term scenarios they might consider to be appropriate. Annual residual radon releases and resulting health effects are estimated and presented, and are compared to background rates, in order to emphasize the essentially endless nature of such releases and the relative magnitude of continuing impacts.

5.7 Cost-Benefit Analysis*

> Comment: A rigorous cost-benefit analysis including costs to society should be performed in determining specific limits (e.g., radon) contained in the criteria. (37, 47, 59, 81, 85)

Response: The staff considers cost-benefit analysis to have only limited applicability and usefulness with respect to the issues addressed by this document (see, for example, new Appendix U and Section 12.3.4.6). This is largely due to the inability to reasonably quantify and convert to dollar value, the long-term impacts and benefits of recommended requirements. However, in view of the many strong comments on this topic, the staff has reviewed and expanded its radon limit evaluation. From this analysis, given in Appendix U, it was determined that the range of uncertainty in the final result was such that practically any flux limit value could be justified within the context of a cost-benefit analysis, depending upon assumptions made and values assumed for key parameters.

The staff realizes that there are both incentives and precedents for basing criteria on a cost-benefit analysis. However, for the subject matters addressed by the criteria recommended here, reliance upon quantitative cost-benefit analysis is decidedly inappropriate.

> Comment: Reasonable costs for avoiding lung cancer fatalities should be included in the analysis. (85)

Response: See Appendix U and Section 12.3.4.6 for the staff position on fully monetized cost-benefit analysis. The valuation of societal costs for lung cancer fatalities is addressed in the cost-benefit analysis contained in Appendix U.

> Comment: Based on the information in the GEIS, radon emission control at or near a zero increment above background levels can be achieved at reasonable cost. (25, 74, 88)

Response: It is the judgment of the staff, as discussed in Section 12.3.4.1, that radon emission control should be such that radon releases are as low as reasonably achievable (ALARA), not as low as possible. In that context, the staff has determined that the residual radon flux limit for reclaimed tailings should be 2 pci/m^2-sec.

> Comment: In performing a cost-benefit balance, total control costs should be presented on an absolute basis and not just as a fractional cost increase per unit of electricity produced. (85)

Response: Costs are presented in the GEIS in several ways in order to provide proper perspective as to their magnitude. The manner of presenting costs suggested in the comment has been more visibly incorporated into the final GEIS (absolute costs, as opposed to relative costs, were provided in several discussions in the draft GEIS, e.g., Sec. 12.3).

> Comment: In a cost-benefit analysis, control costs should be projected into the future if health effect costs are to be applied to future cancers. (85)

Response: See Section 12.3.4.6 and Appendix U concerning the staff position on quantitative cost-benefit analysis as applied to the problem of tailings disposal. Nearly all control costs are incurred in the course of reclamation and are properly considered as present costs. On the other hand, it is difficult to project what the societal costs of a future cancer fatality might

*For a general overview of comments raised on this matter, see the discussion on "Radon Control and Tailings Cover Requirements" in Summary Section 9; see also Section 12.3.4.6.

be. The data base used in estimating the societal cost for a cancer fatality includes examples of present costs willingly incurred to prevent future fatalities (see Appendix U). It is also reasonable to assume that the societal cost for a fatality will increase by at least as much as the discount rate used to estimate present worth of future expenses. Because of the enormous uncertainties regarding such factors and, more importantly, because of the inability to reasonably predict long-term effects, the staff has eschewed reliance on a quantitative cost-benefit analysis.

> Comment: Consideration of realistic time frames, and the inclusion in the alternatives evaluations of the costs of continued surveillance, would completely invert the cost-effectiveness rankings of the tailings disposal alternatives examined. (47, 90)

Response: Such costs are very small in proportion to overall costs, being estimated to have a present worth of approximately $250,000 (in 1978 dollars, see Appendix R). This amount of money is insignificant in relation to other involved costs and has no effect on the ranking of the various tailings disposal alternatives.

5.8 Long-Term Calculational Uncertainties

> Comment: Prediction of cancer deaths over the next 5 to 10 years is fraught with questionable assumptions and uncertainty. Attempting to predict premature cancer deaths from 1978 to the year 3000 is a preposterous and useless exercise. In any case, such risk estimates should be qualified by statements of the uncertainties associated with them. (59)

Response: Statements as to the level and nature of involved uncertainties are made repeatedly within this document; in particular, uncertainties are addressed in Appendices G-7, S, and U. Although substantial uncertainties are unavoidably present in any estimation of long-term impacts such as presented in this document, the staff does not consider these or other similar evaluations to be devoid of value. Such calculations are, indeed, quite often necessary to an informed decisionmaking process and they serve that purpose herein. The estimates of long-term health effect impacts presented within this document are considered by the staff to represent reasonable evaluations. Whether they are, in fact, conservative or nonconservative, and to what degree, is not determinable. They would certainly be inadequate if they were limited to a period of only 5 to 10 years, given the essentially permanent nature of the hazards associated with uranium mill tailings.

> Comment: Present-day population and climatological patterns have been assumed to continue without alteration in the evaluation of environmental impacts. Variability of these factors on the time scale in question is entirely unpredictable. (90, 92, 97)

Response: It is because of the stated unpredictability of these factors, as well as other factors of a similar nature, that assumptions of continuity have been made. The staff considers such assumptions to be both necessary and reasonable. However, the staff has presented information that would allow others to calculate effects based upon their own scenarios about the very uncertain, far distant future. (See Sections 9.4.1, 12.3.4, and 12.6.)

> Comment: The combined overestimates of the number of mills required (by a factor of 1.64), surface radon flux (by a factor of 1.8), and health effects per unit radon release (by a factor of 10) indicate that resulting health effect estimates are too high by a factor of 30. (85)

Response: The required number of model mills in the year 2000 has been adjusted to reflect reductions in both uranium demand and industry-average ore grade. The staff does not agree that surface radon fluxes or health effects per unit radon release have necessarily been overestimated. Uncertainties in these factors are addressed in Appendices G, S, and U, as well as in other portions of this document. These uncertainties have been fully considered in reaching a conclusion as to allowable surface radon exhalation from reclaimed tailings.

5.9 Decision Criteria

> Comment: Cancer deaths caused by radon releases from uranium milling activities cannot be justified because they are a small fraction of the cancer deaths cause by natural radon releases. (25, 37, 74, 97, 98)

Response: The staff considers that reduction of incremental radon exposure levels to levels that are very small fractions of those attributable to natural background to be amply demonstrated by the comparisons given, which include calculations of resulting cancer impacts. Such evaluations, in conjunction with other analyses of costs, uncertainties, and other involved circumstances form the overall rationale for the staff's determination that reduction of residual radon releases to a level of 2 pCi/m^2-sec is as low as reasonably achievable. The staff's conclusions as to allowable residual radon flux, as discussed in Sec. 12.3.4, are based on a wide range of perspectives. In this context the staff has taken full consideration of the absolute incremental risks posed by small continuing radon releases.

> Comment: The proposed radon limit is too restrictive as natural radon releases make releases from even uncovered piles totally insignificant. Also, the natural variability of background radon releases far exceeds the proposed limit. Therefore, reduction of radon releases from tailings piles to the proposed level is not justifiable because total risks will remain unchanged. (52, 53, 85)

Response: The staff has examined radon releases from uranium tailings piles from a wide range of perspectives, including both relative and absolute impacts. From cost-benefit and other considerations discussed in Section 12.3.4, the staff has determined that a 2 pCi/m^2-sec limit is appropriate for reclaimed tailings piles, not including radon released from the cover materials applied. The primary basis for this numerical determination is that such releases would be within the range of natural background exhalation rates, which, as the commenters point out, can vary markedly from place to place. The fact that natural exhalation rates can indeed reach levels substantially above the staff's selected limit, in isolated locations or areas, has no direct bearing on the staff's determination that incremental release rates should be constrained to the limit specified.

> Comment: The proposed radon limit is too low because the underlying analysis ignores the prospects of a cure for lung cancer in the near future, and the potential for reducing other kinds of air pollution without which the effects of radon would be vastly reduced. (52, 85)

Response: The staff considers that it would not be prudent to now require only the reduced levels of environmental protection that would be appropriate if at some later date a cure for lung cancer is developed, or if the claimed synergistic effects of other air pollutants are markedly reduced. It would be irresponsible to plan now on the basis of such speculative assumptions.

> Comment: The costs of proper tailings management stated as a fraction of the price of yellowcake at $30 per pound are made to appear more expensive than in reality because the current price of yellowcake is much higher than that. (54, 74)

Response: The price of yellowcake product on the spot market is somewhat volatile and can change markedly in short time periods. The $30 per pound of U_3O_8 figure used by the staff is considered reasonably representative of prices charged for current deliveries, mostly under contracts agreed to over the last several years. Also, as of this writing, spot market prices for uranium concentrate are within about 10% of the figure used by the staff.

> Comment: At least 10% of product price should be set aside for tailings disposal, decommissioning, post-operational monitoring and maintenance. This will provide a buffer for future errors, and is surely not too great a price to pay for future safety. (109)

Response: Regulations are requiring that tailings be disposed of in a passive condition which does not necessitate active maintenance and significant ongoing surveillance. For additional discussion regarding provision of a contingency or insurance fund, see Section 14.3.5.

> Comment: As the draft states, "if the period of 100,000 years is selected, elimination of the source would appear appropriate." This is appropriate and also in accordance with general NEPA responsibilities to preserve the quality of the environment for future generations. (37, 54, 96)

Response: The quotation cited, out of Chapter 12 of the draft GEIS, is taken out of context from the overall discussion which elaborates on other considerations including the inherent limitations of a cost-benefit analysis. The staff did not and does not judge that residual radon releases should be reduced to zero, nor is this required under NEPA. The complete elimination of residual impacts is not mandated by the NEPA; that Act merely requires a careful balancing of costs and benefits. (See Section 12.3.4.)

Comment: Because of the numerous and significant uncertainties involved in long-term tailings management, the GEIS should adopt a conservative approach leading to adoption (not rejection) of Alternatives 7, 8, and 9, and deep underground burial. (37, 54)

Response: The staff has given deliberate consideration to the uncertainties involved and has reached a different conclusion in that other alternatives, besides those mentioned, are found acceptable. The staff has not "rejected" the alternatives mentioned by prohibiting their use; rather, an inadequate basis was found for requiring them. (See Section 12.3.3.3.)

Comment: The draft GEIS is deficient in that it fails to provide a comparison of the risks from allowable radon releases with risks common to everyday life, thereby indicating the insignificance of the radon associated risks and the lack of need for reduction of radon releases to the level specified in the proposed regulations. Such a comparison would show that it is wasteful and inappropriate to devote massive fiscal resources to reducing the already negligible risks from radon when other more easily controllable risks completely overshadow radon risks. Such other commonplace risks include those from smoking, fossil-fueled energy sources, motor vehicle accidents, football, accidents in the home, air travel, alcohol consumption, and many others. On the basis of a comparative risk analysis we have performed, we find no strong basis for reducing radon releases below about 100 pCi/m^2-sec. (50, 55, 85)

Response: As discussed in Section 12.3, the staff considers that risk comparisons of the kind offered can indeed provide valuable perspective. However, decisions cannot be made on that basis alone. In looking at the uranium milling industry, the staff has determined that a residual radon flux limit of 2 pCi/m^2-sec from buried tailings is appropriate because, in the staff's judgment, that limit is as low as reasonably achievable on the basis of costs of control, reductions in impacts, and extenuating circumstances involving uncertainties, the duration of the impacts, correspondence with background flux variation, etc. (See Sec. 12.3.4.)

Comment: The costs of controls proposed in the GEIS are tremendous. We suggest that the concept of "reasonably achievable" be based, in part, on a cost-benefit analysis approach. Though it may be distasteful, it is necessary to quantify health risks in units of dollar costs for meaningful cost-benefit analyses. Such analyses should recognize site-specific differences, particularly the reduced ability of small operations to support the massive costs for the proposed protection requirements. (52, 55, 59)

Response: For reasons discussed in Section 12.3.4, the staff has found rigorous cost-benefit analysis largely unproductive and inappropriate with respect to the need for long-term protection from the hazards posed by uranium tailings. Variability in site-specific factors, which can impact costs and benefits of various degrees of control has been duly considered by the staff. Therefore, the staff has developed regulatory requirements that are appropriate on a generic basis--to the uranium industry as a whole. In part, these requirements specify minimum acceptable levels of public health and safety and environmental protection. The staff considers that all operations, regardless of size, must meet the specified requirements. The staff conclusion has been that, viewing costs for controls in terms of product price (which essentially normalizes costs with regard to project size), the costs are reasonable.

Comment: The risk estimators specified in GEIS Appendix G-7, when combined with the $1,000 value placed on one whole-body-rem in Appendix I to 10 CFR Part 50, yield a value of $4,000,00 per human life. This is much more than the $37,000 chosen by the staff and indicates that more money should be spent to reduce population risk. This is necessary to assure application of the same standards to a mill tailings pile as to a reactor. (97)

Response: The $1,000 per whole-body-rem figure found in Appendix I of 10 CFR Part 50 arose in the context of a reactor rulemaking proceeding involving vastly different considerations than encountered within the context of this effort. That figure has no direct relevance within this statement. The figure of $37,000 was not "chosen" by the staff. (See Section 12.3.4.6 and Appendix U concerning the staff conclusions regarding monetized cost-benefit analyses.)

Comment: The exercise of calculating radiological impacts to continental populations as far distant as northern Mexico and southern Canada seems to add little meaningful data in view of the negligible effects involved. (85)

Response: The staff does not consider such effects to be negligible; they amount to about 13% of long-range effects predicted for the United States.

> Comment: Due to general erosional processes, all uranium ore bodies will eventually be at the earth's surface. Thus, mining and milling activities conducted now merely alter the timing of impacts that would occur naturally in any case. (85)

Response: The staff would not argue with this comment. However, it does not provide a rationale for not affording reasonably achievable protection from controllable environmental impacts.

> Comment: The GEIS is seriously deficient in that it fails to consider a dose objective as an alternative to the proposed radon exhalation limit. (86)

Response: Setting a dose limit as opposed to a radon flux limit, in stating final tailings cover requirements, is not appropriate for a long-term hazard such as that posed by mill tailings. Exposures to individuals will be dependent in great measure upon where they are located, and there is no way of predicting this over the thousands of years that tailings will remain a hazard.

Certainly, if exposure limitation were adopted as the guiding principle for establishing cover requirements, a location near or even on top of the tailings pile would have to be selected for evaluation purposes, since these represent worst-case locations. In the draft GEIS, the staff evaluated the potential health risks to persons at such locations for the range of alternative radon control levels examined. At the selected limit of 2 pCi/m^2-sec, exposures resulting from tailings releases were consistent with those specified in other cases where, either naturally or due to the presence of tailings, elevated radon exposures occur inside structures. (This is discussed in Section 12.3.4.3.)

Given the long-term uncertainties about actual locations of people, stability of institutional controls, stability of tailings impoundments and the like, and in view of the need to examine perspectives other than just the individual risk perspective as described in Section 12.3.4, expressing tailings cover requirements in terms of radon flux limits is considered to be the most straightforward, appropriate, and practicable approach to be taken in regulation.

> Comment: An arbitrary cutoff at the year 2000 is unrealistic because reactors and uranium mills will continue to operate long after that date. (54)

Response: This document considers the environmental impacts of all conventional U.S. uranium milling activities occurring through the year 2000, as specified in the scope of effort published in the Federal Register before the initiation of this project. Consideration of that time period is quite sufficient for evaluating the impacts of the current uranium milling industry, and assessing the present need for regulatory change. Beyond the year 2000, events concerning uranium recovery operations are too speculative to provide a more meaningful evaluation.

> Comment: Lack of consideration as to the merits of establishing "de minimis" criteria for uranium mining and milling is a significant omission. Such "de minimis" levels would permit disposal of scrap materials as nonradioactive and/or nonhazardous. It also would provide a criterion below which site decommissioning would not have to be performed. (53)

Response: Consideration of "de minimis" levels, per se, is not considered appropriate. The staff sees little problem in disposing of scrap material in accordance with standard procedures, particularly given access to open waste impoundments present at all operating facilities. Lower limits are specified with respect to decommissioning cleanup criteria (see Appendix J, which presents EPA's interim cleanup criteria) and residual radon releases are not limited to zero.

5.10 Long-Term Monitoring

> Comment: Increased monitoring costs will result from tailings disposal by use of less secure disposal alternatives thereby tending to equalize the cost differences between Alternatives 7 and 9 and the other alternatives, which provide reduced potential for long-term isolation. (47)

Response: It cannot be concluded, a priori, that use of disposal methods other than those involving fixation or nitric acid leaching will necessarily result in the need for increased long-term monitoring. The costs of potential monitoring needs would not significantly alter the cost differentials between Alternatives 7 and 9 and the other acceptable disposal methods in any case, and are therefore not included explicitly in the cost-benefit evaluation. As described in Sections 10.3 and 14.3, ongoing costs of "Passive Monitoring Mode" alternatives will be small.

> Comment: Long-term environmental monitoring requirements should be clearly and realistically set forth. (37, 47, 99)

Response: Likely long-term monitoring requirements have not been set forth in Sections 10.3 and 14.3 and in Appendix R. Disposal site reclamation performance objectives include the stipulation that no on-going maintenance be required to preserve isolation. Fulfillment of this objective essentially limits potential monitoring requirements to periodic visual inspections, possibly accompanied by occasional sampling and analysis of underlying groundwater. The precise details of monitoring will depend on variable site-specific conditions and for this reason are not appropriately specified in this document.

5.11 Advanced Technology Alternatives

> Comment: Future developments may sharply reduce the cost of tailings fixation relative to other disposal methods. (26)

Response: This may indeed be the case, but does not alter the need for additional regulatory control in the present. The staff, as well as the uranium mill operators, will keep abreast of developments in this area as a matter of course.

> Comment: The staff should have considered when it might be realistic to install disposal Alternatives 7, 8, and 9 and whether technology forcing actions should be taken. (34, 47)

Response: As indicated in Section 12.3.3.3, at present the staff does not consider that implementation of Alternatives 7, 8, and 9 is necessary to achieve the fundamental objectives of long-term tailings disposal. Although the Department of Energy (DOE) and the industry will have to conduct any major technology development, NRC plans to sponsor some limited research in this area and assure, by working closely with DOE, that research programs are adequate.

> Comment: The draft GEIS has not adequately assessed the long-term consequences of uranium milling. The number of premature deaths (after 1,000 years), the effectiveness of the passive monitoring modes, and the dates when immobilization technologies might be feasible should all be considered in greater detail. (34, 47)

Response: The staff considers that it has adequately addressed the first two items mentioned in this comment (see, in particular, Sections 9.4 and 12.3), and that it is neither useful nor appropriate to speculate as to the specific dates when advanced immobilization technologies may become commercially practicable. Based on analysis of potential long-term effects, the staff has identified a range of tailings disposal alternatives that are adequate and regulations requiring their implementation are being issued.

> Comment: Few above grade disposal sites could withstand maximum rainstorms without destructive erosion and, therefore, the fixation of at least the slimes fraction is necessary for long-term protection. (37)

Response: Regulation changes implementing the conclusions of this document will require all final tailings disposal sites and programs to provide adequate surface erosion protection, via below grade burial, rock cover and/or other methods, to fully protect against maximum rainstorms and other potentially disruptive influences. The staff does not consider fixation to be necessary to provide adequate long-term protection from erosion.

> Comment: The NRC has rejected Alternatives 7 and 9 without sufficient discussion or reason. (47)

Response: The staff considers that its reasons for not requiring implementation of these alternatives are very sound, as well as adequately expounded (see Sec. 12.3.3.3).

> Comment: Alternative 1 could be acceptable, under the right conditions, and Alternatives 7, 8, and 9 are unproven, entail excessive cost, and are therefore wasteful. (86)

Response: As specified herein, Alternative 1 is unacceptable because of associated groundwater contamination and the need for ongoing active maintenance after reclamation. The staff also agrees that Alternatives 7, 8, and 9 are largely unproven, at least on a commercial scale, and involve excessive costs in comparison to other acceptable alternatives (see Sec. 12.3.3.3).

Comment: Alternatives 8 and 9 would provide greater long-term protection than those favored by the staff. (90)

Response: Alternatives 8 and 9 are fraught with some problems that create greater environmental impacts, while simultaneously offering increased protection against others. On balance, the staff sees no need to require such alternatives, though proposals to implement them would be accepted and reviewed in the same manner as any other. (See Section 12.3.3.3)

Comment: The staff has not adequately considered long-range possibilities of groundwater contamination, through increased flowage caused by increased human use of the water, water flow through fractures and faults, changed climatic conditions, and failure of liners. The relatively "slow" movement of radium and thorium in the ground at a West Chicago location cited by the staff, would amount to transport over tremendous distances over the long term. (37, 47, 90, 99)

Response: It should be noted that all of the pollutants are natural components of the local environment and with time will reach an equilibrium determined by the geology and climate then existing, much as if the original ore body had never been disturbed. Over these periods of time, former human manipulations will have less and less significance. In the interim, provisions of the regulations being adopted by the staff will assure that no tailings disposal site will be allowed to result in significant long-term groundwater impacts via the mentioned mechanisms, except perhaps via unforeseen climatic changes which would, by their nature, involve impacts completely overshadowing those from disposed uranium tailings. The staff's conclusions as to how fractures and faults should be dealt with, which can be very significant with respect to seepage transport, are provided in Sec. 12.3.5.

6. REGULATIONS

6.1 Applicability

6.1.1 Existing Sites*

Comment: If a substantial start on facilities for tailings disposal under then-existing standards has been made, it is not appropriate to impose more stringent criteria which would require substantial modifications absent extraordinary circumstances where the health and safety of the public would be affected. (43)

Response: The staff would not expect substantial modifications to be necessary for tailings disposal facilities conforming to the staff's May 1977 Branch Position on Uranium Mill Tailings Management (see Appendix T.3). However, conformance with the applicable requirements of the final regulations being implemented in conjunction with this statement will be necessary in all cases.

Comment: The draft GEIS and proposed regulations fail to address with adequate specificity how the disposal requirements will be made applicable to existing sites. (47, 59, 82, 91, 126)

Response: Regulations were developed recognizing that it may not be practicable to provide the same measures of conservatism at existing sites as can be provided at new sites, where alternatives are not limited. However, certain requirements in the regulations represent minimum levels of protection of public health and safety, and the environment, and can and must be met in all cases; the regulations have been revised from their proposed form to clarify this. For example, the requirement for preservation of groundwater uses, minimum tailings cover requirements, requirements for erosion protection, financial surety provisions, and the broad requirement that no ongoing, active maintenance be needed to preserve the tailings isolation for thousands of years, are all mandatory in all cases. It would not be practicable, on the other hand, to line the bottom of an existing tailings impoundment. Also, objectives concerning remoteness from people, and providing below grade burial, may not be met to the same degree at an existing site as at a new site.

At some point, which must be determined by considering how a site measures up against all of the criteria, it may be determined that tailings should be relocated to a new site, or that while it would be acceptable for existing tailings to be stabilized in place, tailings generated in the future should be deposited at a new location. The conditions which would lead to this

*For an overview of issues raised on this matter, see Section 9 of the summary. See also Section 12.4.

determination cannot appropriately be spelled out in generic fashion in regulations. In any event, a full evaluation of tailings disposal and alternative sites must be completed at each milling operation, and final plans formulated, through a public decisionmaking process such as is provided for by the NEPA and the UMTRCA. (See Sections 12.4 and 12.3.10.)

> Comment: The inclusion of uranium hexafluoride and other plants under the provisions of this rule is proper, since they do indeed have similar waste disposal problems. (79)

Response: With one exception, only source and byproduct material produced by the extraction or concentration of source material from ores is governed by the regulations being implemented in conjunction with this statement, in accordance with the intended scope of this effort and the authority provided under PL 95-604, as amended. The exception is the prohibition of major construction before completion and documentation of a full environmental assessment. This requirement is being made applicable to mills and other major fuel cycle facilities.

> Comment: Mention should be made of technology that can be applied to existing sites to bring their performance up to that to be applied to future mills, in the first paragraph of Summary Section 6.5. (99)

Response: Most of the technology discussed throughout the document is applicable at existing sites, the exceptions being those involving initial impoundment design and construction, particularly as related to groundwater protection.

6.1.2 Nonconventional Uranium Extraction Operations

> Comment: It is not clear whether or not NRC considers mildly radioactive wastewater generated by in situ uranium mining facilities to be byproduct material. Based on the proposed regulations, it appears that NRC considers such liquid wastes to be byproduct material and will, therefore, consider sites where such wastes are disposed by deep well injection to be subject to long-term surveillance fees, annual site inspections, and land ownership transfer requirements. On the contrary, we are of the opinion that deep underground injection wells utilized for the disposal of liquid wastes at mill sites should not be subject to a long-term surveillance charge of $250,000, presumably per well site, as stated in Criteria 10. In addition, we are opposed to requiring annual site inspections, as stipulated in Criteria 12, since such inspections to confirm the integrity of the deep disposal waste system are unnecessary when the host strata is well below grade and any fresh-water aquifer. Our company feels that deep disposal wells are a viable, safe option for long-term disposition of process waste water generated by in situ uranium facilities.
>
> It should be recognized by NRC that state agencies currently permit other industries--i.e., petrochemical--to utilize deep injection wells for the disposal of highly toxic fluids many times more hazardous than those generated by the in situ uranium industry without, we might add, conditional long-term surveillance charges or annual post-closing site inspections. We would recommend that NRC incorporate within the proposed regulations provisions to exempt any byproduct waste systems that can exhibit adequate long-term containment from any requirements for ownership transfer, site inspections, and long-term surveillance fees. (48)

Response: The staff is in substantial agreement with these comments as to deep well injection disposal of above ground in situ liquid wastes. Such wastes are indeed byproduct material and, as such, are subject to the regulations being promulgated on the basis of this document and the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA), as amended. Without prior detailed evaluation, the staff is unable to properly ascertain that the requested exemptions are warranted. Therefore, the staff is unable to extend such exemptions categorically. However, as such exemptions may very well be appropriate, the staff's proposed regulations have been revised to allow requirements for annual site surveillance, long-term surveillance fees, and land ownership transfer to be waived on an individual case basis. It is considered extremely unlikely that such institutional control measures will be required at individual deep well disposal sites.

Comment: The abbreviated treatment given to in situ and other unconventional uranium-concentrating processes should be expanded to include an extensive assessment of these methods. Additional discussion should address not only the mechanics of in situ extraction, but also the limited size and restricted financial scale of such operations. The relative economics of solution extraction make offsite disposal of all "byproduct" material as great a proportional burden as the same requirement would be for the more conventional facilities. This fact, when coupled with a reasonable proposal for the establishment of "de minimis" levels below which the proposed criteria would not apply (which the NRC failed to even consider), shows that the staff's concerns for disposal site proliferation must be suitably qualified in the light of what then actually constitutes a disposal site. (53, 85)

Response: All aboveground wastes produced by in situ or other uranium extraction operations fall within the definition of byproduct material incorporated within the Atomic Energy Act of 1954 by the UMTRCA. A "disposal site" is any site where such wastes are disposed. Under the definition of byproduct material imposed by the UMTRCA, the staff is not at liberty to set "de minimis" levels for such wastes. EPA's interim open land cleanup criteria effectively establish 5 pCi/g of Ra-226 as a temporary de minimis level (see App. J).

Comment: NRC-proposed regulations will preclude consideration of small waste facilities, particularly at in situ mining operations, as a means to reduce potential population exposures and the likelihood of human intrusions at tailings or waste disposal areas. (55)

Response: The staff considers that the proliferation of such small disposal sites would increase potential population exposures (e.g., from radon exhalation), the likelihood of human intrusion, and the burdens of ongoing government surveillance. The objective of the regulation is to minimize the number of final disposal sites, as practicable, while providing for minimum protection standards at all such sites.

Comment: In most cases, tailings or wastes from heap leaching and small processing sites are less hazardous than those from a conventional mill, because such small processing sites are usually used to extract uranium from small or low-grade ore bodies. Therefore, the proposed tailings management and disposal criteria should not be applied automatically to these unconventional operations, but should be evaluated on a case-by-case basis to account for the probable lower hazard. (59)

Response: Final disposal criteria being established by the staff basically address two issues: 1) the adequacy and permanency of isolation; and 2) radon exhalation. The staff considers that the adequacy and permanency of waste isolation should be held to the minimum levels dictated by the proposed criteria, even for wastes produced by small processors which may, or may not, be less hazardous than those produced by conventional mills. The radon limit is expressed as a maximum incremental radon exhalation rate above natural background per unit area. Such a limit is quite equitably applied to both small and large waste volumes, and low and high concentrations of radioactive and toxic materials.

Comments: The licensing requirements in Section 40.3 of the proposed regulations apparently apply to any size operation and would, therefore, be applicable to Bureau of Mines' sponsored studies in environmental technology and control, as well as pilot-plant processing tests of uranium ore. Some mechanism should be established to waive or modify the licensing requirements for pilot-scale tests on uranium ores. (72)

Response: The staff's position on this issue is discussed in the Summary of this document (Section 9.). As indicated there, NRC considers that additional evaluations are necessary before determining what quantities of tailings can be considered "unimportant" and, thus, be covered under a general license or exempted from licensing requirements. The NRC invites additional information on this matter and plans to publish its conclusions on this subject at a later date.

Comment: Regulations pertaining to unconventional uranium extraction processes should be withheld until an in-depth study of all the relevant issues has been conducted. (52, 85, 132)

Response: Regulations regarding unconventional uranium extraction processes are limited to those addressing the final disposal of solid above-ground byproduct waste materials, an issue which has been explicitly and extensively considered in great detail within this document.

> Comment: Ore bodies depleted by in situ solution mining, and the residues which remain, are byproduct materials just as much as the tailings from conventional milling. (91, 101)

Response: The Commission has reviewed the technical and legal basis for the suggested conclusion and determined it to be insufficient. Ore bodies, depleted by an in situ process, have been determined not to be within the definition of byproduct material as stipulated by the UMTRCA.

> Comment: Because in situ extraction impacts are site-specific, the statement should enumerate objective standards for evaluation of proposed in situ operations. Such standards should define site characteristics (geological, hydrological, geochemical, etc.) such that in situ mining would be unacceptable. At the very least, siting criteria and regulations requiring the use of "state-of-the-art" technologies should be developed. (74, 91)

Response: The staff considers in situ extraction to be an important and growing component of the uranium recovery industry, and to be capable of significant environmental impacts without adequate control. As discussed in Sec. 12.2, because of the intensely site-specific nature of the chief environmental impacts of in situ extraction, those involving groundwater contamination, the staff is dubious as to the feasibility or value of a generic assessment of such impacts. Site-specific evaluations will be conducted in connection with each new in situ project, as required by the UMTRCA and 10 CFR Part 51. (See Section 12.3.10.)

6.1.3 Other Areas of the United States

> Comment: The State of Alaska suggests that Alaska be exempted from the proposed regulations based on this study or that a special study of Alaska be conducted, in as much as the study fails to consider the unique environmental conditions of Alaska or other states with previously undeveloped uranium resources (e.g., Tennessee, New Hampshire, and Florida). (13)

Response: The proposed regulations, as well as the regulations to be implemented as a result of this study, necessarily focus on generic problems associated with the present and future uranium milling industry. This industry is now concentrated in the western United States and will be for the duration of this century, according to present information. The staff considers that it is quite appropriate to base this evaluation, as well as requlation changes, on this fact. Also, the staff considers that the requirements to be imposed by way of regulation changes are, in essence, no more than reasonable protective measures that should be undertaken at all sites, regardless of location. In addition, site-specific environmental assessments will be conducted prior to each licensing action, as discussed in Section 12.3.10, as required by the UMTRCA and 10 CFR Part 51.

6.2 Clarity and Definitions

> Comment: Define capable and/or active fault (26, 55), major construction (47, 55), construction (67), remote site (55, 85, 121, 126), maximum credible earthquake (55), major plants (67), elevated levels of radium (73), reasonably achievable (85), reasonably expected best performance levels in terms of a quantitative basis for ceasing operations (86), "failure" in §40.26 in terms of specific parameters for documentation of what constitutes failure, including penalties (92), and prime option (55).

Response:

Active fault. This term has been changed to read "capable fault." The meaning of this term is as defined in §III(g) of Appendix A to 10 CFR Part 100.

Major construction and/or construction. The terms "major construction," as was used in proposed §150.31, and "commencement of construction," as was used in proposed §§30.33, 40.32, 70.23, and 150.31, have been defined to mean any clearing of land, excavation, or other substantial action that would adversely affect the environment of a site. The new definition does not include site exploration, necessary borings to determine foundation conditions, or other preconstruction monitoring or testing to establish background information related to the suitability of the site or the protection of environmental values.

Remote site. The introduction and Criterion 1 of the final Appendix A have been revised to more clearly delineate selection criteria for alternative tailings disposal sites. While the NRC staff considered defining remoteness in terms of population densities, this was not done at this time, since the NRC staff considers site selection to be an optimization process, taking into account several parameters and site features in order to meet the broad objective of isolating tailings and contaminants from man and the environment in the short term, and for thousands of years, without ongoing maintenance. Thus, the term remoteness is used in the final criteria in terms of meeting a broad isolation objective, rather than in precise quantitiative terms. (See also "Siting of Mills" in Section 9 of the Summary.)

Maximum credible earthquake. The maximum credible earthquake is defined in revised Criterion 4 of Appendix A to Part 40 to be that earthquake which would cause the maximum vibratory ground motion, based upon an evaluation of earthquake potential considering the regional and local geology and seismology and specific characteristics of local subsurface material.

Major plants. The term "major plants" was only used in the title and summary of the August 24, 1979 Federal Register notice. The specific plants to which this term applied were, and still are, explicitly defined in §§30.33, 40.32, and 70.23 of 10 CFR 30, 40, and 70 respectively.

Elevated levels of radium. This term, as used in Criterion 6 of Appendix A, is intended to preclude the use of cover material containing radium concentrations in excess of those in surrounding natural surface soils. Since Criterion 6 also states that soils used for cover must be essentially the same as natural local soils, as far as radioactivity is concerned, it appears that an additional specification concerning radium concentrations would be redundant.

As low as is reasonably achievable. This terminology, as used throughout the proposed Appendix A, was intended to have the same meaning as in other parts of the Commission's regulations. This is explicitly stated in the final version of Appendix A.

Reasonably expected best peformance levels. This terminology is no longer used.

Specific parameters for documentation of what constitutes failure and penalties for failure to obey criterion. The criterion to which this comment refers, requires NRC licensees to conduct daily inspections of tailings and/or waste retention systems. Results of such inspections must be documented in a licensee's operational records for subsequent NRC review during inspections by NRC prersonnel. Any failure in a tailings or waste retention system which results in a release of tailings or wastes into unrestricted areas (defined in 10 CFR 20), and/or any unusual conditions (i.e., conditions not contemplated in the design of the retention system) which, if not corrected, could lead to failure of the system and result in a release of tailings or wastes into unrestricted areas, must be immediately reported to the NRC. This inspection and reporting requirement has been a standard license condition in NRC uranium mill licenses for more than fifteen years. The language of the condition has not been misunderstood or led to ambiguities during this period. Thus, the NRC staff believes revisions are unnecessary. Section 40.81 of 10 CFR Part 40 already provides for penalties for violations of NRC rules and regulations. Thus, additional delineation of penalties is unnecessary.

Prime option. The term "prime option" means that tailings management alternative (below grade disposal) which the staff considers to offer the best prospects for long-term isolation and which, for that reason, the staff expects to be either implemented or demonstrated to be impracticable. What is meant by prime option is further explained in Section 12.3.3.2.

> Comment: Delete the word "elimination" in Criterion 2 and the "uranium milling" definitions in §40.4(p). (53, 55)

Response: The NRC staff agrees and has made appropriate changes.

> Comment: Clarify Criterion 2 of Appendix A to (1) replace the word "mill" with the word "tailings" and delete the reference to Executive Order 11988. (55)

Response: The NRC staff agrees and has made appropriate changes.

> Comment: Revise §40.32(e) to permit exemption under §40.14 and other sections of 10 CFR Part 40, including §§40.41(c), 40.41(e), 40.51, 40.61, and 40.62 to incorporate consistent requirements and definitions for byproduct and source materials. (55, 120)

Response: As stated in the August 24, 1979 Federal Register notice (44 FR 50015), the NRC believes that when construction of a mill commences, irrevocable commitments are made regarding tailings disposal. Therefore, a final environmental impact appraisal must be completed, as required by the National Environmental Policy Act, before commencement of construction. The NRC staff also believes that all sections of the Commission's regulations should be consistent, and has made the appropriate changes as recommended.

> Comment: Clarify Criterion 4 of Appendix A to: (1) specify differences in siting, design, and performance standards; (2) minimize upstream catchment areas as a siting criteria rather than a design criterion; (3) indicate topographical features should be considered to provide good wind protection rather than being required; and (4) specify that upstream rainfall catchment areas must be minimized rather than utilized. (55, 105)

Response: Proposed Criterion 4 has been revised to more clearly identify the siting, design, and performance objectives of tailings systems. A typographical error has also been corrected to state that upstream catchment areas should be minimized rather than utilized. The staff believes that good wind protection, by virtue of local topographical features, should be provided, in view of the long-term hazards represented by tailings; with respect to such protection, the word "shall" has been replaced by the word "should."

> Comment: Clarify Criterion 6 of Appendix A by eliminating the last two sentences, which are unnecessary. (55)

Response: The NRC believes these sentences are important so as to emphasize the need for using earth covers which do not contain radium concentrations in excess of those found in nearby surrounding soils. Such covers are necessary in order to meet the overall objective of eventually reducing radon emanation from tailings sites to levels similar to those of nearby surrounding areas, and avoid the use of rock mine waste having high radium content.

> Comment: Clarify Criterion 7 of Appendix A to: (1) delete the redundant words "prior to development," and (2) revise the words "demonstrate compliance" to "measure or evaluate compliance." (55)

Response: The NRC staff agrees with these comments and has made appropriate changes.

> Comment: Clarify Criteria 7 and 8 of Appendix A by changing all "shoulds" to "shalls." (84)

Response: The NRC staff agrees with this comment and has made appropriate changes.

6.3 General Basis and Need

> Comment: Timing should be reconsidered to determine whether a code of new tailings disposal practice should not be postponed until the research and development program in progress at inactive tailings sites is completed. We are not aware of any urgency to establish criteria now. (52)

Response: The staff considers the promulgation of regulations governing acceptable tailings management practices to be a very urgent matter. It is clear, based on an analysis of the UMTRCA, that the Commission has not only the authority, but also the immediate duty, to ensure that the management of uranium mill tailings is carried out in a manner that will protect the public health and safety and the environment. As new mills are constructed and more tailings are generated, the options for dealing with tailings disposal become fewer. With respect to new facilities, it is critically important that the siting and design criteria of the regulations be enacted so that mistakes of the past are not repeated. The staff also finds clear need for improved regulatory control over both radiological and nonradiological effluents, to reduce such effluents to as low as reasonably achievable levels, at operating facilities.

The staff recognizes that research, much of it sponsored by NRC, is still being conducted in many areas covered in the rules. However, the regulations are established on the basis of knowledge obtained from licensing experience and research conducted to date. Research will continue and changes can be made to regulations without difficulty, if the research indicates that changes are necessary. However, it is considered most likely that research will provide a basis for supplementing the broad criteria of the regulations with more specific regulatory guidance, as opposed to necessitating a change in the overall objective of any criterion.

> Comment: Commencement of mill construction should not be prohibited until an affirmative final environmental statement is issued, because the only significant resource irretrievably committed by commencement of construction is the risk capital invested. Such business risks should not be categorically disallowed by regulation, without other compelling reasons. (55)

Response: The draft GEIS provides conclusive evidence that the impacts of the construction of uranium milling facilities can be both significant and long-lasting. In that regard, the staff considers it inappropriate that such impacts be allowed without first performing all evaluations necessary to the determination that those impacts are warranted, and documenting that appraisal for public review by publishing a final environmental statement. It is noted that the staff, if it were to allow construction before adequate environmental review, would have no authority by which to prevail upon the operator for redress of construction impacts, if the operator's proposed facility was rejected. The staff considers it necessary and appropriate to prevent the possibility of such a situation.

> Comment: The regulatory actions proposed in the GEIS are based largely on NRC management objectives. For example, the radon flux limit is geared to meet the NRC objective of "returning sites to conditions near those of surrounding environs," and NRC proposes that seepage into groundwater be reduced to "the maximum extent reasonably achievable." Public health standards should be based on a demonstrable health effect, with consideration towards the cost and benefit of controlling that effect. (59, 85, 86, 131)

Response: Both the draft GEIS and this final statement provide an adequate rationale for returning radon exhalation rates to within the level specified in the revised regulations, completely external to the objective of returning radon releases to near-background levels. This objective is, in reality, the conclusion of the staff's analysis, in which various levels of radon emission control were examined (see Chapters 9 and 12). Similarly, the conclusion that groundwater seepage should be reduced to levels which are as low as reasonably achievable is amply supported by this statement (see Chapters 6, 9, and 12, and Appendix E).

The staff cannot agree with the opinion that public health standards should, without exception, be based on direct, demonstrable health effects. It is also necessary to protect and preserve the natural environment, and man, from those adverse impacts which cannot, for one reason or another, be physically demonstrated but for which there is a preponderance of supporting scientific evidence (as the staff believes there is for the hazards associated with mill tailings; see Appendix G-7, for example). The staff has reached the conclusion that it is likely that the radon limit of 2 pCi/m^2-sec will, in the future, eliminate several unnecessary health effects per year. On the basis of the evidence available, the staff considers the application of this radon limit to be appropriate, despite the impossibility of physically exhibiting any individuals conclusively shown to have contracted lung cancer as a result of radon in the general environment.

> Comment: The proposed radon exhalation limit is based on the truly improbable assumption that a residence will be built directly on top of the disposal site. (59)

Response: The staff considers it appropriate to evaluate such a situation because it cannot be assumed that it will never happen. In fact, worse scenarios than this can reasonably be postulated. However, because of the unlikely nature of such scenarios, reduced emphasis is placed upon them, as described in Section 12.3.4.3. The radon limit is well-justified for reasons other than that stated in the comment. (See Sections 9.4.2 and 12.3.4.)

> Comment: The information provided in the draft GEIS demonstrates that the environmental and public health risk associated with uranium milling, even as represented by the model mill, is minimal and thus does not support the restrictive regulatory actions proposed. The radon exhalation limit is a prime example. (59)

Response: The staff considers the radon limit and the other requirements to be embodied in the regulations to be well-justified (see Chapter 12).

> Comment: The technical criteria set forth in Appendix A to proposed 10 CFR Part 40 incorrectly assume, without supporting evidence, that radon emissions form the surface of a uranium tailings area pose a significant threat to the public health and safety. (60)

Response: The staff believes the preponderence of scientific evidence is that exposure to radon and its daughters produces health effects, as described in Appendix G-7. The evidence available persuades the staff that such releases are very probably a significant threat to public health and safety, and therefore warrant the controls being required by the staff. The staff's principal bases for this conclusion are contained or referenced within this document (see Sections 6.4, 9.3, and 12.3.4, and Appendices G and S).

> Comment: The Commission has offered no justification whatever for requiring all of the existing operations to conform to the Appendix A technical criteria at this late juncture, when arrangements for the disposal of uranium mill tailings and wastes are already developed. (60, 77)

Response: See Section 12.4 for a full discussion of this issue. The staff considers that it has adequately demonstrated sufficient need for all tailings management requirements embodied within its revised regulation changes. The basic need for these requirements is independent of whether a tailings impoundment is already operating or not; only the costs of compliance may be significantly different. To the extent such cost differentials exist and are appropriate to consider, the staff's revised regulation changes allow such consideration. However, the staff cannot consider such costs to the extent that such consideration would allow nonconformance with the stated purpose of the Uranium Mill Tailings Radiation Control Act of 1978, PL 95-604, as amended:

> "...to provide a program to regulate mill tailings during uranium or thorium ore processing at active mill operations and after termination of such operations in order to stabilize and control such tailings in a safe and environmentally sound manner and to minimize or eliminate radiation health hazards to the public." (underlining added)

> Comment: The Commission states that specific methods of tailings disposal, mill decontamination, site reclamation, surety arrangements and arrangements to allow for transfer of site and tailings ownership must be worked out and approved before a license is granted. Obviously, a viable amendment clause must be added to allow for industry to make mutually acceptable revisions in their commitments as time develops and an operation matures. (61)

Response: The opportunity for mutually acceptable revisions is always present, through the process of license amendment.

> Comment: ALARA is an inappropriate standard for long-term control. The only ethical standard which would not erode difficultly-evolved human rights would be a standard which requires that the mined radionuclide hazard be equal to or less than the premined hazard. (63)

Response: The staff disagrees with this comment. Hardly any human activity can be conducted without some residual environmental impact. The complete elimination of all impacts is, in the staff's judgment, not warranted. In any case, however, because final radon flux limits are established to assure they are within the variation in flux from natural soil, the residual impacts will be negligible increases over background (see Section 12.3.4).

> Comment: The draft GEIS inadequately considers the cost-effectiveness of alternatives and does not provide adequate support for the proposed rules. (71, 85)

Response: The staff disagrees with these comments as discussed in Summary Section 9, "Radon Control and Tailings Cover Requirements." [See also Chapters 8, 9, 11 and 12 (in particular 12.3.4.6), and Appendices K and U].

> Comment: The major recommendations in the draft GEIS and the proposed regulations appear to have resulted from internal management and policy decisions rather than from any logical scientific conclusions and cost-benefit analyses, as would be the normal purpose of the NEPA decisionmaking process. (77, 85)

Response: While it is true that many previously adopted staff positions either were or are very similar to portions of those regulations now being implemented, the staff has proceeded to develop those regulation changes with an open mind and substantial public input. The staff considers that there is ample basis for the regulation changes being made and that those changes are in full accord with the intent of the NEPA (in particular, see Summary Section 9, and Chapter 12, Section 12.3).

> Comment: The following are similar comments related to the matter of cost-benefit justification of radon flux limits:
>
> (a) Instead of imposing inflexible, preselected criteria, NRC should examine in the draft GEIS the reasonableness of various levels of radon flux control in relation to the incremental health benefits and incremental costs of these control levels. (85)

(b) With respect to existing mills, general guidelines on target levels of risk and cost-effectiveness (incremental cost per incremental health effect) can and should be provided. In reality this should be done for all mills, new and existing, but it is particularly important for existing mills since they cannot now determine that their tailings disposal project is uneconomic and should not be undertaken. (77, 85, 86)

(c) The NRC has not taken a scientific and logical approach to its proposed conclusions and regulations for the control of tailings. Justification for the proposed required tailings cover is lacking. There is no cost benefit analysis or justification for the 2 pCi/m^2-sec above background radon emanation limit. (77, 85)

(d) Any regulatory actions must be developed from the standpoint of rigorous cost-effectiveness analysis in order that any regulatory action will have a properly demonstrated basis and purpose and meet the objectives of the draft GEIS. (85, 96, 127)

Response: The staff considers the cost-benefit evaluation presented in revised Section 12.3 to be scientific, logical, and supportive of the proposed requirements.

The staff reached a conclusion in the draft GEIS that attempting to establish tailings cover requirements on the basis of a quantified, incremental cost-benefit evaluation, is unreasonable and, indeed, may be misleading. In response to comments such as those above, however, the staff reexamined and expanded its evaluation of the strictly monetized, incremental cost-benefit methodology. Conclusions expressed in the draft statement concerning the impracticability and inappropriateness of attempting to set a radon exhalation limit by this method were fully reconfirmed. This is discussed more fully in Section 5.2.2 of the Summary and in Sec. 12.3.4.6. Given the long-term nature of the mill tailings hazards, and the complexity and uncertainty associated with predicting actual levels of radon emissions and impacts over the long-term, it is concluded that the problem of determining tailings containment requirements cannot be reduced to the purely mathematical formulations required for the quantitative cost-benefit optimization methodology. This mathematical process grossly oversimplifies the problem and, thus, while this appears to offer a "rational approach" to decisionmaking, it can be misleading and arbitrary.

One of the obvious problems with this methodology is that arguments can easily be made for virtuallly opposite positions (little or no control, versus absolute control of radon releases) merely by choosing short or long time frames over which to integrate potential health impacts. This was, in fact, done by commenters. The monetary worth of averting a health effect ("life loss" or "life shortening" due to cancer) is another highly subjective factor which can vary widely and, thus, make more uncertain the level of control which should be required. While arbitrary decisions might be made concerning these factors, there is no practicable way to uniquely correlate long-term containment performance with containment costs.

The staff established the proposed final radon flux limit based upon an evaluation of a wide range of public health and cost factors, and the variability of site-specific conditions (see Section 12.3.4). More specifically, these factors included evaluation of alternative radon release limits in terms of: costs for applying a final tailings cover under a full range of conditions, such as will occur with varying ore grades, impoundment sizes and shapes, cover material types and so on; impacts on maximally exposed individuals, as they compare with existing radiation protection standards; total population exposures, as they compare with population exposures from natural and technologically enhanced radon releases, both short and long term; and, radon fluxes that occur from natural soils. Costs for providing radon control will be reasonable. Also the staff has fully considered the impact of these requirements on existing sites (see Section 12.4).

Comment: The draft GEIS does not demonstrate the need for the proposed regulations; it merely addresses the effects of the proposed rules. (85)

Response: The staff considers the draft GEIS to have amply demonstrated the need for the proposed rules. The potential impacts resulting from the base case, in which no controls were applied, is discussed in Chapter 6. The costs and benefits of providing control to avoid such impacts are fully presented in Chapters 9, 11, and 12.

Comment: The costs of complying with the staff's regulations cannot be justified because they are a small fraction of the price of the uranium produced. (77, 85, 86)

Response: No such justification is claimed. However, such cost comparisons provide valuable perspective as to the overall impact of the regulations on the uranium-producing industry and the price of nuclear-generated electricity.

> Comment: As to tailings cover requirements, our conclusion is that large expenditures of societal resources to reduce radon flux from tailings piles to very low levels is neither cost-effective nor reasonable. There are many more effective ways to reduce societal risks. The inflexible level of 2 pCi/m^2-sec specified in the proposed licensing criteria is unreasonable. Site-specific considerations, such as the amount of cover material available at a reasonable cost, must strongly influence the acceptable radon flux rate. (85)

Response: The staff's analysis has resulted in the conclusion that a residual radon flux of 2 pci/m^2-sec from reclaimed tailings constitutes emission reduction to a level which is as low as reasonably achievable, with all involved circumstances being duly and simultaneously considered (see Sec. 12.3.4). The staff would not disagree that other commonplace risks of everyday life might be reduced at a more favorable cost-benefit ratio. However, the staff's responsibility herein is solely with respect to assuring proper management of the hazards associated with uranium milling.

> Comment: The draft GEIS (Chapter 12) explains what requirements may be imposed, but does not explain why the requirements are necessary. It is essential that the next draft of the GEIS contain information explaining the basis and purpose of the regulations. The omission of this data in the current draft is a critical omission. (85)

Response: The staff considers the draft GEIS (and also this final statement) to have made very clear the need, basis, and purpose of the proposed regulations. As previously discussed, the potential impacts of the base case, in which no additional controls are implemented, are described in Chapter 6. The cost and benefits of incremental controls were evaluated in Chapters 9 and 11, and final conclusions regarding appropriate requirements are presented and discussed in Chapter 12.

> Comment: When the GEIS is redrafted, it should specifically define the public health goals which NRC plans to achieve, and explain how these goals were developed. Operators may then select the most cost-effective methods of meeting these goals, taking into consideration site-specific conditions. The flexibility provided in achieving performance standards will protect public health, maximize U.S. production of uranium, minimize production costs and encourage new and improved mining and disposal technology. (85)

Response: The staff considers that its regulations have clearly defined purposes, and allow appropriate kinds and degrees of flexibility. The development of tailings disposal goals is clearly ennunciated in Section 12.3. See also Summary Section 9, "Form of Regulations" for more discussion of the issue of flexibility of regulations.

> Comment: The justification presented in the GEIS for establishing the maximum radon emanation rate and the minimum cover thickness criteria for reclaimed tailings piles is not based upon physical or biological data. (85)

Response: The staff considers that appropriate use has been made of available physical and biological data throughout the document (in particular, see Section 12.3, Appendix G, and Appendix P).

> Comment: There has been no showing that it is practicable to require passive maintenance, i.e., no need for ongoing active maintenance to preserve isolation. Criterion 12 should be modified to allow active maintenance where appropriate. (85)

Response: The staff's position is that final tailings impoundment systems should not require active maintenance (see relevant discussions in the Summary and Chapter 12, Section 12.3.3.1). The technical basis that "no active maintenance" is achievable is contained in Section 9.4.1.

> Comment: NRC should state the public health goal to be achieved by stipulating that wastes from "small remote above-ground extraction operations" shall preferably be disposed of at large existing sites. (85)

Response: The staff considers that it would be beneficial to avoid the unnecessary proliferation of numerous small tailings disposal sites. This is merely common sense. In view of this, as stated in draft GEIS Summary Section 6.6, "the staff believes that consideration should be given to consolidation of such tailings on a case-by-case basis where environmental benefits, costs and problems of long-term control can be fully examined and balanced." The objective of this requirement, as indicated in Criterion 2 of the revised regulations, is to reduce perpetual surveillance obligations.

> Comment: The objectives of the draft GEIS cannot be achieved without appropriately recognizing the broad diversity of present and future operations. (86)

Response: The staff has taken such diversity into full consideration in the development of the revised regulation changes associated with this document (see Chapter 12 and Appendix S).

6.4 Adequacy

> Comment: An exclusion area around a tailings site should be required during active use and prior to final stabilization to prevent residential encroachment. (26)

Response: The Commission's final regulations specify that tailings or waste disposal areas shall be located and operated at sites such that potential population exposures are reduced to the maximum extent reasonably achievable. Furthermore, NRC regulations restrict effluent releases from millsites so that EPA and NRC environmental exposure limits are not exceeded. In view of these requirements, the staff does not believe that an additional regulation which specifies an outer exclusion area is warranted. In addition, although the primary means of control must be the reduction of effluent releases at the source, site-specific radiological assessments, conducted in the manner discussed in Section 12.3.10, will indicate where the restricted area boundary should be.

> Comment: A tailings impoundment should not be located where long term integrity requires additional engineered structures. (26)

Response: The staff is in general agreement with this comment; in fact, the final regulation changes emphasize siting over design.

> Comment: It appears that disposal utilizing monitoring and the active care mode under custody of government agencies would be advisable to provide long-term environmental protection against continued groundwater seepage and surface erosion. It may therefore not be a desirable principle to return sites to near background conditions, but permanently restrict them so as to preclude any potential harm to the public and use the active care mode. (26)

Response: The NRC staff believes, for the reasons stated in the draft GEIS, that it is desirable to return tailings sites to conditions comparable to natural background. One reason for this belief is that potential long-term public exposures will be reduced to levels corresponding to natural background. Also, as was stated in the August 24, 1979, Federal Register notice, and discussed in the draft GEIS, the UMTRCA requires the final disposition of tailings or wastes at milling sites to be such that the need for long term maintenance and monitoring of sites, after license termination, shall be minimized, and to the maximum extent practicable, eliminated. As indicated in Sections 12.3.10 and 13.4, the staff considers the primary means of isolating the tailings must be by physical barriers since, among other considerations, the continuity of long-term institutional control is speculative at best. As was further stated in the Federal Register notice, depending on the specific conditions of a particular site, as determined during the period following site reclamation and before termination of a mill operator's license, a determination may be made that more frequent inspections or more comprehensive monitoring are required.

> Comment: All surface waters should be contained onsite during construction and operation to prevent surface water pollution. (31)

Response: The NRC staff does not believe there is sufficient justification for a Commission regulation requiring rain water to be contained during site construction or mill operation. While the NRC evaluates all potential environmental impacts associated with the construction and operation of any specific mill under the provisions of the National Environmental Policy Act, adequate surface water runoff controls are generally dictated by local building and environmental codes. Waste liquids resulting from process operations are required by NRC regulations to be contained so as to prevent surface water contamination.

> Comment: A single set of regulations appropriate to all milling situations is impractical. (38)

Response: The NRC does not believe its final regulations are impractical. The regulations specify, for the most part, broad performance objectives rather than specific design standards. They also provide appropriate flexibility (for example, several different surety arrangements are specified to be acceptable to the NRC) and leave mill operators free to find the most cost-effective means of compliance while maintaining the required levels of overall protection of human health and safety and the natural environment. Furthermore, where minimum or maximum numerical limits are specified in the criteria, the staff evaluated reasonable variations of conditions that could affect such limits. See, for example, Section 12.3.4 concerning tailings cover requirements.

> Comment: Construction of a mill should not begin until the issuance of a license, not after completion of the review required by the National Environmental Policy Act. License denial should be automatic and explicit if construction commences prior to the issuance of a license. (92, 135)

Response: The final NRC regulations in §§30.33(a)(5), 40.32(e), and 70.23(a)(7) clearly state that the Commission shall have grounds for denial of an application for a license if construction commences prior to a Commission conclusion, pursuant to 10 CFR Part 51 of the Commission's regulations, that a license should be issued. The staff considers the protection afforded by this requirement to be warranted and adequate.

> Comment: The draft GEIS and proposed regulations fail to consider steps which must be taken in the event remedial action is needed at a mill tailings disposal site. (47)

Response: Chapter 7 of the draft GEIS discussed a variety of potential accidents which might occur at uranium mills, including possible remedial actions. This discussion has been updated in the final GEIS and now includes the Church Rock accident which occurred in 1979. As is discussed in the final GEIS, remedial actions include the collection and return of tailings and contaminated earth resulting from the accident, to the tailings impoundment, to the maximum extent reasonably achievable.

It is the NRC staff's belief that it would be impractical to specify in NRC regulations criteria appropriately covering all unforseeable situations which could occur due to accidents. Thus, the NRC staff has not attempted to promulgate standards for such contingencies.

> Comment: Integrity criteria should be developed in NRC regulations so as to prohibit issuance of licenses to irresponsible persons with a history of violations. The GEIS should describe how responsibility and integrity of applicants is assured by NRC. (74)

Response: It is the general practice of the NRC to assume that applicants can comply with statements and representations contained in license applications. Following the issuance of a license, the NRC conducts periodic inspections to confirm compliance with applicable license conditions and regulations. Should violations of NRC regulations occur, penalties are imposed in conformance with NRC statutory authority, as provided in § 40.81 of 10 CFR Part 40. Furthermore, NRC requires licensees to obtain a financial surety to assure that payment of long-term surveillance fees and decommissioning and reclamation are conducted, as required by the terms of the license.

> Comment: The NRC should amend § 40.31(g) to include transfer of byproduct material. Clear authority to transfer byproduct materials among licensees is imperative. (53)

Response: The transfer of byproduct material is clearly covered in §§ 40.3 and 40.51 of 10 CFR 40. § 40.31(g) is intended to require that applications for mill licenses must contain proposed specifications for achieving the requirements and objectives set forth in Appendix A to Part 40.

> Comment: The NRC findings in the draft GEIS do not reflect a well-considered permanent solution, but represent a quick and dirty attempt to postpone a solution to the mill tailings problem. (54)

Response: The NRC staff does not agree with the opinion set forth in this comment. As indicated throughout Chapter 12 of the draft GEIS, the staff considers that compliance with the criteria set forth in Appendix A of Part 40 will result in the long-term stability of mill tailings. The staff further considers that the criteria are in conformance with the statutory mandates contained in the Uraninum Mill Tailings Radiation Control Act of 1978, as amended.

> Comment: NRC-proposed licensing procedures, i.e., issuing both a byproduct material license and a source material license, are not efficiently designed and are not in conformance with § 209 of the UMTRCA, in that they do not consolidate, to the maximum extent practicable, licenses and licensing procedures. (55)

Response: The proposed licensing requirements set forth in the NRC's Federal Register notice of August 24, 1979, were developed to deal with two different licensing situations so as to conform to the legal mandate of the UMTRCA, including § 209. The first situation dealt with NRC licensing byproduct material in Agreement States during the interim period until November, 1981. The second situation was applicable to NRC licensees in non-Agreement States. Subsequent to the November, 1979, amendment to the UMTRCA (Public Law 96-106), several effective rule changes to the NRC's regulations contained in the Federal Register notice of August 24, 1979, were revoked (see Federal Register notice (45 FR 12377) dated February 26, 1980). Furthermore, several of the proposed amendments set forth in the August 24, 1979 notice are no longer required and have been omitted in the Commission's final regulations.

The final regulations do not vary significantly, insofar as licenses and licensing procedures are concerned, to those prior to the UMTRCA. Under the final rules, only one license application is required from applicants covering both mill operations and tailings management. Upon approval of the application, a single license will be issued by the Commission in the same manner as was the practice prior to the UMTRCA. Thus, the NRC staff believes that its licensing procedures and licenses are consolidated to the maximum extent practicable, and are in conformance with the UMTRCA, including § 209.

> Comment: The NRC has failed to establish an objective of "containment" which includes migration and erosional releases. Salt migration is an indication of the need for a "containment" objective. (56)

Response: The NRC staff disagrees with this comment in that the criteria set forth in both the proposed and final regulations explicitly stress containment of tailings and wastes as an objective to be achieved by isolation and immobilization. For example, Criterion 2 of the proposed regulations stated that tailings or waste disposal areas shall be located at sites where disruption and dispersion by natural forces are reduced to the maximum extent reasonably achievable. Criterion 5 stated that steps shall be taken to reduce seepage of toxic materials into groundwater to the maximum extent reasonably achievable. As another example of containment measures being specified, a minimum cover requirement has been established to account for, among other reasons as described in Section 12.3.4.7, potential salt migration. In general, the final regulations have been revised to more clearly emphasize isolation and immobilization (i.e., containment) of tailings. Contrary to the opinion of the commenter, the primary objective of the staff's final regulations is to ensure appropriate isolation of tailings and wastes, and associated hazards, from humans and the environment.

> Comment: NRC regulations generally lack guidance concerning existing mills. (56)

Response: As was stated in the draft GEIS the proposed regulatory requirements were developed primarily in consideration of what can be done in prospective milling operations. The NRC staff considers, however, that these requirements should be incorporated to the maximum extent reasonably achievable at existing sites. The final regulations have been revised, however, to more clearly indicate applicability with respect to existing mills. Applicability to existing mills is further discussed in the Summary Section 9 and in Section 12.4. As indicated in these sections, certain requirements in the regulations represent minimum levels of protection of public health and safety and of the environment (e.g., minimum tailings cover requirements, requirements for erosion protection, financial surety provisions, and the broad requirement that no ongoing, active maintenance be needed to preserve tailings isolation) and can and must be met in all cases. A determination concerning how an existing site measures up against all of the criteria will be made on a case-by-case basis.

> Comment: Public hearings on tailings locations should be held and any local vote against location should be accepted as final. Also, indigenous populations (i.e., native American Indians) should be asked and allowed the right to veto any milling project in their area. (69, 92)

Response: NRC regulations already contain provisions for public hearings (see 10 CFR Part 2, "Rules of Practice For Domestic Licensing Proceedings"). Also, Part 51, "Licensing and Regulatory Policy and Procedures for Environmental Protection" provides provisions for public participation in the consideration of environmental aspects of proposed NRC actions. Concerning local-level voting and vetos, the NRC does not have the statutory authority to impose requirements based solely on such decisions.

> Comment: Criterion 4(a) should include limits on upstream catchment areas and prohibit sites not meeting limits. This criterion should read, "No upstream catchment should be necessary (as determined by the NRC in conjunction with the Agreement State) to provide upstream rainfall catchment. . .". Criterion 4(e) should give required earthquake strengths of dam structures. (74, 92)

Response: In developing the criteria on upstream catchment areas, the NRC staff recognized that there are several interrelated parameters which must be considered when evaluating the suitability of alternative sites for a tailings impoundment. These include such factors as the geology, hydrology, seismology, meteorology, and topology of the site. By placing a specific limit on the upstream catchment area, the NRC staff believes that the most suitable impoundment site and/or tailings management plan might be excluded or unnecessarily rejected when all interrelated parameters are evaluated. Thus, the NRC staff does not believe that a specific limit should be imposed on catchment areas as suggested.

The criterion on earthquake specifications now requires an impoundment to be designed to withstand a maximum credible earthquake which might occur at the site where the impoundment is located. Thus, the criterion permits flexibility in that the strength of the dam structure must be based on earthquake parameters of the site at which the structure is located.

> Comment: The NRC should clarify its rules by adding an additional expiration date to § 40.26(b)(2). (74)

Response: § 40.26(b)(2) as set forth in the NRC's August 24, 1979, Federal Register notice provided a general license to cover byproduct material in Agreement States until November 8, 1981. In view of amendments to the UMTRCA in November, 1979 (i.e., Public Law 96-106), the NRC has no jurisdiction at this time over byproduct material in Agreement States. Thus, § 40.26(b)(2) was revoked as an effective NRC regulation in the Commission's Federal Register notice of February 26, 1980 (45FR 12377).

> Comment: Criteria 8 should have some penalty associated with continuation of yellowcake drying and packaging operations without effluent control devices in operation. Penalties for deliberate misrepresentation, covering up leakages, overexposures, and off-site losses should be made a federal offense, with appropriate mandatory fines and/or prison sentences. Compensations should be established for situations resulting from violations of any of the proposed rules, or any inadvertent losses of source or byproduct materials resulting in off-site dispersion of these materials, without the requirement by the contaminated land's owner to prove specific resulting losses in court. (79, 92)

Response: §§40.71 and 40.81 of 10 CFR 40 already contain provisions concerning misrepresentations and violations of NRC regulations. These provisions are based on, and limited by, NRC stationary authorities.

> Comment: Results of site inspections required by Criterion 12 should be made publicly available. (79)

Response: Results of all NRC inspections are made publicly available. All inspection reports are placed in NRC public document rooms. Individual copies of such reports may be obtained upon request by members of the public.

> Comment: §150.31, concerning requirements for Agreement State regulations of byproduct materials, should be strengthened by requiring sworn testimony and a minimum public review period of 90 days in rulemaking cases. (79)

Response: Although the NRC staff believes that in many cases these suggestions may be useful, it would not be appropriate for the NRC to mandate this in the regulations. Two reasons support this opinion: 1) such requirements go beyond the mandate of the UMTRCA, and the legislative history indicates that an expansive interpretation of these provisions would be improper, and 2) such requirements exceed what is required of the NRC, contrary to the scheme of minimum Federal requirements to establish a uniform national program for tailings management.

The regulations, as presently drafted, accurately represent the requirements of the UMTRCA. The legislative history of the provisions of the Act imposing these requirements make it clear that the NRC is not supposed to embellish them without additional procedural steps. In describing these provisions in congressional floor debate, Representative Dingell, one of the principal authors of the Act, stated-

> . . .[A]gain, I stress Chairman Udall and I do not intend any trappings of adjudicatory proceedings in adding this provision.*

Further, the suggested requirements would impose upon the Agreement States procedural requirements more stringent than those imposed upon the NRC. The NRC, for example, is not required to take sworn testimony under oath in informal rulemaking procedures. Similarly, the Administrative Procedure Act, 5 U.S.C. 553 (1976), provides that Federal agencies such as the NRC offer a comment period plus thirty days' notice prior to promulgating a regulation, and allows immediately effective regulations in certain circumstances. Although section 275 of the Atomic Energy Act of 1954, as added by the Mill Tailings Act, provides for a 90-day period before final promulgation of EPA regulations governing mill tailings, that requirement clearly applies only to EPA - not to NRC or the Agreement States. Thus, because the regulatory program for Agreement State mill licensing described in section 274 of the Atomic Energy Act, as added by the UMTRCA, provides for a scheme of minimum Federal standards, it does not appear appropriate for NRC to impose upon the States requirements more stringent than those NRC must itself follow.

> Comment: At least annual monitoring will be necessary for several years before we can consider "walk-away" situations. (84)

Response: As noted in the draft GEIS (see Sections 10.3 and 14.1), the need for, and details of, any postoperational monitoring programs will depend upon the mode of tailings disposal and site-specific parameters. As described in Section 10.3, it is expected that surveillance consisting of something on the order of annual inspections is expected indefinitely. There will also be a period of more intensive monitoring (the so-called compliance determination period referred to in Figure 14.1 and described in Section 10.3) following, reclamation, but before a licensee will be released (by license termination).

> Comment: Potentialities of accidents, spills, abandonment of poor sites and other related incidents are not addressed in the regulations. (89)

Response: The issues identified in this comment are all discussed in the GEIS. They are not explicitly addressed in new Appendix A to 10 CFR 40 since they are already covered in other parts of the Commission's regulations and operating conditions of specific licenses. For example, should an accident occur, remedial cleanup can be required as a condition of further licensed operations. Additional information on terms and conditions of licenses is contained in § 40.41 of 10 CFR 40. Also, section 40.81 of Part 40 provides penalty provisions for violations of NRC regulations in terms of the issues identified in this comment. Surety arrangements discussed in Section 14.2, and required by Criterion 9 of the regulations, will provide for full site reclamation in the event of abandonment.

> Comment: Criterion 6 should guarantee the determination of natural background by the NRC or Agreement State before licensing. (92)

Response: Data concerning natural background radiation levels, obtained by the applicant throughout the course of the preoperational monitoring program, is submitted to the NRC in conjunction with a license application. It has not been NRC practice to make independent background level determinations in the past. However, should there be sufficient doubt of any measurements made by applicants, either the NRC or an Agreement State may make confirming measurements and/or withhold licensing action until such time as any questions on such measurements have been resolved. The NRC staff does not believe there is sufficient justification, in view of present regulations concerning commencement of construction and preconstruction monitoring, etc., to warrant a regulatory requirement that NRC or an Agreement State must determine the natural background at a prospective mill site.

> Comment: Criterion 7 should require an investigation of natural disease rates within a 50 mile radius of a prospective mill site, two years before any major site construction. (92)

Response: The NRC staff has estimated, in its generic environmental impact assessment, the potential number of health effects which might result from the operation of a uranium mill. The potential number of health effects, based on reasonably conservative assumptions, are estimated to be so small as to be undetectable within a fifty mile radius of a mill. Therefore, the NRC staff does not believe a regulatory requirement should be imposed on an applicant to perform such investigations.

* Cong. Rec. 1112,968 (daily ed., Oct. 14, 1978).

> Comment: Criterion 8 should include water contamination as a potential source of radiation exposure. (92)

Response: Criterion 8 deals with the prevention of airborne effluents from milling operations. The reduction of potential radiation exposures from water contamination is addressed by Criterion 5.

> Comment: The criteria in Appendix A should include a requirement for the development of a back-up repository capable of holding tailings for utilization for cleanup purposes, should there be a high seepage volume or spill. (92)

Response: Through utilization of the conservative design, testing and analysis guidance of NRC Regulatory Guide 3.11, and companion guides, and with the full independent geotechnical reviews performed by NRC in licensing facilities, there is sufficient assurance that embankments (to the extent they are used under Criteria 3 and 4 of the final regulations) will not fail as to make secondary catchments unwarranted. In fact, it is very possible that reliance on secondary catchments can lead to less than scrupulous attention to sound primary impoundment design and construction.

Similarly, the staff considers that with the seepage control measures prescribed in Criteria 5 of the final regulations, combined with required groundwater monitoring programs (see Chapter 10), a secondary catchment is not needed for seepage collection.

> Comment: A dynamic monitoring and mitigation plan, including the postoperational and operational phases, should be required before an operating or construction permit is given for a mill. (99)

Response: As delineated in Regulatory Guides 3.5 and 3.8, and in Chapter 10 of this document, applicants are required to provide extensive information on proposed monitoring and mitigation plans to the NRC in support of license applications (also see Appendices R and V). These plans are thoroughly reviewed pursuant to the provisions of the Atomic Energy Act and the National Environmental Policy Act. Comments on such plans are obtained from the public and state and Federal agencies, such as the U.S. EPA, prior to acceptance and approval by the NRC. Approved plans do provide for changes which might be needed based on development of new knowledge and management techniques. It should be noted also that licenses are issued for only a five year period and are updated and renewed at the end of this time so as to take into account current knowledge and management practices. Although Section 10.3 generally characterizes likely long-term monitoring requirements, specific details of monitoring programs will be established on a case-by-case basis.

> Comment: Section 12.2.1 of the GEIS should also address short-term siting and design requirements, such as sequentially filled and stabilized tailings cells, for public health and safety protection during operations. (99)

Response: Criterion 8 of new Appendix A to 10 CFR 40 requires consideration of progressive reclamation schemes, for the purposes mentioned.

> Comment: Monitoring and enforcement of regulations are inadequate. Funding for routine monitoring with independent testing systems for surprise visits (inspections) should be provided. More follow-up is needed to ensure that noncompliance items are corrected. A special enforcement section within the New Mexico environmental improvement division and within the NRC is needed. (120)

Response: The NRC staff considers its uranium mill regulatory program to be entirely adequate in these and other respects. The Commission's Office of Inspection and Enforcement regularly inspects milling operations, and takes steps as necessary to insure that noncompliance items are promptly corrected. In addition, the adequacy and effectiveness of an Agreement State's inspection program is one of the factors considered in NRC's periodic review of Agreement State program adequacy.

> Comment: The use of deep mines for tailings disposal should be better addressed. (126)

Response: The staff considers the level of attention to deep mine tailings disposal provided in the draft GEIS to be appropriate, given the generic purpose of the evaluation. This issue is discussed in Sec. 12.3.3.3; the final regulation changes allow for deep mine disposal as appropriate.

Comment: Operational controls and operational inspections for tailings impoundments should be instituted and/or improved. (126)

Response: The NRC staff has developed criteria relating to operational controls and operational inspections of mill tailings systems. These criteria are delineated in Regulatory Guide 3.11.1 entitled, "Operational Inspection and Surveillance of Embankment Retention Systems for Uranium Mill Tailings." These criteria were issued for public comment in April, 1979. The criteria provide guidance on in-service inspection and surveillance which should be performed by licensees at regular intervals, to check the conditions of retention systems and associated facilities, and to evaluate their structural safety and operational adequacy. Also, Criterion 8(A) of new Appendix A to 10 CFR 40 requires daily inspections by qualified personnel.

Comment: There needs to be an "as built" review inspection of mills and tailings impoundment systems. (126)

Response: It is NRC practice to conduct preoperational "as built" inspections of all uranium mills and impoundment systems.

Comment: Monitoring is needed along the full length of the tailings distribution system. (126)

Response: Criterion 8(A) of the revised regulations specifies daily inspections of tailings or waste retention systems.

Comment: The Commission should adopt criteria for the transport of tailings since wastes from in situ operations must be relocated. (105)

Response: Federal regulations (i.e., Department of Transportation) already exist which cover the transport of low level radioactive materials. These regulations are written in terms of performance criteria and apply to all types of low level radioactive materials, including tailings. Above ground wastes from in situ or other extraction operations are not required to be relocated (see Sec. 12.5). Criterion 2 states that, in order to avoid the proliferation of small disposal sites, relocation of these sites shall be the case unless it is demonstrated to be impracticable, or that the advantages of onsite disposal clearly outweigh the benefit of reducing perpetual surveillance obligations.

Comment: The Commission should attempt to provide some guidance and develop a policy on reducing to the extent possible, the number of sites in any given area. A regional plan should be developed for management of mill tailings, including numbers of and standards for disposal sites within a region. (105, 115)

Response: The staff does not recognize a present significant need to carry out these suggestions, inasmuch as new mills are evaluated in the context of any nearby existing operations and impacts. Cumulative impacts from multiple mills in a single area are addressed in this statement (See Chapters 6 and 9).

Comment: The Commission should require records on the location of tailings to be recorded at local levels of government. (105)

Response: The provisions of the Uranium Mill Tailings Radiation Control Act specify ownership requirements of land on which tailings are located. Under these provisions, it is anticipated that such land will either become the property of the Federal government or the state in which the land is located. Such changes in land ownership are customarily reflected in local land records. Separate records will be maintained by the NRC, through normal licensing procedures. In the event government land ownership is determined to be unnecessary, Criterion 11 of Appendix A to 10 CFR 40 requires that the owner and any future owners be made aware that tailings are located on the land and, thus, the land owner will be subject to perpetual NRC licensing which may include land use restrictions. Notification of future owners would in all likelihood require placement of notice in the local public file, usually held at the county courthouse.

6.5 Specificity/Flexibility

Comment: The imposition of a requirement for a 3-meter earthen cover should be delayed until superior covering processes are abailable in a few years. (52)

Response: The staff considers it prudent to specify the minimum thickness, given the firm knowledge of the problems discussed in Chapter 12. The NRC, as well as other government agencies and industry, will continue to conduct research into tailings cover material technology. It is not beyond the realm of possibility that techniques could be found for economically resolving the concerns that lead to the minimum cover thickness requirement, under certain conditions, which would make it reasonable to relax the requirement. However, the staff is aware of no technology that would do this and cannot ignore known problems upon the speculation that they might, in the future, be resolved. (See Summary Section 9 and Section 12.3.4.7.)

> Comment: The second draft GEIS should attempt to develop more flexibility of approach, to recognize a greater number of alternative situations. Heap leaching should be considered in detail. (52)

Response: The staff considers that the revised regulations being implemented provide appropriate flexibility. The staff has developed regulations mindful of the fact that the problem of mill tailings management is highly site-specific. The precise details of a program can be worked out only when unique conditions of a site are known. At the same time, however, the staff has tailored the regulations to be appropriately specific where required: (1) for fairness to license applicants and mill operators (it reduces uncertainty about what requirements are and, thus, allows them to plan their operations reasonably); (2) to assure consistency in application of requirements which would not occur if regulations are too broad; (3) to assure that a minimum level of protection exists in veiw of protential problems. For example, a minimum cover thickness is specified, and criteria for surface stabilization are established, to account for known problems which potentially threaten long-term tailings cover performance (see Summary Section 9, and Chapter 12).

The staff considers that this statement addresses heap leaching in an appropriate level of detail.

> Comment: While we recognize that the definition given in Section 40.4 (a-1) is taken from UMTRCA, it is too general to provide the basis for effective regulation. The NRC should interpret the law to distinquish between hazardous and nonhazardous wastes, so as to exclude the latter from profitless regulation. With respect to the same definition, we recommend that explicit provision be made for unconventional extraction techniques. In-situ mined ore bodies are mentioned, but other techniques are also used. (53)

Response: The staff is bound by the wording of the UMTRCA and otherwise considers that such wastes as are included in the definition of byproduct material are indeed hazardous or potentially hazardous, and should be regulated in accordance with the conclusions of this document.

> Comment: Specific methods should not be established for tailings management. Instead, the technical criteria should be limited to concise statements of the goals or objectives, perhaps taking the form of standards of performance. To establish by rule techniques or methods is to assume that there is nothing new to be learned. The Technical Criteria should be totally revised to establish the societally and environmentally beneficial targets for the design of tailings management systems without limiting the flexibility as to the methods to achieve those targets. (55, 85)

Response: The staff considers the requirements to be imposed under the revised regulations to be appropriate, given the current state of knowledge. If appropriate at some future time, these requirements will be modified. The staff considers the alternative of waiting indefinitely for uncertain technological improvements to be unacceptable (this issue is further addressed in Summary Section 9). The staff has developed regulations mindful of the need to avoid being overly restrictive. The staff recognizes, as stated repeatedly in this document, that the problem of mill tailings management is highly site-specific. The precise details of a program can be worked out only when unique conditions of a site are known. For example, the extent of potential groundwater impacts, or the erosion potential of a tailings disposal program, depends critically upon topographic, geologic, hydrologic, and meteorologic conditions, which can vary significantly from site to site. The regulations have been drafted to allow sufficient flexibility to appropriately reflect this fact.

At the same time, however, the staff has tailored the regulations to be appropriately specific where required: (1) for fairness to license applicants and mill operators (it reduces uncertainty about what requirements are and, thus, allows them to plan their operations reasonably); (2) to assure consistency in application of requirements which would not occur if regulations are too broad; (3) to assure that a minimum level of protection exists in view of potential problems. For example, a minimum cover thickness is specified, and criteria for surface stabilization are established, to account for known problems which potentially threaten long-term tailings cover performance.

Comment: The NRC has failed to recognize that mill wastes and tailings, in some circumstances, may be found to be nonhazardous. (55)

Response: The staff can not envision circumstances under which the wastes governed by the regulations associated with this statement could be appropriately considered non-hazardous.

Comment: Several technologies of actual or potential application in the uranium industry are not thoroughly evaluated in the GEIS, and the proposed rules are therefore found to be misdirected. Such examples include solution mining, heap leaching, reprocessing of tailings, vat leaching, and tailings disposal underground in conventional undergound mines or hydraulic borehole mining cavities. (55, 85)

Response: While the evaluations provided within the GEIS of such technologies may be limited, the staff cannot agree that the revised regulations are misdirected in terms of applicable requirements. Detailed evaluations of the processes mentioned are not within the scope of this document, as identified by the Commission early in the planning of this effort (as discussed in Section 1.2).

Comment: In the Introduction section of Appendix A to 10 CFR 40, the word "requirements" should be replaced with the word "criteria." (55)

Response: The change suggested has been adopted.

Comment: When consideration is given to disposing of tailings or other wastes at "remote sites," it is necessary to clearly delineate countervailing considerations which could negate the requirement of disposal at remote areas. (55)

Response: As written, the revised regulations specify that the quality of remoteness must be optimized in conjunction with other qualities which are delineated (see the discussion of this issue in the Summary and in Sec. 12.3.2; also see revised Criterion 1 of new Appendix A to Part 40).

Comment: Consolidation of disposal sites as required by Criterion 1 would impinge upon the authority of a company to have its own mill; this concentration by the government should not be forced on industry. (55)

Response: Consolidation of wastes from small aboveground operations is required unless it is demonstrated to be impracticable, or that the advantages of onsite disposal clearly outweigh the benefit of reduction in perpetual surveillance obligations. The staff perceives no loss of opportunity, by virtue of this stipulation, for a company to have its own mill.

Comment: The final two sentences of Criterion 6 appear unnecessary. The use of synthetic materials for caps should not be totally dismissed by regulation, for to do so is an unjustified restriction of technological development. Cover material restrictions based upon radium content likewise do not need to be established since an overriding limit on incremental radon flux would be sufficient. "Elevated levels of radium" is not defined and will not be defined until EPA standards are set. These referenced sentences should, therefore, be stricken. (55, 77)

Response: Regarding justification for the mentioned cover requirements, please refer to Section 12.3.4.7. "Elevated levels of radium" is defined in terms of the radium content of surrounding natural soils.

Comment: The Technical Criteria should specify the required containment period as a principal performance factor. (56)

Response: The staff has stated in revised Criterion 1 that isolation should be provided for "thousands of years." The staff can be no more specific because of the problems associated with reviewing disposal plans against the vast uncertainties inherent in examinations of longer time frames. However, the overall objective of the staff's regulations is to assure isolation indefinitely far into the future.

Comment: The feasibility of applying thick earthen covers, or using other methods, should be evaluated on a site-specific basis, possibly through the current licensing process. (59)

Response: The staff's evaluation of alternative cover technologies is conclusive in that thick earthen covers will be necessary in all cases. This conclusion, based on current knowledge, is appropriately reflected in the staff's proposed and final regulations (see Sec. 12.3.4, which evaluates the full range of possible conditions and concludes that this requirement is reasonable.).

> Comment: The proposed rules advanced in the draft GEIS unreasonably reduce planning flexibility, and serve to restrict advances in the state of the art. (71)

Response: The staff believes planning for the future, with respect to final tailings disposal, must occur now, and must necessarily be based on currently available knowledge. This approach does not forfeit any opportunity for later revision, as may be appropriate in view of new information. The staff has developed regulations mindful of the fact that the problem of mill tailings management is highly site-specific. The precise details of a program can be worked out only when unique conditions of a site are known. At the same time, however, the staff has tailored the regulations to be appropriately specific where required: (1) for fairness to license applicants and mill operators (it reduces uncertainty about what requirements are and, thus, allows them to plan their operations reasonably); (2) to assure consistency in application of requirements which would not occur if regulations are too broad; (3) to assure that a minimum level of protection exists in view of potential problems. For example, a minimum cover thickness is specified, and criteria for surface stabilization are established, to account for known problems which potentially threaten long-term tailings cover performance. (See Summary Section 9 and Section 12.3.)

> Comment: Particularly because of the very general nature of NRC's criteria, there is room for great variation in how those criteria may be interpreted and applied by particular Agreement States, assuming that Agreement States choose to follow NRC's criteria at all. What to NRC may be a populous area might by some states be deemed "remote"; what to NRC might be unacceptable above-grade disposal might to some states be "below grade." (74)

Response: The staff acknowledges that it has not been able to be numerically definitive in a number of instances. This is primarily due to the intensely site-specific nature of the problems addressed. The staff has concluded that regulatory guides better serve the purpose of exemplifying acceptable methods of achieving the criteria contained in the revised regulations. The staff's final regulations largely specify performance objectives, against which proposals will be judged in the case-by-case reviews required under the UMTRCA and 10 CFR Part 51, which are documented and made available for public scrutiny.

> Comment: There is a lack of flexibility in the regulations, particularly regarding the 3-meter minimum cover thickness and the radon emanation limit. (77)

Response: The staff considers that the minimum cover thickness requirement and the radon exhalation limit should be met in all cases. This is more fully discussed in Sec. 12.3.4 and Summary Section 9.

> Comment: Criterion 4 should be redrafted with points (a) through (f) shown as recommendations, by using the word "should" instead of "shall." (86)

Response: The suggested change would not convey the staff's intended meaning. The staff cannot consider the requirements enumerated under proposed Criterion 4 as optional. The staff considers that these factors must be considered in the tailings management program developed by the applicant.

> Comment: The use of a dose objective should be considered in order to allow for short term off-normal performance of yellowcake emission control systems. This would be consistent with practices at nuclear power plants. (86)

Response: The staff considers that such releases must be maintained as low as reasonably achievable in order to minimize individual and population exposures. The use of a dose objective would not be an effective means of achieving this goal, and would be duplicative of present requirements effectd by EPA under 40 CFR 190.

> Comment: The proposed criteria establish very specific requirements and "prime options" which preclude individual and site-specific consideration of each mill license application. (85)

Response: As previously discussed, the staff has allowed flexibility, to the extent such flexibility is considered appropriate on the basis of current information. Regulations now being implemented by the staff will be periodically examined by NRC on the basis of new information, to determine if changes or revisions to the requirements are warranted. (See Summary, Section 9 "Form of Regulations.")

> Comment: In addition to self-sustaining vegetative cover and riprap, another option should allow a license applicant to use any other techniques or methods which meet NRC's health goals. (55, 85)

Response: The staff is not aware of any viable alternatives for providing adequate surface erosion control other than those presently stipulated in the new Appendix A to Part 40. As indicated above, these requirements are established on the basis of information available at this time. Alternative techniques will be evaluated by the staff as they are developed, to determine their effectiveness in providing the necessary protection. Regulation changes now being implemented will be revised in the future, as appropriate, to reflect new information.

> Comment: Criterion 12 requires that final disposition of tailings should be such that "active maintenance is not necessary to preserve isolation." This establishes passive maintenance as a specific requirement in mill licensing and ignores the need for site-specific considerations recognized and encouraged in the draft GEIS. (85)

Response: The draft GEIS did not recognize or encourage site-specific considerations to the extent that such consideration would allow for final tailings disposal in such a fashion as to require active maintenance to preserve isolation.

6.6 Indian Issues

> Comment: The Federal Government should license and retain regulatory control over uranium operations on Indian lands in Agreement States. (58, 75, 126)

Response: Uranium operations on Indian lands in Agreement States can take place in two different institutional forms, (i) where the operator is operating as a private industrial enterprise, or (ii) where the operator is an Indian tribe (or tribal council) recognized by the United States as a legal entity.

In the first case the legal position of the Atomic Energy Commission, and now of the NRC, is that private industrial concerns operating on Indian lands would be subject to the jurisdiction of the Agreement State. This view is reached on the basis of the Atomic Energy Act of 1954, as amended, which confers regulatory jurisdiction over "persons" with respect to receipt, possession, use, transfer, etc. of source, special nuclear, and byproduct materials within the territorial jurisdiction of the United States as a whole. Under § 274 of the Act, this jurisdiction over persons is relinquished to the State under an agreement. Further, § 274 of the Act provides no basis to distinguish for jurisdictional purposes between private persons depending upon where within a state they operate.

Two exceptions to the above exist. First, in 10 CFR 150.10, NRC jurisdiction is retained over agencies of the Federal government in Agreement States. Federal government agencies (with the exception of Atomic Energy Act activities of the Department of Energy which are not subject to licensing) remain subject to licensing and regulation by NRC in Agreement States.

The exclusion of Federal agencies from Agreement State regulation is a corollary of constitutionally based Federal-State relationships (Const. Art. VI, Cl.2). It is not a requirement of the Atomic Energy Act. Whether an Indian tribe, tribal council, or other group of Indians would be licensed by NRC or the Agreement State would depend, under current rules, upon whether the Indian entity could legitimately be considered a Federal agency for the purpose of nuclear materials licensing. Thus, exclusion of Indian entities from Agreement States regulation must be based upon some legal authority or principles of law other than those found in the Atomic Energy Act, as amended. If an Indian entity can demonstrate that it should be treated legally like a Federal agency, the NRC would be the licensing agency.

Second, persons conducting activities subject to licensing in areas of exclusive Federal jurisdiction within an Agreement State are under the jurisdiction of NRC. This also results from Constitutional requirement (Const. Art. I, Sec. 8, Cl.17).

> Comment: Individual Indian land allotments subject to a Federally imposed restraint on alienation should be included in the concept

of "Indian lands" not subject to title and custody transfer when used for the disposal of tailings (see Criterion 11, paragraph G, and proposed 10 CFR 150.15a(b)(6)). (80)

Response: Section 83(b)(8) of the Atomic Energy Act of 1954, as added by the Uranium Mill Tailings Radiation Control Act of 1978, states that the UMTRCA provisions for transfer of title and custody to land shall not apply to "lands held in trust by the United States for any Indian tribe or lands owned by such Indian tribe subject to a restriction on alienation imposed by the United States." Criterion 11, paragraph G, and proposed 10 CFR 150.15(b)(6) are paraphrases of the statutory language. In view of the explicit statutory language, NRC has no discretion to include individual Indian allotments in the concept of tribal lands in its regulations.

Comment: Long term surveillance funds for projects on Indian lands should be deposited in the U.S. Treasury in trust for the affected Indian tribes. (58)

Response: Unless otherwise directed by statute, all funds collected by agencies of the United States are to be paid into the Treasury generally (see 31 U.S.C. Ch. 10). To deposit long-term surveillance funds from projects on Indian lands into the Treasury in a trust account for the affected tribes would require an Act of Congress. NRC could not direct such a disposition on the basis of present authority. Further, since the Department of Energy, or the Federal agency responsible for surveillance at sites ultimately transferred to the Federal government, would monitor disposal sites on Indian lands as well, such a requirement for a special trust account would be unnecessary and inconsistent with the general program established in the regulation.

Comment: Affected Indian tribes should be consulted in advance of licensing of projects on Indian lands. (44)

Response: Affected Indian tribes will be consulted in advance of NRC licensing of projects on Indian lands. Since a private operation on Indian lands in an Agreement State would undoubtedly need a lease from, or contract with, the tribal entity, it appears to NRC that tribal consultation with Agreement State licensing authorities can be secured through the leasing or contracting arrangement. In addition, the Agreement State regulatory agency would undoubtedly coordinate with any affected Indian tribe in the course of preparing and/or soliciting comments on their environment appraisal (required under the UMTRCA).

6.7 Legal Issues

Comment: The new requirements for Agreement State regulation of uranium milling processes (source material licensing) are effective immediately. The proposed regulations should reflect this interpretation of the Uranium Mill Tailings Radiation Control Act of 1978. (47, 65, 91)

Response: Amendments to the UMTRCA clarify this issue (See Pub. L. No. 96-106 § 22, 93 Stat. 799 (1979).) The amendments provide that the new requirements of Section 274o of the Atomic Energy Act of 1954, as amended by the UMTRCA, "shall apply only to the maximum extent practicable during the three-year period beginning on the date of the enactment of the [the UMTRCA] Act." [Pub. L. No. 95-604 § 204(e)(2), 92 Stat. 3037 (1978).] The proposed regulations, which make the new requirements of Section 274o mandatory in November 1981 - three years after enactment of the UMTRCA - are entirely consistent with the law as it now stands. The NRC is, however, taking steps during the interim period to assist the Agreement States in meeting the requirements of Section 274o to the maximum extent practicable.

Comment: The NRC has failed to establish that uranium mill tailings constitute a threat to the public health or the environment and consequently, the proposed regulations are unfounded. Many of the proposed rules are arbitrary, capricious, and are without rational support. The technical criteria set forth in proposed Appendix A to 10 CFR Part 40 incorrectly assume, without supporting evidence, that radon emanations from the surface of a uranium tailings area pose a significant threat to the public health and safety. This assumption, moreover, is contrary to the actual experience of long-experienced mill operators. The proposed criteria and rules purport to be based upon a draft GEIS on uranium milling which is itself deficient. Indeed, many of the licensing criteria which the Commission has derived from that draft statement are, for various specific reasons, arbitrary, capricious and unreasonable. (53, 55, 59, 60, 85)

Response: The environmental and health effects of uranium milling and mill tailings are discussed at length throughout the draft GEIS. See, e.g., Ch. 6, "Environmental Impacts"; Ch. 12, "Proposed Regulatory Changes"; Section 12.3, "Benefit-Cost Analyses and Rationale for Regulatory Requirements"; and App. G, "Calculations for Radiological Assessments." The draft GEIS supports the conclusion that regulation of uranium milling and mill tailings is necessary to protect the public health and safety and the environment.

Further, the proposed regulations governing uranium milling and mill tailings are based not only upon the draft GEIS, but also upon the mandate of the Uranium Mill Tailings Radiation Control Act of 1978. This mandate is based upon the Congress' finding that:

> "...uranium mill tailings located at active and inactive mill operations may pose a potential and significant radiation health hazard to the public, and that the protection of the public health, safety, and welfare and the regulation of interstate commerce require that every reasonable effort be made to provide for the stabilization, disposal, and control in a safe and environmentally sound manner of such tailings, in order to prevent or minimize radon diffusion into the enviroment and to prevent or minimize other environmental hazards from such tailings." Public Law 95-604, § 2(a), 92 Stat. 3021 (1978).

Thus, in addition to the draft GEIS' conclusion that the program set forth in the proposed regulations is required, the NRC is under a mandate from Congress to formulate a strong regulatory program covering mill tailings.

> Comment: Section 150.31 of the proposed regulations, setting forth requirements for Agreement State licensing of uranium milling and uranium mill tailings, merely repeats the language of the Uranium Mill Tailings Radiation Control Act of 1978 without providing needed guidance to the States. For example, the regulations fail to define the words "to the maximum extent practicable," confirm that the State must perform an independent environmental review, or provide guidance as to what type of "major construction activity" is prohibited until the State's environmental analysis has been completed. (47, 74)

Response: Section 150.31(c)(3) has been amended to make it clear that the Agreement State must perform its own environmental analysis. The phrase "major construction activity" has been further defined. Further, guidance is being developed for the uranium mill states in the form of criteria to be used for entering into amended agreements.

> Comment: The regulations dealing with site and byproduct material ownership fail to provide any additional guidance to that provided in the UMTRCA as to when and how land transfers will be affected [sic.] and when use of surface and subsurface estates of such transferred land will be permitted....In essence, Criterion 11 of the regulations merely recites the language of the UMTRCA.
>
> Specifically, criterion 11B should enumerate the terms and conditions of licenses requiring land transfer, 11D should specify exactly how use of surface or subsurface estates of transferred land would be permitted, and 11E should state the weight NRC will give to the status of land ownership in applying the grandfather clause for milling operations that predate the effective date of the UMTRCA. (47)

Response: It is not practical, at this time, to make the regulations concerning land transfer extremely detailed. First, the Commission has had no experience in carrying out this new requirement and accordingly has no base of experience on which to draw in making the required policy determinations (such as the weight to be given the status of land ownership). Second, it should be obvious that many of these decisions will have to be made on a case-by-case basis: no two licenses, landforms, or ownership situations will be the same. Third, the regulations, and the statute on which they are based, are more detailed than many others used by the Commission.

For example, the UMTRCA provides that if any private use of the tailings disposal site is permitted, it must take place under careful supervision. Under Section 83b.(1) of the Atomic Energy Act, if private ownership is permitted, the site must be under NRC regulation. That section also provides that subsurface or surface estates of land transferred to the United States or a State may be put to use if the Commission determines by order that such use would not endanger the public health, safety, or the environment. In such cases, the original owner who transferred the land to the government must be given rights of first refusal. Section 83b.(7) provides that there may be no transfer of title from the government to a private party under Section 83b. unless the transfer is carried out in the same manner as provided in Section 104(h) of the UMTRCA, which permits the Department of the Interior to dispose of certain subsurface mineral rights.

It should also be noted that the Commission is required to follow the Administrative Procedure Act and, of course, the National Environmental Policy Act of 1969 (NEPA) when making such determinations regarding land transfers. Thus, the Commission will solicit public participation when making decisions regarding land transfer and subsequent use of tailings disposal sites.

> Comment: The draft GEIS gave very brief consideration to the issue of commingled tailings, only referring to the Uranium Mill Tailings Radiation Control Act of 1978 assigning primary responsibility to the Department of Energy for carrying out remedial actions. The GEIS should exempt all tailings generated under AEC contract pending final action of the U.S. Congress. (49, 59, 86)

Response: The NRC is aware of the difficulties existing milling operations may have in complying with the new requirements established in the GEIS and in the regulations implementing the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA). In fact, the legislative history of that Act states:

> "The NRC should take such factors into account and provide a means to alleviate or mitigate those problems where appropriate while assuring that the purposes of the act are fully met." H.R. REP. NO. 951480, Pt. 2, 95th Cong., 2d Sess. 44 (1978) (emphasis added).

This same legislative history, however, makes it clear that under the law as it now stands, the NRC is to impose and enforce all its regulatory responsibilities on commingled tailings:

> "The committee is aware that at some mills, tailings were accumulated years ago under Federal contract. But, as noted earlier in this report, the tailings are commingled with tailings derived from commercial operations. Also, they are subject to regulation by the NRC or the States. Consistent with the views of the committee as to the basis for Title I, the committee does not believe it appropriate to finance the stabilization of any part of these tailings which are subject to regulation under the 1954 act. However, Subcommittee Chairman Dingell has recently written to the DOE concerning these mills to obtain more data. The committee expects NRC to exercise all its responsibility concerning these sites under the 1954 law." H.R. REP. No. 95-1480, Pt. 2, 95th Cong., 2d Sess. 42 (1978) (emphasis added).

Thus, until the controlling statutes are amended, the NRC is required by the Atomic Energy Act of 1954, as amended by the Uranium Mill Tailings Radiation Control Act of 1978, to regulate commingled uranium mill tailings in the same manner as other tailings, so as to ensure that the purposes of the UMTRCA are fully met.

> Comment: NRC should recognize that Section 275 of the Atomic Energy Act, 42 U.S.C 2022, requires EPA to promulgate standards covering uranium mill tailings by May 1980. The standards are to have general application for the protection of public health, safety, and the environment from radiological and nonradiological hazards associated with processing, possession, transfer and disposal of mill tailings. The Act contemplates that standards first be developed by EPA and then, rules be promulgated by NRC, rather than the order of events currently being proposed. Because of the statutory requirement of public participation in the development of EPA's standards, neither NRC, EPA, nor anyone else can presently anticipate EPA's final standards. In this regard, it should also be noted that the published listing of information EPA intends to rely on in developing the standards is by no means limited to the information contained in the draft GEIS. (53, 55, 59, 60, 85, 86)

Response: Nothing in the Uranium Mill Tailings Radiation Control Act of 1978 or its legislative history indicates that the NRC is without authority to promulgate regulations covering uranium milling and uranium mill tailings pending promulgation of the EPA standards required under Section 275 of the Atomic Energy Act of 1954. To the contrary, under Sections 81 and 84 of that Act, the Commission is under an immediate duty to insure that the management of uranium mill tailings is carried out in a manner that will protect the public health and safety and the environment. Moreover, it is clear from the statutory scheme applicable to the Agreement States that NRC's minimum Federal standards are to be promulgated as promptly as possible, so that the Agreement States, pursuant to Section 104 of the Uranium Mill Tailings Radiation Control Act, will be able to have those minimum Federal standards in place by November 8, 1981.

As stated in the preamble to the proposed regulations, 44 Fed. Reg. 50015, 50016 (1979), the NRC is aware that its regulations covering uranium milling and mill tailings must comport with the standards of general application to be established by EPA under Section 275. The NRC staff has been and will continue working closely with EPA to coordinate this effort. To date, our understanding from EPA is that our regulations and their proposed general standards will be compatible.

> Comment: The NRC has failed to heed the mandate of the U.S. Congress, as specified in the Uranium Mill Tailings Radiation Control Act of 1978, Section 206(a), which establishes the authority and responsibility of the U.S. Environmental Protection Agency with regard to promulgating health and environmental standards for uranium mill tailings (Section 275 of the Atomic Energy Act, as amended). Specifically, Section 275b.(1) provides that EPA shall "promulgate standards of general application for the protection of the public health, safety and the environment from radiological and nonradiological hazards...of byproduct material....
>
> The Atomic Energy Act Section 275b.(2) (as amended) makes clear that the standard setting function of EPA must be consistent with the Solid Waste Disposal Act as amended by the Resource Conservation and Recovery Act. Furthermore, it is clear in UMTRCA and the amended Atomic Energy Act, Section 275.(d) [sic.], that the NRC is not responsible for standard setting. The NRC responsibility is in the area of "implementation and enforcement of the standards" promulgated by EPA. (55, 59, 86)

Response: The Commission's authority over uranium milling and mill tailings extends beyond Section 275 of the Atomic Energy Act. Although standards and requirements established by NRC must be consistent with those of the EPA, the NRC is indeed authorized to establish its own standards and requirements. Section 84 of the Atomic Energy Act of 1954, as added by the Uranium Mill Tailings Radiation Control Act of 1978, provides that:

> "The Commission shall insure that the management of any byproduct material, as defined in Section 11e.(2), is carried out in such manner as-
>
> ...conforms to general requirements established by the Commission, with the concurrence of the Administrator, which are, to the maximum extent practicable, at least comparable to requirements applicable to the possession, transfer, and disposal of similar hazardous material regulated by the Administrator under the Solid Waste Disposal Act, as amended." (Emphasis added.)

Further, Section 83 specifically authorizes NRC standard-setting. It provides that the Commission shall establish license terms and conditions it determines necessary to assure that the "licensee will comply with decontamination, decommissioning, and reclamation standards prescribed by the Commission...." (Emphasis added). Accordingly, the Commission has concluded that it has ample authority to promulgate regulations such as those proposed.

> Comment: Although Congress has established the definition of byproduct materials to include tailings and wastes from source material processing operations, Congress did not require that a single set of standards apply to all such materials. Moreover, the UMTRCA, Section 206, requires EPA to set health and environmental standards for mill tailings (Section 275 of the Atomic Energy Act). It is clear that Congress intended standards to be developed based upon assessed risk, and that certain levels of radionuclide content would be declared by such standards as below levels recognized as hazardous. NRC, in turn, would then be obliged to recognize the distinction established by EPA with respect to the degree of risk or hazard associated with various types of wastes or specific radionuclides. (55)

Response: NRC will conform its regulations to those of EPA, as required by the Mill Tailings Act. If EPA establishes the distinction suggested, the NRC would follow suit. It should be pointed out, however, that nothing in the Mill Tailings Act specifically calls for exemption of certain levels of radionuclide content. To the contrary, the Act mandates that radioactive and nonradioactive hazards be regulated.

> Comment: In addition to the relevant pre-existing authorities contained in the cited Federal statutes (i.e., the Atomic Energy Act, the Resource Conservation and Recovery Act, the Clean Air Act, and the Federal Water Quality Act), mention also should be made of the applicability of authority contained in the Safe Drinking Water Act and the Toxic Substances Control Act." (41)

Response: Section 13.5.2 of the GEIS has been changed to incorporate this suggestion.

> Comment: The proposed regulations should not address ore pads because no uranium milling or ore processing to create source material takes place until ore enters the mill and is processed in the first step of ore grinding. Further, uranium ore on the pad could in no way be considered byproduct material, since it has not been processed. (55)

Response: Section 205.(a) of the UMTRCA amends the Atomic Energy Act of 1954 by adding a new Section 84 which states in part that "the Commission shall insure that the management of any byproduct material, as defined in section 11e.(2), is carried out in such manner as... the Commission deems appropriate to protect the public health and safety and the environment from radiological and nonradiological hazards associated with the processing and with the possession and transfer of such material..." [emphasis added]. The storage of ore on an ore pad prior to milling clearly constitutes an activity associated with processing. Under the language of new Section 84, therefore, it is within NRC's authority to regulate ore pad activities.

> Comment: What is the basis for the determination, appearing in the definition of Section 11e.(2) byproduct material, that underground ore bodies depleted by solution extraction techniques do not constitute the tailings or wastes described in Section 11e.(2)? (92, 99)

Response: Although the Mill Tailings Act was primarily directed at the hazards associated with mill tailings from conventional uranium extraction processes, the congressional floor debate on the legislation indicated that there was some concern that in situ operations, though covered by the new Act, should not fall within its requirement that mill tailings and their disposal site be ultimately owned by the Federal or State governments. On the bases of this legislative history and language in the Mill Tailings Act suggesting that the terms "tailings or wastes" are terms of art in the industry referring to discrete materials capable of controlled disposal, the Commission concluded that the Act does not require regulation of the underground ore bodies depleted by solution extraction processes. It has been NRC practice in licensing in situ facilities to require that such sites be returned to baseline conditions; therefore, potential long-term hazards at these sites are eliminated. Surface wastes from in situ operations, however, are sufficiently like those tailings and wastes from conventional milling operations to merit regulation under the Mill Tailings Act. The underlying analysis for this conclusion appears in a memorandum to the U.S. Nuclear Regulatory Commission from Howard K. Shapar, Executive Legal Director, entitled Staff Response to the Commission Request for Further Information Regarding SECY-79-88 "Timing of Certain Requirements of the Uranium Mill Tailings Radiation Control Act of 1978" (May 7, 1979). This document is available in the NRC's Public Document Room.

> Comment: NRC should have licensing authority over all DOE owned mill tailings, and NRC should not at any time release its jurisdiction over disposal sites for radioactive wastes. (69, 79)

Response: Under the UMTRCA, the NRC will retain regulatory authority over inactive mill tailings and their disposal sites. Section 83b.(1) of the Atomic Energy Act of 1954, as amended by the UMTRCA, provides that even if the Commission determines that government ownership of a tailings disposal site is not required, "such property and materials shall be maintained pursuant to a license issued by the Commission...." Similarly, Section 84b.(5) provides that the Commission may, pursuant to a license, rule, or order, require the Federal or State agency with custody of tailings and their disposal site to undertake monitoring, maintenance, and emergency measures as may be necessary. Section 84 provides similar authority to the Commission. Thus, it is clear that the UMTRCA requires that the NRC assume and retain regulatory authority over mill tailings that have been disposed of. Criterion 11 of Appendix A to 10 CFR 40 does, in fact, require this.

Comment: How will the NRC apply the criteria for uranium milling and tailings management to existing sites, where enormous amounts of tailings have already been generated? (49, 60, 85)

Response: Except for the provision in Section 83b.(4) of the Atomic Energy Act of 1954, as amended by the UMTRCA, which grandfathers certain requirements pertaining to the transfer of title to tailings and their disposal sites to a government agency, the statutes governing NRC regulation of uranium milling and mill tailings management make no provision for exemption or waiver of existing sites from the new requirements imposed by the Uranium Mill Tailings Radiation Control Act of 1978. The legislative history of the Act makes it clear that NRC is to regulate all milling operations--old and new--in a manner that will prevent the need for future remedial actions to clean up inadequately stabilized tailings piles.

See H.R. REP. NO. 1480, Pt. 2, 95th Cong., 2d Sess. (1978). Thus, the NRC is under a mandate to regulate older, existing sites so that the public health and safety and the environment are adequately protected, as would be the case with new sites.

The Commission is aware, however, that this same legislative history also provides that the Commission is to take the problems of existing mills into account "while assuring that the purposes of the act are fully met." (Id., at 44.) Thus, the NRC staff will evaluate each existing operation on a case-by-case basis to determine that long-term stability objectives are satisfied.

It is the Commission's position, as discussed in Section 12.4 and Summary Section 9, that certain requirements in the regulations represent minimum levels of protection of public health and safety, and of the environment, and can and must be met in all cases; the regulations have been revised from their proposed form to clarify this. For example, minimum tailings cover requirements, requirements for erosion protection, financial surety provisions, and the broad requirement that no ongoing, active maintenance be needed to preserve isolation, are mandatory in all cases. It would not be practicable, on the other hand, to line the bottom of an existing tailings impoundment. Also, objectives concerning remoteness from people and providing below grade burial may not be met to the same degree at an existing site as at a new site.

Comment: The proposed regulations are premature and should be issued for comment only after the final GEIS has been published. The procedure being followed for the concurrent review and public comment on the proposed rules and draft GEIS may violate due process. (6, 26, 49, 55, 60, 73)

Response: There appears to be some confusion regarding the timing of the final environmental impact statement and the final regulations. Although the proposed regulations were accompanied by a draft GEIS, the adoption of the final rules will be based on a final generic environmental impact statement. This is consistent with the Supreme Court's rulings that NEPA requires a final environmental impact statement only when an agency reaches the stage of offering a firm proposal (such as the preparation of final regulations). Kleppe v. Sierra Club, 427 U.S. 390 (1976); Aberdeen & Rockfish R. Co. v. SCRAP, 422 U.S. 289 (1975). We are neither aware of, nor have we been directed to, any legal precedent establishing that compliance with NEPA, in the manner the NRC proposes in this case, would violate due process.

Comment: Take as given the situation where sub-grade material is temporarily dislocated from an open pit or underground mining facility for the purpose of graded ore removal for processing and is subsequently replaced without ever having undergone any extractive or altering treatment. Then, at some later date, this material is deemed recoverable and is extracted by solution extration operations. Based on the revised definition of byproduct material, is it true that this material will not classify as byproduct material and thus, will not fall under the jurisdiction of the UMTRCA? (61)

Response: We understand the situation which has been posed to be one in which mine wastes are reburied, then subsequently the subject of in situ extraction operations. Although we cannot provide a definitive legal opinion in the absence of a concrete factual situation, it would appear that such mine wastes undergoing in situ extraction might be treated as an underground ore body for the purposes of Section 40.4(a-1), which states, "Underground ore bodies depleted by such solution extraction operations do not constitute 'byproduct material' within this definition."

Comment: The standards of protection developed by NRC to apply to existing or planned tailings systems should not be more stringent than standards applied to the remedial action programs for abandoned tailings. The levels of risk should dictate the nature of the response regardless of the origin or current status of the tailings. To do otherwise is to build a dichotomy of responsibility for similar materials between the public sector and private enterprise. (55)

Response: NRC agrees that DOE-reclaimed remedial action sites should meet the same environmental and public health and safety standards as similar sites regulated under Title II of the UMTRCA and intends, through its role of concurrence and consultation in Title I remedial action programs, to ensure that such standards are met. It should be pointed out, however, that NRC cannot, under Title II of the Act, disregard nonradioactive hazards associated with uranium milling operations. Section 84 of the Atomic Energy Act, as added by the UMTRCA, states that the NRC shall insure that management of tailings and wastes is carried out in a manner that-

> "the Commission deems appropriate to protect the public health and environment from radiological and nonradiological hazards associated with the processing and with the possession and transfer of such material..."

Implementation of the new requirements at existing sites, where tailings disposal options are limited, is discussed in Summary Section 9 and Section 12.4.

6.8 Agreement State Issues

> Comment: The GEIS fails to give an overall assessment of how the Agreement State program has been operating. The document should compare the history of operations in Agreement States in terms of licensing practices, records of accidents, and types of tailings disposal programs authorized, with comparable information in non-Agreement States in order to allow the public to determine whether the Agreement State program is functioning properly. The GEIS should contain a detailed evaluation of the adequacy of each Agreement State's program and should describe what NRC's role will be in future regulation of the uranium milling industry in Agreement States. (47, 78, 120)

Response: A review of the adequacy of each Agreement State's program is performed annually. The UMTRCA establishes definitive requirements which the Agreement State programs must meet. Following establishment of these requirements, the NRC's review of Agreement States' programs adequacy will include many of the considerations referred to above. The NRC staff is presently developing a revised set of criteria, to be used as of November 1981, in evaluations of the adequacy of state programs for regulating uranium milling activities. Although such an evaluation is not within the scope of this GEIS, these evaluations are made available in the NRC Public Document Room.

> Comment: The regulations should require the Agreement States to immediately implement the provisions of Section 204 of the UMTRCA with respect to source material licenses. (47)

Response: The amendments to the UMTRCA, contained in Pub. L. 96-106, clarify that the requirements of § 204 shall be applicable, to the maximum extent practicable, prior to November 1981.

> Comment: The regulations should provide specific guidance concerning the interpretation of the requirement for Agreement States to adopt standards which are equivalent to the extent practical or more stringent than standards adopted by the Commission. What situations would justify a state's imposition of standards less stringent than those imposed by the Commission? (47)

Response: The Commission has interpreted this requirement, that Agreement States adopt standards which are equivalent to the extent practicable or more stringent than standards adopted by the Commission, to mean that in all cases standards imposed by the states must be at least as stringent as standards imposed by the Commission. Some flexibility is retained in order to permit the states to regulate in the most effective manner within their jurisdiction. However, the staff expects that these requirements will be met in all cases.

> Comment: Section 150.31(c)(3) should require that the written analysis to be conducted be an independent evaluation prepared by the state. (47)

Response: Section 150.31(c)(3) has been revised to clarify that the written independent evaluation must be prepared by the state, as required by the UMTRCA.

> Comment: The regulations must address the review procedure to be followed and the criteria to be used in November 1981, and subsequently, to determine whether Agreement States' programs are equivalent as required under § 204 of the UMTRCA. Specifically, the regulations should address the frequency with which NRC will review Agreement State programs, the criteria that will be used in judging the adequacy of the states' programs, and procedures which will be used that permit public particiation. (47, 74, 91)

Response: As stated in the "Guide for Evaluation of State Radiation Control Programs, Rev. 3" issued February 1, 1980, UMTRCA requires NRC to periodically review the adequacy of state programs. Although Congress did not address the frequency of such reviews, NRC considers that they should be conducted at least once every 18 months. Upgraded criteria to be used in such reviews have been prepared and sent to the states, along with a status report indicating where the state stands with regard to the criteria. These criteria address statutes, regulations, technical criteria, resource requirements, etc. There is no mechanism at the present to provide for public participation in the state program reviews conducted by NRC. However, these reviews are documented and placed in the NRC's Public Document Room.

> Comment: NRC needs to reexamine the strength of Agreement States' regulatory agencies. (51)

Response: As indicated in response to previous comments, NRC reviews the adequacy of each Agreement State's regulatory program on an annual basis. The scope of this review is being expanded as a result of the specific requirements, as established in Section 204 of the UMTRCA, which Agreement States must now meet.

> Comment: How will NRC ensure that tailings disposal requirements are implemented at existing sites in Agreement States? (74)

Response: State implementation of tailings disposal requirements will be evaluated during the annual Agreement State program reviews discussed above.

> Comment: NRC should strengthen its support of Agreement State programs. The GEIS should include a more extensive discussion of the relationships between NRC and the Agreement States. (86)

Response: The relationship between the NRC and the Agreement States is described in Section 274 of the Atomic Energy Act of 1954, as amended. As indicated in Section 13.3 of this document, the NRC has sought to strengthen the Agreement States' programs by providing technical assistance to the states since April of 1978, and by promulgating specific regulations which can serve as minimum national standards. In addition, the NRC staff has issued many regulatory guides which the Agreement States can use in making licensing determinations. Also, the NRC staff has held several training courses for state personnel during the past year on various aspects of uranium mill and mill tailings disposal regulation.

> Comment: Dual jurisdiction should be continued because the state offices are underfunded, understaffed, and are subject to pressure from the applicants and/or licensees. (87)

Response: The language which created the dual jurisdiction situation (i.e., where both NRC and the Agreement States had licensing responsibility) was eliminated by the amendments to the UMTRCA (P.L. 96-106). As a result of the new language, dual jurisdiction does not and cannot in the future exist. Regarding the contentions that state offices are underfunded, understaffed, and subject to pressure from applicants and/or licensees, these are factors which are considered in the periodic evaluation of the adequacy of Agreement State programs mentioned above, and will be major factors considered in the November 1981 and all subsequent determinations.

> Comment: Regulations should specifically identify what steps will be taken by the regulatory agency (either NRC or states) in the event of noncompliance or repeated noncompliance. (89, 91)

Response: The Commission's enforcement procedures are specified in 10 CFR Part 40, §40.81. In addition, enforcement procedures are covered during the periodic reviews of Agreement State programs.

> Comment: The regulations should provide for a review of whether an Agreement State has the resources to effectively evaluate mill license applications and renewals, to inspect operating mill sites and to monitor inactive tailings sites. Provisions for assistance to help the states meet these needs should be specified. (89)

Response: As previously discussed, such a review of the adequacy of Agreement State programs is conducted periodically. With respect to NRC providing assistance to the states, throughout the last several years, during which time NRC has been upgrading the uranium recovery licensing program and preparing to promulgate final regulations, the Commission has been providing technical assistance to the states in an effort to upgrade their programs as well. After November of 1981, however, the states' programs must be able to meet the requirements established in Section 274 of the Atomic Energy Act, as amended, without direct assistance from the NRC. As mentioned above in response to other comments, the NRC staff is developing criteria to be used for evaluating the effectiveness of state programs. A major factor in these reviews will be the consideration of resource levels available to states on an ongoing basis.

> Comment: The GEIS should examine alternative funding systems within states to provide adequate resources for the needed regulatory control. (91)

Response: The NRC is concerned with the adequacy of Agreement States' resources to provide for the needed regulatory control. This factor is considered in each state's adequacy review. However, an examination of alternative funding systems to provide these resources is not within the scope of the GEIS.

> Comment: Agreement States should be required to promulgate regulations equivalent to the regulatory requirements specified immediately. This should be coupled with a comprehensive study of the adequacy of both federal and state regulatory programs for milling. Such a study, which would be within the scope of the GEIS, should be conducted by an independent party. (91)

Response: The UMTRCA requires Agreement States to promulgate regulations which are equivalent to the minimum standards established by NRC by November 1981 or before, to the maximum extent practicable. As indicated in the GEIS and the final regulations, these minimum standards are considered adequate to serve as the basis for federal and/or state regulatory programs.

> Comment: There should be a state counterpart to the scoping meeting required in federal reviews. Public participation at this stage of the review is very effective. (91)

Response: The intent of the Congress (found in the legislative history) to not require states to follow the NEPA process, including scoping meetings and full environmental impact statements, is clear. Congress did require the states, in new Section 274o., to provide procedures which include the opportunity for public participation through written comments and a public hearing. Although there is no state requirement to provide opportunity for public participation at the scoping stage of the review, Colorado held scoping meetings for two proposed mill projects in early 1980.

> Comment: State regulatory effectiveness is inhibited by inadequate financial resources. Provisions must be made for NRC technical assistance and minimum standards for license fees and financial arrangements. The regulation should state that NRC will suspend or revoke Agreement State status in the event of inadequate state government funding. (91)

Response: As previously discussed, the adequacy of financial resources is carefully considered in the periodic review of Agreement State programs. Under the provisions of the Agreement State program, if the NRC found a state office to be insufficiently funded to provide adequate regulatory control, their Agreement State status could be terminated. The adequacy of financial resources is a major factor in the periodic review of the adequacy of Agreement State programs.

> Comment: The regulations should require a review of existing facilities in Agreement States within a specified period of time. (91)

Response: Proposed Appendix A to Part 40 has been amended to require that at active mills, programs meeting the technical and financial criteria shall be developed in connection with license renewal, or proposed programs shall be submitted for review with supporting information within nine months of the effective date of the regulations. Working out the details of an optimum program at any given site is a lengthy, time consuming process. These required reports will be a major first step in this process.

> Comment: The specific standards which Agreement States must comply with and the penalties for noncompliance should be spelled out in the regulation. (91)

Response: Specific technical and financial standards which the Agreement States must use in their uranium mill licensing program are specified in the regulations. Other criteria which they must meet (e.g., procedural requirements, resource levels, etc.) are outlined in the "Guide for Evaluation of State Radiation Control Programs, Rev. 3, Feb. 1, 1980." In the event that the NRC determines that a state's program is not equivalent to the NRC's or does not provide an adequate level of regulatory control, this portion of the agreement could be revoked. A revised set of criteria to be used in evaluating the equivalency of state programs for entering into amendmend agreements in November 1981 has been prepared by the NRC staff.

> Comment: Since NRC only has control over radioactive elements, the states should be encouraged to pass regulations on uranium milling and mining. (115)

Response: The premise of this statement is incorrect. Section 84 of the Atomic Energy Act, as amended by the UMTRCA, states that "The Commission shall insure that the management of any byproduct material, as defined in Section 11e.(2), is carried out in such manner as - (1) the Commission deems appropriate to protect the public health and safety and the environment from radiological and nonradiological hazards associated with the processing and with the possession and transfer of such material...." In light of this and the Congress' desire to eliminate dual jurisdiction (evidenced by the November 1979 amendments to the UMTRCA), NRC considers the most effective arrangement to be one in which either NRC or a state (through an agreement under Section 274) regulates. NRC has no direct authority over uranium mining or mine wastes. Impacts from mining operations are considered on a case-by-case basis, where appropriate (where it is not possible to distinguish these impacts from those associated with the milling operation). However, as mentioned in Section 1.2, EPA is currently preparing a report, as directed by Congress in Section 114(c) of the Uranium Mill Tailings Radiation Control Act, on the potential health, safety, and environmental hazards of uranium mine wastes.

6.9 Technical Issues

6.9.1 Siting

> Comment: Emphasis on consideration of cultural resources should be at the site selection stage rather than at the site preparation stage. (38)

Response: The staff agrees. Major site construction should not occur until after a full NEPA review has been completed, as discussed in Section 12.3.10. Such a review would include consideration of cultural resources to the extent appropriate.

> Comment: The availability of suitable alternative tailings disposal sites should be resolved generically. The NRC should consider requiring location of sites only where tailings can be disposed of below grade safely. Mills should be sited on the basis of safe tailings disposal and not on the nearness of uranium ore. (47, 56)

Response: The staff agrees that primary emphasis in the site selection process should be placed on adequate tailings isolation rather than short-term conveniences (see Section 12.3.2). However, the staff does not consider it appropriate or necessary to require full below grade disposal in order to achieve adequate isolation. The general availability of acceptable full below grade disposal sites is not addressed within this document, due to practical considerations; site-specific licensing evaluations routinely consider that matter, however (see Section 12.3.3.2).

> Comment: The criteria listed in Criterion 4 pertaining to above grade disposal sites only, raise questions as to whether below-grade sites will receive adequate review consideration, particularly because no extensive search for alternative sites is required. (47)

Response: The requirements to be imposed under proposed Criterion 4 address the basic problem of controlling surface erosion, as well as earthquake protection. The staff has considered the above comment and determined that the requirements of proposed Criterion 4 should be applicable to all sites. The Technical Criteria have been revised to clarify this (see Sections 12.3.2 and 12.3.3.2 on this matter).

> Comment: Below grade siting must be utilized only when proper conditions prevail. The NRC must therefore balance its discussion of the prime option and the above grade option by providing guidelines for assuring an extensive search for below grade sites, and a set of detailed criteria for evaluating sites for below grade disposal. (47)

Response: The staff considers the guidance and requirements provided in the regulations being promulgated to be adequate in these respects. (See also Sections 12.3.2 and 12.3.3.2 on this matter.)

> Comment: The proposed regulations focused too much on different technologies for tailings liners and failed to give adequate thought to the question of tailings locations. (51, 74, 81, 89)

Response: The staff has revised its proposed regulations to be more emphatic with respect to initial siting requirements and considerations. (See Sections 12.3.2 and 12.3.3.2 on this matter.)

> Comment: The meaning of the word "remote" needs to be clarified. Tailings disposal facilities should not be sited in the vicinity of any location which can be expected to attract future population growth and habitation or where valuable economic resources are present. (74, 91)

Response: Such aspects as mentioned are part of the overall quality of "remoteness" which the staff is requiring to be optimized, under revised Criterion 1 of Appendix A to Part 40. (See Summary Section 9, "Siting of Mills.")

> Comment: The regulations should address the question of acceptable upstream catchment area quantitatively. (74)

Response: Susceptibility to erosion damage due to upstream drainage is a multi-dimensional problem involving not only upstream drainage area but; maximum acute precipitation; maximum sustained heavy precipitation; topographic features with respect to channeling and velocity of runoff; infiltration capacities and rates; and, engineered protective features (e.g., riprap) provided. In view of these confounding factors, the staff finds it inappropriate to specify a simple numerical limit on upstream drainage area. This issue is further addressed in the Summary Section 9, under the topic "Form of Regulation."

> Comment: Criterion 1, as it addresses mill locations, is unnecessary. Most uranium mills are located in remote sites because that is where the ore is found. (86)

Response: The staff continues to consider the issue of remoteness appropriate for inclusion in its regulations. This will be a practical consideration only for those operators who would locate in other than remote areas.

> Comment: Criterion 2 should include the words "natural events within 80,000 years," as determined by the best geological estimates available. Some provision for a forthcoming ice age in the next 25,000 years should be included. (92)

Response: The staff considers these suggestions to be impractical and unnecessary. Protection against glaciation cannot be effectively provided by other than deep mine disposal, which is very costly and could pose severe environmental and safety problems although, in some limited cases, it might be possible to implement (see Section 12.3.3.3).

> Comment: The GEIS does not adequately consider siting and design requirements to avoid or limit the consequences of operational and post-operational failures. (91, 99)

Response: The staff considers that large-scale catastrophic impoundment failures are a valid concern during mill operation when the impoundment is saturated. The staff addresses engineering considerations by mechanisms other than regulation. These mechanisms include detailed regulatory guides (for example, R.G. 3.11), license conditions, construction inspections, and routine inspections during operation. New criterion 8(A) requires daily inspection of impoundments by qualified personnel. With regard to postoperational failure, major elements of the staff's final regulations stipulate measures required to assure long-term stability (see Criteria 3 and 4). (Also see discussions in Sections 9.4.1 and 12.3.3.)

> Comment: The NRC is encouraged to develop a buffer zone around uranium mills to restrict occupancy. (105)

Response: The staff considers such a buffer zone to be unnecessary, in view of requirements to comply with the maximum offsite radiation exposure limits embodied in the EPA regulation, 40 CFR Part 190, and the maximum offsite air concentration limits specified in 10 CFR Part 20 of the Commission's regulations. The adequacy of the protection of the public health and safety in the vicinity of the mill is also evaluated in the course of the radiological assessment performed for each mill, on a case-by-case basis.

> Comment: The definition of remote site is inadequate in that it does not address potential effects of the site in terms of potential alteration of weather patterns and related effects on human health. (141)

Response: The staff does not consider the impact of a uranium mill on weather systems to be of sufficient potential significance to warrant attention.

6.9.2 Groundwater Protection

> Comment: Tailings should be isolated completely from groundwater; tailings impoundments should not be located near aquifers unless there are impermeable liners or other methods for intercepting seepage. (21, 115)

Response: The staff has identified isolation of tailings and tailings solutions from groundwater as the primary method of providing groundwater protection. The staff considers it inappropriate, however, to state that tailings can in no case be placed in contact with groundwater. For example, where tailings solutions are separated from tailings solids, and where the tailings solids are dewatered, washed and treated to remove and/or immobilize residual contaminants, solids might be adequately disposed of in contact with groundwater. In such a case it would have to be shown by sufficient testing and onsite data that there would be virtually no possibility for significant impacts with respect to present water uses. In no case, except for possible disposal by deep well injection into aquifers which are clearly not usable, would contacting tailings solutions with groundwater be considered acceptable.

With regard to location of tailings impoundments, the staff has revised the proposed regulations to more clearly establish the overriding importance of siting in mill tailings disposal. More specifically, avoiding sites where geohydrologic conditions are conducive to groundwater contamination is identified as one of the most important siting factors. Beyond this, the regulations call for seepage control measures, as necessary, such as lining the bottom of impoundments, to adequately isolate tailings solutions.

In any case, the specific method or combination of methods of seepage control and siting decisions must be made considering site-specific geologic and hydrologic conditions, as provided for in the revised regulations.

> Comment: Tailings impoundments should not be allowed in flood plains, near flowing watercourses, in groundwater recharge areas, or where there is hydraulic connection with surface water bodies or streams. Also, tailings should not be located where impoundment failure can lead to surface water contamination. (25, 74)

Response: The final regulations have been revised from their proposed form to emphasize, more so than in the proposed regulations, the overriding importance of siting in developing tailings disposal programs. Furthermore, the regulations require positive seepage control measures to be taken, if necessary, to assure tailings solutions do not degrade groundwater uses. The regulations also require that tailings be sited where they cannot be disturbed or disrupted by natural forces (for example, in areas where there is only very limited upstream surface drainage). The staff considers these requirements to effectively rule out inappropriate siting in flood plains, groundwater recharge areas, or in other areas where geohydrologic conditions would lead to unacceptable groundwater or surface stream impacts. (Also see Section 12.3.5 concerning the unlikely occurrence of groundwater recharge by precipitation infiltration in semiarid western milling regions.)

Being affected by site-specific conditions as much as it is, the problem of groundwater protection must be evaluated, and optimum mitigating siting and design measures worked out, on a case-by-case basis. This is one of the major reasons for the staff's conclusion in the GEIS (Sections 1.2 and 12.3.10) that site-specific, documented environmental assessments should be prepared, by the NRC and Agreement States in connection with each licensing action, for public review and comment. The regulations identify the concerns that must be addressed by applicants and licensees, and independently by the regulatory agency, in such assessments.

> Comment: More emphasis should be placed on proper siting than on design features such as liners to protect groundwater. Because there is potential for failure, total reliance on containment technology such as liners should not be allowed. Also, some seepage will inevitably occur even without failures. Regulations should specifically prohibit location of tailings sites over underground drinking water supplies, or aquifers used for irrigation or livestock watering. (51, 74)

Response: The proposed regulations have been revised to emphasize, more so than in the proposed regulations, the overriding importance of siting in mill tailings disposal; the thrust of the regulations is that containment design cannot be relied upon to compensate for inadequate siting. As indicated in the GEIS, protecting groundwater sources is a complex, site-specific problem; it is not appropriate to prohibit, on a generic basis, location of impoundments near drinking water supplies. A combination of site geologic features, such as thick impermeable soil and rock formations which isolate solutions from groundwater, and seepage control measures, may provide the required protection of underlying groundwater supplies, which normally exist in geologic units at one or more depths below a site.

> Comment: Too much emphasis is placed on seepage barriers such as clay and synthetic liners in groundwater protection criteria. This will result in retention of solutions in the tailings, making it difficult to operate heavy equipment on the tailings during final covering and increasing potential for impoundment failure. (59, 73)

Response: As stated in Section 12.3.5, the surest and most appropriate way to protect groundwater from toxic contaminants in tailings solutions is to control seepage. The staff recognizes additional technical problems are posed to some degree by not allowing uncontrolled seepage from impoundments. However, these problems are not insoluable; they can be rectified by using dewatering techniques, such as tailings drainage systems, as described in GEIS Chapter 8.

> Comment: The regulations should not be specific about methods of achieving groundwater protection; broad performance goals such as protection of groundwater at a restricted area boundary should be all that is presented in the form of regulations. The emphasis should be on limiting toxic contaminant migration rather than on limiting seepage. (55, 59, 73, 85)

Response: The staff considers that the GEIS and associated final regulations fully recognize the site-specific nature of (and need for flexibility in addressing) groundwater protection problems. However, the staff considers that the surest way to avoid degradation of groundwater uses is to control seepage. Once substantial seepage has occurred, it is either extremely difficult or impracticable to control. Also, given the uncertainties regarding actual hydrogeologic conditions at a site which always exist, particularly as these conditions might provide channels or paths for rapid movement of contamination into groundwater formations, it is prudent to not place more reliance than is necessary on isolation or containment by natural underlying materials.

After weighing the alternatives, the staff determined not to take the approach of specifying limits on contaminant concentrations at restricted area boundaries. In addition to uncertainties which inevitably exist in the geologic and hydrologic conditions, and with respect to geochemical processes (which determine rates of contaminant migration), the long-time frames over which seepage migration will be occurring force use of conservative groundwater models to predict whether, on a prospective, prelicensing basis, maximum concentration limits would be met or not. In most cases, without protracted, expensive, and complicated site studies, it is not possible to gain the degree of confidence needed to relax seepage control measures and rely on natural conditions to adequately protect groundwater.

Therefore, the simplest, surest, least-expensive and most reasonable approach to groundwater protection appears to be requiring consideration, and application as appropriate, of available technology in providing seepage control.

Comment: The GEIS should be more specific concerning geohydrologic conditions which should be met at disposal sites. For example, there should be a minimum distance between the historical high groundwater table and the bottom of liners used in the impoundment. (25)

Response: The regulations being established are as specific as appropriate, given the highly variable and complex nature of the factors which determine the extent of potential groundwater impacts at a site. Being extremely specific about how to protect groundwater, such as specifying minimum distances from groundwater to the bottom of impoundments, is not appropriate, given that permeabilities and other hydrologic parameters of underlying rock and soil strata can vary tremendously. Also, groundwater protection is one of several objectives in tailings disposal. Developing a tailings disposal program is a process of optimizing on all objectives simultaneously with tradeoffs being made among objectives in the course of this process. It is not appropriate or reasonable to be very specific and conservative in addressing one goal without considering what effects there are on other goals. (This is further discussed in Section 12.3.3.)

Comment: Isolation of tailings from groundwater of very poor quality or where there is shown not to be detrimental effects should not be required. (53, 86)

Response: Regulations provide flexibility for licensees or applicants to demonstrate that contacting tailings with groundwater will not degrade the quality of usable groundwater. The concern expressed in this comment is, thus, accounted for.

Comment: Better guidance concerning the conditions under which tailings can be contacted with groundwater, than is currently specified in regulations is required. (21, 84)

Response: In general, contacting of tailings solids with groundwater would be permitted only when it could be shown that the condition of the tailings, and site geohydrology, are such that there would be no significant deterioration of groundwater uses over short and long-term periods. This would likely require tailings dewatering, washing, neutralization, and/or other treatments, to assure that contaminants which might exist in mobile chemical form in tailings solutions, are not contacted with groundwater to any significant degree. The water quality, quantity, yield and other important hydrologic parameters of affected aquifers, would have to be clearly established. As stated in Section 12.3.5, this problem is so variable and site-specific that highly specific requirements in regulations on this matter are impractical.

Comment: The criteria that seepage must be reduced to the maximum extent reasonably achievable does not stipulate the uses for which waters would be retained. Prevention of the degradation or dimunition of surface and groundwater would be a guiding principle of regulations. (105)

Response: The staff agrees with the thrust of this comment. The purpose of the seepage control, and other similar control measures prescribed in the final regulations, is to protect existing or potential groundwater uses. While this is clearly the purpose of the regulations, it was not stated explicitly in the proposed regulations. The final regulations have been revised to explicitly state this as a major objective of any tailings disposal program.

Comment: The criterion calling for reduction of seepage to the maximum extent reasonably achievable is unacceptable because it allows considering costs. Where there is any doubt about protecting future generations, costs cannot be a factor. (92)

Response: The staff considers that the stringent groundwater protection measures specified in the regulations provide adequate assurance of public health and safety protection, over short and long-term periods. There will be minimal residual impacts with tailings disposal under the regulations being established just as there are with development of any technology, whether related to power generation or not. Cost must be considered as appropriate, so as to assure that available economic resources are not unduly expended in eliminating insignificant impacts.

Comment: Solid waste activities should not be allowed to cause underground drinking water sources to exceed established drinking water standards (EPA Criteria for Classification of Solid Waste Disposal Facilities and Practices - 44 FR 53438 - 9/13/79). Thus, the EPA Interim Drinking Water Regulations can be used as a basis for groundwater criteria. (99)

Response: The regulations being established require that state-of-the-art seepage control measures be implemented in disposing of tailings. The staff believes this requirement will assure groundwater quality is appropriately protected. More specifically, where groundwater quality is initially of drinking water quality, it must remain at this level, both during and after milling operations.

> Comment: At a minimum, guidelines must be established that define the geographical limits at which groundwater quality must be preserved. Specifically, the acceptable size of groundwater contamination in relation to distances from the wetted perimeter of the pond and site boundaries must be specified. A time frame over which such an evaluation is to be made has to be specified. Under the proposed EPA criteria for radioactive wastes, controls which are based on institutional functions should not be relied upon for longer than 100 years. (99)

Response: The thrust of the staff's final regulations is to assure containment of contaminants for long periods of time without the need for active maintenance, or reliance on other institutional controls.

The staff has evaluated alternative methods of groundwater protection, and the regulations call for use of those methods which will control seepage. The staff considered casting regulations in the form of groundwater quality-limits applicable at a given distance over a given period of time, as suggested in this comment. However, because of uncertainties and limitations in groundwater transport modeling, the staff has determined it to be more appropriate and straightforward to require application of what is essentially "best available technology" with respect to seepage control. The staff considers this approach will assure that existing and potential uses of nearby groundwater formations will be preserved.

> Comment: If tailings are located where they might affect water users, a fund to compensate those private property rights in surface and groundwaters which are potentially affected should be created from assessment on mill operators. This is needed because contamination will likely not occur until after the mill operator has left the scene. All potentially affected water users should be notified and a hearing mechanism established to permit expression of concerns. (76)

Response: The staff considers a special fund, such as proposed in this comment, to be unwarranted. Groundwater protection measures specified in the final regulations assure that present or potential groundwater uses are not degraded. The regulations conservatively require that seepage be controlled from tailings impoundments. As described in Chapter 10 (Section 10.3), and required by the regulations, operators shall conduct groundwater monitoring programs to identify potential seepage problems during the time when the mill operator is under license, and can be required to remedy any identified problem. As discussed in Chapter 12 (Section 12.3.10), and reflected in the regulations, site-specific, documented environmental appraisals prepared independently in connection with each licensing case, and made available for public review and comment, should assure that local, potentially affected citizens have an opportunity to understand proposed projects and express their views and concerns.

> Comment: If EPA adopts a 10 pCi/l standard for uranium in drinking water, how will it affect NRC regulatory efforts and risk estimates? (92)

Response: The NRC will necessarily reflect in its regulations whatever relevant standards are developed by the EPA. As discussed in Chapter 13, and in responses to other comments, the EPA is establishing standards under the Uranium Mill Tailings Radiation Control Act; revisions will be made to NRC regulations, as necessary, after final EPA standards are issued. The groundwater protection measures called for in the staff's final regulations are state-of-the-art, and should assure that groundwater contamination limits are met, if and when they are established.

> Comment: Tailings should be incorporated in a solid matrix such as asphalt or cement to prevent groundwater contamination. (130)

Response: Tailings solidification in cement or asphalt was considered as an alternative in the GEIS. For reasons stated in Section 12.3.3, the staff considers it would be unreasonable to require solidification; the costs are very much greater than those of other alternatives found acceptable, without corresponding equivalent benefits.

Comment: Monitor wells and leachate detection systems should be required. (25)

Response: The staff's final regulations require that an operational environmental monitoring program be implemented at uranium recovery facilities. Such programs must include groundwater monitoring as discussed in Chapter 10 and in NRC Regulatory Guide 4.14 (see Appendix V). Some seepage from impoundments is expected in most cases; particularly where nonsynthetic liners are used, leachate detection is not warranted. Where synthetic liners are used, it is appropriate to utilize such systems, and the regulations reflect this as a requirement. The potential for, and potential consequences of, failure of a synthetic liner are considerably greater than with a clay liner which is relatively thick and is also self-healing.

Comment: NRC's apparent conclusion on page 12-26 of the draft GEIS that groundwater contamination by selenium and other materials over a large area is acceptable, and that no regulatory changes are needed in light of this, is not supported. (74)

Response: This comment is a misinterpretation of the conclusion stated on the referenced page. The conclusion referred to stated that no regulatory program changes "beyond (emphasis added) those identified for tailings management and disposal" appeared necessary to control non-radiological impacts of milling. The proposed new groundwater protection criteria for tailings disposal are aimed very specifically at controlling all contaminants in potential seepage water, whether radiological or nonradiological. Also, the staff's conclusion was made in the context of the existing regulatory framework, which is designed to control all environmental impacts from milling, as described in Chapters 12, 13, and 14. For example, there must and will be under the Uranium Mill Tailings Radiation Control Act, environmental assessments for all uranium mills, which include consideration of nonradiological impacts.

Comment: There should be a secondary catchment of sufficient capacity to retain the maximum accident that could occur from a facility. (74)

Response: The staff considers that requiring a secondary catchment is not appropriate or warranted. Where retention structures are constructed, the staff applies Regulatory Guide 3.11, "Design, Construction, and Inspection of Embankment Retention Systems for Uranium.Mills," and other similar guides, which specify methods which should be followed in design and quality assurance aspects of embankment construction. Regulatory Guide 3.11 conservatively recommends that impoundments be sized to hold floods resulting from greater than the probable maximum precipitation event. In addition, the staff performs a complete, independent geotechnical review of any proposed embankments. The staff considers it important that emphasis be placed upon constructing sound primary tailings retention structures where below grade burial is not feasible. The same approach is applied to evaporation ponds.

Comment: The toxic materials in tailings were initially in the ore. While partially solubilized in the milling process, these materials will be demobilized by the same processes which initially deposited them in the ore body. (86)

Response: While this immobilizing process may eventually occur for some contaminants, it may not occur in the case of many others. Also, significant public health impacts may occur before such immobilization has fully taken place. The staff considers it appropriate to require seepage control and isolation of contaminants from groundwater, as in the regulations being established.

Comment: Preliminary information indicates there may be excessive levels of uranium in many Western drinking water supplies. Although there is not a direct connection, future releases of uranium to ground and surface water should be given high priority. (56)

Response: The staff considers that the stringent groundwater protection and seepage control criteria in the staff's final regulations, and overall mill licensing procedures, address the concern raised in this comment.

Comment: The NRC preference for lined tailings impoundments is based on a simplistic seepage and groundwater model (Appendix E) that does not account for factors discussed in the GEIS which will impede contaminant migration, such as, slimes buildup, chemical reactions, lateral dispersion, adsorption and so on. (59)

Response: The NRC position on seepage control expressed in the final regulations is not derived solely from the seepage evaluation presented in Appendix E, but was arrived at considering all of the complex factors related to groundwater protection presented in Section 12.3.5 and other related sections of the GEIS.

> Comment: In the Section 6.2.4.1.3, rather specific projections of mass transport are made for periods of up to 300 years for contaminated groundwater. In Section 6.2.4.2, statements are made which, in effect, say that such calculations really cannot be done or at least not very accurately. This inconsistency should be corrected. (99)

Response: There is no real inconsistency between these sections. In the first, a simplified groundwater contaminant transport analysis is discussed to illustrate, from a conservative point of view, what potential impacts from seepage are.

In the second section, the inherent limitations of such an analysis, on something as highly site-specific, variable and difficult to precisely understand without extensive and expensive subsurface investigations, are discussed. The regulations being established appropriately reflect these limitations.

6.9.3 Minimum Cover Thickness

> Comment: The requirement for a minimum of 3 meters of earthen cover is not adequately justified and is over-conservative and purely arbitrary. It is not, and cannot be, justified on a reasonable risk-benefit basis; is shown by the GEIS not to be necessary to control radon exhalation to the specified limit; and, in view of separate requirements, is not necessary to provide long-term isolation. No analyses are provided to show that a 3-meter thick cover is necessary to protect against the potential damaging effects of erosion, root penetration, or burrowing animals. The GEIS does not address the improbability of use of the tailings pile as a residential site or provide any analyses of the consequences of using thinner covers. (53, 55, 59, 67, 71, 77, 85, 86, 134)

Response: The staff considers the bases for the 3-meter minimum cover requirement to have been adequately addressed in both the draft and final GEIS. For a complete discussion of the need for this requirement, see Section 12.3.4.7.

> Comment: The proposed requirement for a 3-meter minimum thickness cover of earthen material unnecessarily precludes other available alternatives capable of providing adequate protection, or alternatives becoming available through research and development. Covers of less than 3 meters thickness, and of nonearthen materials should be allowed; cover requirements should be determined on a site-specific basis considering environmental, economic and other site-specific factors as appropriate. (53, 55, 59, 86)

Response: The staff recognizes that research into tailings cover material technology will continue. Therefore, it is not beyond the realm of possibility that techniques could be found for economically resolving the concerns that lead to the minimum cover thickness requirement, under certain conditions, which would make it reasonable to relax the requirement. However, the staff is aware of no technology that would do this and cannot ignore currently existing problems based upon the speculation that they might, in the future, be resolved.

In determining that a minimum 3-meter earthen cover should be required in all cases, the staff has duly considered the ranges of costs and environmental impacts that might be incurred on a site-specific basis, by evaluating reasonable variations of cover materials availability, ore grade, impoundment area, and similar site-specific factors. Although costs and impacts associated with providing such a cover may vary, as discussed in Section 12.3.4.7, the staff continues to consider the stated requirement to be appropriate and necessary to provide minimum acceptable levels of protection.

> Comment: The amount of cover material required for reducing radon emissions is overestimated in the GEIS. Mesurements made by the U.S. EPA indicated that 3 feet of earth would reduce radon emission by a factor of 8. (85)

Response: The calculational models used by the staff in estimating radon attenuation are based on the most advanced research performed on this matter, as well as on the full body of radon diffusion literature that exists. The staff considers its models are adequate (see Section 9.3.4, and Appendix P).

> Comment: The GEIS fails to adequately address the special problems faced by existing mills if the cover requirements are retroactively applied. (86)

Response: The staff considers the cover requirements to be appropriate for existing sites, despite the existence of "special difficulties" arising from any unavoidable lack of advance planning or difficulty in obtaining adequate amounts of cover materials. In this regard, the staff has deliberately and justifiably assigned a higher priority to adequate environmental and public health protection than to fiscal inconvenience. This issue is explicitly and more completely addressed in Section 12.4 of this document.

> Comment: Three meters of earth cover cannot reasonably be assumed to provide isolation for thousands of years. The minimum thickness requirement should apply continuously, not just at the time of reclamation. Burial adequacy should be checked by frequent air monitoring as well as cover depth measurements. (62, 115, 126, 130)

Response: The staff considers that erosion protection requirements, in addition to the minimum cover thickness requirement, will provide adequate isolation for thousands of years. In fact, the erosion protection requirements, contained in Criteria 3 and 4, are far more important, with respect to long-term stability considerations, than the amount of initial cover placed over the tailings. (See Section 12.3) Monitoring will be required, as appropriate, to demonstrate the continued adequacy of isolation, and remedial actions will be required to redress any significant degradation.

6.9.4 Radon Limit

> Comment: The proposed radon flux limit is not justified and has no scientific basis. (50, 52, 55, 59, 70, 71, 74, 85, 86)

Response: The staff has determined that the 2 pCi/m^2-sec limit is as low as reasonably achievable. This conclusion has been reached after thorough examination of this issue from a wide array of perspectives. For a detailed discussion, refer to Section 12.3.4 of this document; also see the discussion of this issue in Summary Sections 5.2.2 and 9.

> Comment: The radon flux limit was not based upon doses to individuals. (85, 86)

Response: A part of the basis for the selected limit involves consistency with the Surgeon General's guidelines, which address maximum doses to individuals (see Section 12.3.4.3).

> Comment: The total population dose projected with the radon flux limit is too low to justify the limit; thus the limit is too low. (55, 59, 70, 85, 86)

Response: See Section 12.3.4 for discussions of the full range of factors considered in establishing radon limits. The staff agrees that total radon releases from reclaimed tailings piles are small compared to releases from background sources. The primary basis for the limit is that incremental radon releases be comparable to background variability in the immediate vicinity of the tailings, and that individuals be protected from receiving doses exceeding the Surgeon General's guidelines. The significant problems associated with establishing a limit based upon an optimization of costs and population doses are discussed in detail in Section 12.3.4 and Appendix U.

> Comment: The radon flux limit is too high because it could be decreased for a minor additional cost. The radon flux limit should be at background because future generations must receive the burden of elevated radon releases without receiving any benefit. (63, 70, 74, 88, 92, 98)

Response: The staff considers that the reasons for not selecting a lower value of limiting radon flux, as expressed in Section 12.3.4.2, are valid. The residual risks are considered to be negligible compared to those normally encountered due to human activities, including man-induced radon releases not associated with uranium extraction. (See Section 12.3.4.4.)

> Comment: The scenerio specifying future land use for dwellings is unreasonable because the UMTRCA specifies ultimate federal government ownership of the sites. (52)

Response: In establishing radon flux limits, minimum cover thicknesses, etc., the staff has recognized the requirement for ownership transfer to a government agency, and the improbability of residential construction over deposited tailings (see Sections 9.4.2 and 12.3.4.3). However, government control cannot be guaranteed indefinitely far into the future.

> Comment: The radon emission regulation should be based on airborne radon concentrations at the property boundary rather than on radon flux from the reclaimed tailings pile. (50, 52, 59)

Response: Setting a concentration limit as opposed to a radon flux limit in stating final tailings cover requirements is not appropriate for a long-term hazard such as that posed by mill tailings. Exposures to individuals will be dependent in great measure upon where they are located, and there is no way of predicting this over the thousands of years that tailings will remain a hazard.

Certainly, if concentrations were adopted as the means of establishing cover requirements, a location near or even on top of the tailings pile would have to be selected for evaluation pruposes, since these represent worst case locations. In the draft GEIS, the staff evaluated the potential health risks to persons at such locations for the range of alternative radon control levels examined. At the selected limit of 2 pCi/m^2-sec, exposures resulting from tailings releases were consistent with those specified in other cases where, either naturally or due to the presence of tailings, elevated radon exposures occur inside structures. (This is discussed in Section 12.3.4.3.)

Given the long-term uncertainties about actual locations of people, stability of institutional controls, stability of tailings impoundments and the like, and in view of the need to examine perspectives other than just the individual risk perspective as described in Section 12.4, expressing tailings cover requirements in terms of radon flux limits is considered to be the most straightforward, appropriate, and practicable approach to be taken in regulation.

> Comment: The radon flux limit is inconsistent with the EPA pending standards for radium of 5 pCi/g in soil. (55)

Response: The proposed NRC limit on radon flux does not conflict with the EPA criterion because the flux limit is defined as 2 pCi/m^2-sec above background (i.e., from the tailings). The flux limit is within the range of uncertainty associated with fluxes from soils containing radium concentrations of 5 pCi/g. Also, the permanency and size of areas devoted to tailings disposal make the problem of radon exhalation quite different than that from relatively thin layers of contamination, which are expected to dissipate through natural processes in any case.

> Comment: Radon release levels should be based on measured radon control, not on "calculated release levels." (56, 81, 105)

Response: Use of a calculated level provides for a uniform degree of control without depending upon particular site background measurements. Furthermore, any measurement of the radon flux also includes the radon originating in the cover (a background contribution) that must be measured separately, or estimated with calculations, and then subtracted from the original measurement in order to determine the component from the tailings. This is cumbersome and introduces additional uncertainties on top of those arising from the naturally high variability of instantaneous radon emissions and measurement (see Sections 9.3, 10.3.1, and 12.3.4.9).

> Comment: The radon flux limit is meaningless compared to fluxes from uranium mine overburden soils and other soils in the area. (55, 74, 85, 86)

Response: It is not within the scope of this GEIS to analyze impacts from uranium mine overburden. The staff has proposed a radon limit for mill tailings that is consistent with protecting the health and safety of the public. The existence of some mine overburden piles that fail to meet this limit is no reason to relax the limit for mill tailings.

The staff also recognizes that there is a wide variation in the radium concentration in soils and, thus, in the surface radon fluxes from natural soils. At the upper end of the spectrum are uranium ores, by definition. There are background locations with surface fluxes exceeding the proposed limit, but these occasional, isolated areas are infrequent and are often associated with the ore body being processed. The variability caused by these isolated areas is accommodated in the limit, by specifying that the limit is a value above background, and by setting that incremental limit to a value exceeding 90-95% of the background flux distribution.

> Comment: The radon flux limit should not be met by spreading the tailings thinly over large areas. (79, 97)

Response: There are tremendous economic disincentives for speading the tailings thinly over large areas. The costs associated with meeting the minimum cover thickness requirement will minimize the areal extent of the piles.

> Comment: The GEIS should evaluate the tradeoffs between adding water to the tailings and cover to reduce radon emissions and removing water from the tailings to reduce leaching of contaminants into the groundwater. (74)

Response: The tradeoff mentioned is discussed in Summary Section 5.1, and in Sections 9.2, and 12.3.7 of the body of this document.

6.9.5 Above vs. Below Grade

> Comment: Technical Criterion 3 unnecessarily designates below-grade disposal as the "prime option" for uranium mill tailings management. To designate below-grade impoundment as the prime option prematurely judges against the other options. It, therefore, requires a greater amount of justification for an above-grade option than for a below-grade option. Below-grade disposal is not, and should not be considered to be, the prime option due to groundwater protection problems and the difficulty of implementation.
>
> The evaluation of all alternative plans, including above-and below-grade options, must consider all factors, including costs and economics, on a site-specific basis. Any alternative that meets specified performance objectives should be considered acceptable without regard to a prime option. (55, 59, 71, 73, 85, 86)

Response: Below-grade disposal was designated as the prime option because tailings stored below-grade are least susceptible to disruption and dispersion by natural forces. The designation of below-grade disposal as the prime option was not a premature judgment, but resulted from a careful and systematic evaluation of alternative disposal methods. As should be clear from the wording used in the criterion itself, there was not any lack of consideration of cases in which full below-grade disposal might be impracticable. In an attempt to remove the misconception from which this comment stems, the revised regulations require that disposal be below-grade to the "maximum extent reasonably achievable," thus clarifying that the criterion is an objective which must be given full consideration during the siting and design of tailings impoundments.

> Comment: The statement that below-grade disposal "virtually eliminates exposure of the tailings to surface erosional effects" is in error where a substantial elevation difference exists across the proposed pit, as occurs where pits are located on slopes. The prime option is inequitably favored by the lack of applicability to below-grade disposal of the siting and reclamation requirements specified in Criterion 4. These or similar requirements must be made applicable to below-grade disposal sites to assure a stable reclamation cover. (47, 55, 59, 105)

Response: Upon reconsideration the staff has determined that the concerns addressed by the requirements of proposed Criterion 4 are indeed universal and are present with below-grade as well as above-grade disposal sites. Therefore, those requirements have been clarified so as to reflect their applicability to all final disposal sites.

> Comment: Aboveground disposal options cannot be assumed to provide "reasonably equivalent isolation of the tailings from natural erosional forces", as required by proposed Criterion 3, in view of

> the long-term potential for large-scale climatic changes. Therefore, Alternative 6 should not be endorsed and below-grade disposal should be required for new mills. (34, 38, 47, 74, 79, 91, 92, 115, 121)

Response: The staff's proposed siting and erosion control criteria have been revised so as to be universally applicable to both above-grade and below-grade tailings disposal sites. Among other specifications, these criteria require that measures be taken to reduce surface erosion of reclamation covers to negligible levels. Given the uniformity of these requirements, and the similar susceptiblity of below grade disposal sites to potentially enhanced erosional forces due to long-term climatic changes, the staff considers that reasonably equivalent long-term erosion protection can indeed be provided at above-grade disposal sites. The objective of the criteria is to provide a uniform minimum level of erosion protection for all slopes and cover surfaces, regardless of whether the tailings are deposited above or below the original site grade. Below-grade disposal is designated as the prime option because adequate erosion protection can be more easily attained, with reduced reliance on engineered erosion protection measures, and for other clear advantages. Section 9.4.1 of this document includes a thorough discussion of the features which can be employed to minimize the chance of disruption by each potential failure mechanism. This discussion should make it clear how above-grade (or "partially below-grade") systems can be sited and designed to ensure long-term stability.

> Comment: All tailings should be disposed of below any useable or potentially useable aquifers. (92)

Response: To require that all tailings be disposed of below potentially useable aquifers is impractical and unnecessary. Aquifers may be expected to exist in strata at great depths below the earth's surface. It should be noted that seepage from tailings impoundments is not anticipated to present a problem over the long-term and could continue only as long as water exists in the tailings, as precipitation moisture is not expected to infiltrate through the cover and tailings and become available for transporting contaminants to groundwater (see Sections 12.3.5 and 9.3).

> Comment: The regulations should contain specific site selection and tailings management criteria which would explicitly define conditions leading to: (1) the selection of a particular below-grade option; (2) the conclusion that below-grade disposal is unacceptable; (3) the conclusion that above-grade disposal is acceptable; and (4) the conclusion that above-grade disposal offers erosion protection "reasonably equivalent" to below-grade disposal. Siting standards should be stricter for above-grade disposal, due to the potential for impoundment failure during operation. Financial surety and long-term care provisions should also be more stringent for above-grade disposal. (47, 91, 92)

Response: The staff considers it highly impractical and inappropriate to formulate regulations so specific, detailed, and inflexible as to essentially dictate the outcome of an in-depth process of site selection and alternatives evaluation. Such assessments unavoidably require the exercise of considerable judgment and experience in evaluating the many variables involved. It is precisely for this reason that the staff's revised regulations require adherence to minimum performance standards while simultaneously providing both the staff and the industry the flexibility needed to optimize environmental and public health protection levels, on a case-by-case basis, with due consideration of all factors involved.

With respect to potential operational failure of above-grade impoundments, protection is provided through requiring that design be in accordance with standards equivalent to those outlined in Regulatory Guide 3.11, and through preconstruction review and onsite inspection during construction. Criterion 8(A) also requires mill operators to conduct and document daily inspections. In addition, proposed sites and tailings management systems and alternatives are all evaluated in the context of a complete environmental assessment, a major purpose of which is to minimize uncertainties about operational and postoperational system integrity. Special protective measures, when necessary, are required by way of license condition. As these protective measures are best developed on a case-by-case basis, the staff has determined that it would not be appropriate or practicable for the regulations to provide additional protection by way of special siting requirements for aboveground impoundments.

Financial surety arrangements reflect cost estimates based on a specific decommissioning and reclamation plan committed to by the operator. Thus, these arrangements are also site-specific and will vary in accordance with general management design. Long-term surveillance requirements assume a passive monitoring mode; however, these will be evaluated on a case-by-case basis, taking all considerations into account simultaneously. The staff sees no reason for more stringent minimum requirements of this kind to be generically applied to above grade disposal sites, given that all sites must be reclaimed so as to avoid requiring ongoing active care.

> Comment: Cost is specified as a factor to be weighed in deciding whether to dispose of tailings below-grade. In addition to absolute cost, a company's ability to bear that cost should be considered so as to not unduly restrict the uranium production industry to large, cash-rich conglomerates. (61)

Response: The staff considers the costs of adequate environmental protection to be part of the cost of doing business. It would be entirely inappropriate to allow the degree of compliance required to hinge on the applicant's ability to financially support an adequate program of environmental and public health and safety protection, as this would, in essence, amount to an undeserved public subsidy.

> Comment: Below-grade burial should be explicitly defined as meaning burial below the original natural grade. (82, 91)

Response: The staff does not consider this to be necessary; text has been added to the final regulations to explain that full below-grade burial eliminates the need for any specially constructed retention structure.

> Comment: The wording of Criterion 4 should be changed to indicate that compliance with the six enumerated sub-criteria is required only as needed, because they are not universally applicable. (85)

Response: The staff considers compliance with each of the mentioned subcriteria to be appropriately required in all cases (not just for above-grade disposal sites). However, the staff has relaxed the wording with respect to wind protection by replacing the word "shall" with the word "should."

> Comment: Consideration of above-grade disposal alternatives should not be constrained by the requirement to demonstrate erosion protection reasonably equivalent to the NRC's single "prime option." (86)

Response: The staff continues to consider that any acceptable above-grade disposal program must provide erosion protection reasonably equivalent to that offered by below-grade disposal. This can frequently be accomplished through the use of gentle slopes and cover stabilization as needed, in accordance with Criteria 3 and 4. Alternatives not providing such protection would not be acceptable. (Also see Section 9.4.1.)

6.9.6 Reclamation Surety

> Comment: Self insurance should be considered for addition to the list of acceptable surety mechanisms - with requirements for qualification specified. (21, 60, 77, 85, 86, 99)

Response: The basis for not accepting self insurance, in fact, for ruling this option out, is contained in Section 14.2.3.7 of this GEIS. Since such an arrangement would provide no additional assurance, other than that which would already exist through license requirements, self insurance will not satisfy the surety requirement.

> Comment: The regulation states that the surety shall cover (1) decontamination and decommissioning of mill buildings and the milling site to levels which would allow unrestricted use upon decommissioning, and (2) reclamation of tailings and/or waste disposal areas in accordance with the technical criteria delineated in Section I of this Appendix. This requirement is in direct conflict with the NRC staff conclusion (Section 14.3) that mill structures and sites should be decommissioned to allow unrestricted use of portions of the site away from the tailings disposal area. (55)

Response: The staff has concluded that mill structures should be decontaminated to levels which allow unrestricted use. The only areas which will remain under a restricted use situation are the tailings disposal areas. The regulation, as stated, is consistent with the conclusions reached in this GEIS.

> Comment: The 20-year bonding period used by NRC in its cost analysis does not take into account the time required for tailings to dry out. This may result in a serious underestimation of the costs of bonds to uranium mill operators. (59)

Response: The costs provided in the draft GEIS were given as examples only. A five-year period after operations cease, during which surety coverage would be required, was included in the scheme described in the draft GEIS. In some cases, a longer period may be necessary to allow tailings to dry; however, even this five-year period of time may not be necessary in some cases if, for example, an operation involves staged reclamation of dewatered tailings. This highlights one of the many advantages associated with systems involving phased reclamation.

> Comment: Financial surety regulations should allow flexibility for alternative surety mechanisms which, although not acceptable on a generic basis, may be acceptable on a case-by-case basis. (59)

Response: This is explicitly provided for in Section 14.2.4 of the GEIS and Criterion 9 of new Appendix A to 10 CFR Part 40.

> Comment: Financial surety regulations should take into account the fact that operators of commingled tailings piles are not responsible for all of the costs of tailings cover, seepage mitigation, and other measures required to bring sites into compliance with proposed regulations. The GEIS and regulations should provide for the sharing of the financial liability and address Congressional responsibility. (59, 77, 85, 86)

Response: Please refer to responses to comments regarding commingled tailings in Category 6.7 of this appendix. Under the terms of the UMTRCA, the staff is not at liberty to set lower standards for commingled tailings.

> Comment: The GEIS does not address the problem of availability of surety bonds. Surety associations say the market for this type of arrangement is questionable. (64, 85)

Response: Flexibility exists in terms of acceptable types of mechanisms to satisfy the surety requirement. Furthermore, the evidence indicates that the surety market is competitive since some bonds have been obtained. However, there does seem to be resistance on the part of some bonding companies and banks to becoming involved in issuing bonds or letters of credit to companies subject to government regulation. The staff considers this resistance to be the result of a misunderstanding of the requirements. The requirement establishes the need for a surety which covers specific decommissioning and reclamation activities committed to by the operator in his license. The surety mechanism is not intended to be a floating liability which guarantees the performance of whatever standards are in place fifteen or twenty years in the future. Therefore, the surety liability is clearly defined and limited. In the event that additional surety coverage is needed, it would be the licensee's responsibility to obtain additional coverage by increasing the amount of the original instrument, using a combination of mechanisms, or replacing the original instrument with one which covers the total larger amount.

> Comment: Third party (federal, state, local or private entity) responsibility should be considered for addition to the list of acceptable surety mechanisms. (85, 86)

Response: "Third party" surety, as described here, essentially constitutes self insurance and, therefore, is not considered acceptable for the reasons stated in Section 14.2.3.7. Self insurance provides no additional assurance beyond that already existing by way of license requirements.

> Comment: The NRC should not duplicate State bonding or surety programs. (85)

Response: Criterion 9 of the final regulations and Section 14.2.5 of this GEIS, explicitly provide for accepting consolidated surety arrangements which satisfy minimum standards.

> Comment: The regulations should allow a licensee to change the method of surety at the time of license renewal. (85, 86)

Response: New Appendix A to 10 CFR Part 40, Criterion 9, and Section 14.2.4 of this GEIS, explicitly permit this flexibility.

> Comment: The regulation should distinguish between a surety to be held during operations and a surety to be obtained immediately prior to the cessation of operations. (85)

Response: As indicated in the regulations and the GEIS, one financial surety arrangement, established prior to the commencement of operations and adjusted regularly to cover the maximum amount of work to be performed, will satisfy the surety requirement.

> Comment: The amount of surety should be adjusted to recognize any increases or decreases resulting from inflation, changes in engineering plans, activities performed, and other conditions affecting costs. (85, 86)

Response: This is the intent of the staff, as indicated in Criterion 9 of the final regulations, and Section 14.2.4 of this GEIS.

> Comment: During the reclamation and decommissioning period at the end of operations, the amount of the surety should be reduced annually to take into account work performed. (85, 86)

Response: Appendix A to 10 CFR Part 40, Criterion 9, and Sections 14.2.4 and 14.2.5 of this GEIS, have been amended to provide for an annual review of the surety amount during the entire operational and postoperational period. During the operational period, this review would only be to adjust for inflation. During the operational period the required amount of surety coverage is the maximum necessary during the effective term of this license. For an operation involving phased reclamation, this obviously takes into account work performed since performance of reclamation according to a specified schedule would be a requirement of an operator's license. Any deviations from this schedule would have to be handled through a separate license amendment application. During the postoperational period, work performed will be taken into account and the required coverage will be reduced accordingly.

> Comment: The terms of a surety bond should be the normal terms of the surety industry and should be for the term of each license renewal period. (85)

Response: In order to provide a high level of assurance that sufficient funds will be available to perform decommissioning and reclamation work, the staff has concluded that the term of the surety must be open-ended (i.e., the surety must remain in force until decommissioning and/or reclamation activities covered by the surety arrangement are completed), or provide the same level of assurance as an open-ended arrangement. This degree of assurance could be provided with a surety instrument which is written for a specified period of time (e.g., five years) yet which must be automatically renewed unless the ensurer notifies the beneficiary (the Commission or the State regulatory agency) and the principal (the licensee) some reasonable time (e.g., 90 days) prior to the renewal date of their intention not to renew. In such a situation, the surety requirement still exists and the licensee would be required to submit an acceptable replacement surety within a brief period of time so as to allow at least 60 days for the regulatory agency to collect. Proof of forfeiture must not be necessary to collect the surety, so that in the event that the licensee could not provide an acceptable replacement surety within the required time, the surety could be collected prior to its expiration. Such an arrangement demands efficient procedures for collecting the surety so that bureaucratic red tape will not prevent the beneficiary (regulatory agency) from collecting in the required time frame (before expiration of the surety). Procedures to initiate collection must be automatic and nondiscretionary. The conditions described above would have to be clearly stated on the surety instrument, and agreed to by all parties. In essence, there is no difference between this situation and an open-ended arrangement since, even under the latter, the surety company or the financial institution is under no obligation to increase the amount of the surety. If the amount of required surety coverage increases (as a result of inflation, expansion of the affected area, etc.), it remains the licensee's responsibility to provide adequate surety coverage. There is no advantage to the automatically renewed form of surety coverage for the surety company or financial institution. In either situation the ensurer's obligation would remain the same. The only reason for permitting the automatically renewable type of surety coverage described above is that this provides greater flexibility for the licensee, in terms of the types of mechanisms from which to choose in order to satisfy the surety requirement. Irrevocable letters of credit are not written under open-ended terms, but have been written under the automatically renewable conditions described above.

> Comment: No form of surety shall become payable until a final determination has been made that the licensee has failed to complete the requirements of its license. (85, 86)

Response: Under the provisions of Criterion 9 of the final regulations, the surety would become payable upon the licensee's failure to perform decommissioning and reclamation in accordance with the provisions of their license, and on a schedule established by license condition. In the case of a surety written for a specified, automatically renewable period of time, the surety would become payable if the surety company indicated their intention not to renew, and the licensee was unable to replace the surety in a specified amount of time.

> Comment: The regulation should permit a combination of surety mechanisms to assure that sufficient funds will be available. (85, 86)

Response: Such a combination of surety mechanisms is explicitly provided for in Criterion 9 of new Appendix A to 10 CFR Part 40.

> Comment: The amount of surety required should be the costs of decontamination and decommissioning less the projected net worth of the licensee. (85)

Response: Such consideration of the projected net worth of the licensee essentially constitutes self insurance and, therefore, is unacceptable for the reasons stated above and in Section 14.2.3.7. Projected net worth does not provide any assurance that these assets would be readily accessible to the Commission in the event of failure to perform.

> Comment: The amount of the surety should exclude the costs of interim decommissioning and reclamation work performed during milling operations. (85)

Response: In an operation which involves staged reclamation, the amount of the surety would be the maximum amount to decommission the mill, and perform the necessary reclamation activities during that license period, plus the long-term fund amount.

> Comment: Surety should remain in effect until the decommissioning program has been approved or until the site is transferred to the responsible government agency, whichever comes first. (85)

Response: Since the tailings disposal site will not be transferred to the responsible government agency until the decommissioning and reclamation program has been completed and approved, and the license has been terminated, the surety must remain in effect until the license is terminated as described above. (See Chapter 14.)

> Comment: The UMTRCA does not contemplate financial arrangements of the duration contemplated by the GEIS. The UMTRCA refers to the licensee providing financial assurance only when the license is about to terminate. (86)

Response: Financial assurance provided only when the license is about to terminate would not provide the level of assurance which the Commission considers necessary to ensure that decontamination, decommissioning and reclamation standards will be met. Further, the broad authority provided under Section 83a of the Atomic Energy Act, as amended, states that "Any license issued... shall contain such terms and conditions as the Commission determines to be necessary to assure that... the licensee will comply with decontamination, decommissioning and reclamation standards prescribed by the Commission."

> Comment: The amount of the surety should include additional estimated costs (limited to 10%) which may arise from contracting requirements or the need to bring personnel and equipment to the site to perform work. (86)

Response: Cost estimates which form the basis for the bond amount must be contractor costs, which include personnel and equipment, and should include any additional costs (e.g., profit and overhead). Costs for profit and overhead, and contingency costs, can amount to as much as about 50% (see Appendix K-8).

> Comment: Costs should be based on a licensee's costs rather than third party costs since the licensee is responsible. (86)

Response: The purpose of the surety requirement is to provide assurance that reclamation will be performed in the event of licensee default. Costs to the licensee to perform decommissioning and reclamation would probably be less than if an independent contractor performed the work and, therefore, sufficient funds might not be available if the amount of required surety coverage were based on licensee costs.

> Comment: Advances in state-of-the-art technology should be stated as a reason for changing the amount of the surety. (91)

Response: As indicated in the response to a previous comment regarding the need for greater flexibility in terms of reasonable bases for adjusting the required amount of surety coverage, Criterion 9 and Sections 14.2.4 and 14.2.5 of the GEIS have been amended to incorporate this flexibility.

6.9.7 Long-Term Funding

6.9.7.1 Amount of Long-Term Fund

> Comment: A long-term fund charge of $250,000 seems too low for mills with a high productivity. These operations may cause an increased potential hazard and, thus, require more frequent or expanded monitoring. (21, 89)

Response: The assumption is made that any site to which the $250,000 (1978 dollars) long-term monitoring charge applies will be decommissioned and reclaimed in such a manner to restrict long-term needs to periodic visual inspection. All sites, even those which are already in existence, will be required to comply with the technical criteria which assure long term protection; therefore, the $250,000 (1978 dollars) charge should be appropriate and sufficient. However, sufficient flexibility exists under Criterion 10 to increase the charge if it is determined that additional site control measures are necessary at a given site. For an annual inspection, the size of the pile will be of little significance.

> Comment: The long-term fund charge of $250,000 is totally inadequate and there is no analysis to support it. The amount does not take into account fencing, detailed monitoring, repair, natural disasters, and unanticipated problems. (26, 89, 99, 100, 130, 134, 135)

Response: The analysis to support the $250,000 (1978 dollars) one-time charge for long term surveillance is contained in Appendix R. It is correct that this figure does not cover any fencing, extensive monitoring, or repairs, nor does it take into account care required as a result of natural disasters or unanticipated problems. Characterization of the situation over the long term, following decommissioning of a facility, is based upon the assumption that the other criteria governing disposal of uranium mill tailings will be complied with. Thus, the situation would be one in which "passive monitoring" would be appropriate. As stated above, however, if it is determined that additional site control measures are appropriate (e.g., fencing), a higher amount may be charged.

> Comment: Costs of surveillance are not entirely independent of the size of the facility; therefore, a flat charge of $250,000 is inappropriate and should be adjusted to take into account the dependence on size. (52, 63, 70)

Response: The type of surveillance which is contemplated only involves an annual visual inspection and minimal sampling. No maintenance is included. Therefore, size of the facility is of little consequence.

> Comment: The $2,500 annual cost associated with long term site surveillance is the upper bound of the cost estimate and there is no justification for having chosen this overly conservative figure. (55)

Response: The justification for the $2,500 annual cost is contained in Appendix R of this GEIS. Although it may properly be characterized as an upper bound figure, it is not overly conservative. Given the uncertainties involved, and the fact that some groundwater monitoring is likely to be needed, the staff considers this figure appropriate.

> Comment: In those situations in which the state is the ultimate custodian of a tailings disposal site, annual surveillance costs would be lower than if the federal goverment were performing inspections, since the proximity of the state agency to the site would reduce associated travel costs. (55)

Response: Travel costs and the portion of the inspector's salary upon which these calculations are based, which represent travel time, are only a small fraction of the associated costs. In addition, since no one knows at this time if any state will elect to retain custody of a tailings disposal site, it is prudent to establish a standard figure which may be marginally conservative.

> Comment: If the NRC determines that government land ownership is not necessary to protect the public health and safety, little or no costs for long-term site surveillance would be incurred and, thus, the $250,000 would be unnecessary or at least too high. (55)

Response: The determination concerning the necessity for government land ownership can be made at any time prior to termination of the license. Thus, unless an exemption is granted prior to the initiation of operations, provision must be made to ensure the payment of the long-term surveillance fee. Certainly, if long-term surveillance is determined to be unnecessary, the associated fee would be waived also. This is allowed by the final regulations.

> Comment: The financial criteria are a farce in the face of present inflation. (62, 77, 134)

Response: It is assumed that this comment refers to the assumed 1% real interest used to calculate the long-term fund charge. As discussed in Chapter 14, it is nearly impossible to predict what inflation and interest rates will be over the long-term future. The procedure of comparing these rates and averaging the differences over a period of time in recent history was, in the staff's judgment, the only reasonable approach to take.

> Comment: It is questionable whether the flat one-time rate of $250,000 will adequately compensate for surveillance requirements in the future. (63)

Response: The $250,000 requirement referred to in this Criterion is in 1978 dollars and will be adjusted annually prior to actual payment in accordance with inflation as indicated by the Consumer Price Index. Therefore, if a facility were to decommission and have their license terminated in 1990, and inflation had been at a steady rate of 10% from 1978 to 1990, the actual amount which the licensee would have to pay would be about $800,000.

> Comment: $250,000 may be appropriate for below grade tailings disposal facilities; however, not for less permanent disposal methods. (70)

Response: Disposal methods which do not assure reasonably equivalent long-term protection will not be approved. However, Criterion 10 is written to allow some flexibility if additional measures, such as fencing, are deemed necessary or appropriate.

> Comment: $250,000 long-term fund charge is not consistent with the UMTRCA requirement that long-term charges be kept to a minimum and, if possible, eliminated. (73)

Response: The staff does consider that the specified charge is a reasonable minimum, given that costs could indeed be much higher if fencing is needed, monitoring needs are more than minimal, or if inspection frequency greater than on an annual basis is needed. For a complete discussion of the basis for this charge, see Appendix R.

> Comment: $250,000 charge is several times too low since, based on the Congressional appropriation of $6 million for remedial action at each inactive site, only one containment failure would use up all of the monies collected from 24 operations. (74)

Response: This comment appears to confuse the issue of tailings reclamation and stabilization and ongoing site surveillance. (See Section 14.1) Currently active and future operations will not be left in the same unstable condition as many of the now-inactive sites were. Thus, the situations are entirely different. The quoted cost for remedial action ($6 million) is primarily for covering and stabilizing impoundments, actions which at active mills will clearly be funded by mill operators, as guaranteed by surety. (See Sections 14.1 and 14.2) Current operators will be required to take measures to assure that disposal sites remain stable over the long term. Based on the requirements which will be imposed on currently active and future operations, the staff considers it reasonable to assume a passive monitoring situation over the long term. However, Criterion 10 contains some flexibility if it is considered appropriate to take additional steps at a particular site (see Section 14.3).

> Comment: Criterion 10 should include provision for decreasing the charge on a site-specific evaluation. (77)

Response: Criterion 10 contains a provision for eliminating the long-term fund charge altogether in the event that long-term surveillance and land ownership is deemed unnecessary. Further, the criterion has been clarified to reflect provision for flexibility to increase the charge on the basis of site-specific conditions; however, as long as some monitoring is appropriate, costs could hardly be reduced substantially, since they are now based only on an annual visual inspection.

> Comment: Flexibility in establishing the amount of long-term reclamation and monitoring sureties is essential. Each surety will vary and it may be impractical to set the same amount for all situations. (84, 85, 86)

Response: There seems to be some confusion between Criterion 9 and Criterion 10. Financial sureties, required by Criterion 9, and discussed in Section 14.2 of this GEIS, are to cover costs associated with reclamation and decommissioning. The long-term fund charge, required by Criterion 10, and discussed in Section 14.3, is designed to cover costs associated with ongoing surveillance expected to consist of periodic visual inspections. The only connection between these two requirements is that since the long-term fund charge is not paid until the termination of operations, it is to be covered by the financial surety during the operational period. The amount for the reclamation surety is variable, being dependent on the decommissioning and reclamation plan committed to in the license. Although the amount of the long-term fund charge is also somewhat flexible, for those sites which are expected to be characterized by the "passive monitoring mode" over the long term, a standard long-term fund charge has been established.

6.9.7.2 Applicability of Long-Term Fund for Certain Operators

> Comment: The regulation implies that deep well disposal sites, in which mildly radioactive waste water generated by an in situ facility is injected, would be subject to long-term surveillance fees. Annual site inspections of such deep well sites is unnecessary and a long-term fund charge is inappropriate. (48)

Response: Criterion 10 has been revised to indicate that if it can be determined that no monitoring is necessary, as in the case of acceptable deep well disposal, no long-term monitoring charge should be required.

> Comment: The long-term fund charge should be eliminated for those licensees who are required to decontaminate their sites and dispose of wastes at another facility in order to avoid proliferation of sites. (53, 86)

Response: Clearly a site which has been completely decontaminated will not require long-term monitoring; therefore, no long-term fund charge is appropriate. This provision has been clarified in Criterion 10.

> Comment: It is not clear if discrete wastes from in situ processes are subject to long term fund charges. (73)

Response: In the event that the in situ site is completely decontaminated by removal of any aboveground wastes, or in the event that no long-term surveillance is deemed necessary, the long-term fund charge would be eliminated.

> Comment: The charge for long-term monitoring should cover all sites generated by a particular operator. (86)

Response: The monitoring and surveillance of each tailings disposal site will be treated separately. Since, as described in Section 14.3 and Appendix R, the long-term fund charge is for visual inspection and report writing, it is the staff's judgment that each separate site should be required to pay individual long-term funding charges.

6.9.7.3 Miscellaneous

> Comment: Criterion 12 states that site inspections shall be conducted by site owners. In the event of private ownership, payment of the long-term fund charge to either the state or federal government would be inappropriate. (55)

Response: Criterion 12 has been clarified concerning this point. In the event of private ownership, (e.g., at sites grandfathered by Section 204(b)(4) of the Uranium Mill Tailings Radiation Control Act), if site surveillance is determined to be necessary, this surveillance would be conducted by a government agency.

Comment: Long-term funds should be deposited in an earmarked account rather than deposited in the U.S. General Treasury. (71, 73, 85, 86)

Response: The staff considered this option, as indicated in Section 14.3.4, and rejected it on the basis that it would require a significant level of administrative effort and would offer no real advantage. The arrangement, described in Section 14.3 and required by Criterion 10, is designed to be the functional equivalent of an earmarked perpetual fund, yet avoids its management load.

Comment: The charge for long-term surveillance should be paid at the beginning of operations in order to avoid difficulty in collection at the time of termination of operations. (74, 79)

Response: The charge to be paid for long-term monitoring will be covered by the financial surety arrangement during the operational period, in order to avoid any serious problems with collection. As discussed in the draft GEIS, since the final determination concerning who will be the ultimate custodian of the disposal site does not have to be made until the termination of operations, payment of the long-term fund before this determination would make the situation unnecessarily complicated.

Comment: Annual surveys are not necessary, particularly after 20 years or so, once reclamation permanency and radon control have been demonstrated. (77)

Response: Stability from erosional forces and radon control are not the only long-term considerations. Human and/or animal intrusion is another factor which must be considered, and this is something which would require surveillance essentially forever, on a regular basis.

Comment: Criterion 10 should include a provision for refunding monies if, after five years, surveillance costs are running less than interest accrual. (77)

Response: With a fund designed to cover costs of such a long-term nature, where it is impossible to accurately predict inflation or interest, an initial imbalance one way or the other would likely be compensated for in future years. In light of the long-term surveillance contemplated, refunds would be inappropriate. As discussed in Section 14.3, the objective was to establish a simple, equitable arrangement in the face of great uncertainty concerning long-term interest and inflation.

Comment: Criterion 10 states that the long-term fund amount will be adjusted annually in accordance with the change in the Consumer Price Index. It is assumed that this inflation factor would apply only up to the time of termination of the license. (77)

Response: That is correct. The language of Criterion 10 has been clarified to reflect this.

Comment: Consideration should be given to an emergency fund to be used in the event of failure of the integrity of the tailings disposal system. (21, 70, 126)

Response: As described in Section 14.3.5, consideration was given to an insurance fund to cover costs associated with unforeseen events such as catastrophic occurrences. However, since the likelihood of such an occurrence is negligible, and design against it would be impractical beyond that which is already required in terms of siting and design, it does not seem reasonable to require insurance for such an eventuality. Flexibility exists so that if greater uncertainty about long-term performance exists at a particular site, a higher fee may be charged.

Comment: Financial criteria do not make any provision for operational or postoperational containment failures such as Church Rock. (56, 82, 91, 99)

Response: Various requirements contained in the final regulations assure that design, construction, and operation of tailings disposal systems will be such that the type of containment failure described will not occur. Further, the Church Rock failure occurred during the operational period, while the operator was still financially accountable. Such a failure would be most unlikely once tailings are stabilized and the operator is released from further obligations.

6.9.8 Nonproliferation

> Comment: Small quantities of byproduct material should be exempted from the regulations because of the small incremental hazards involved and because of the difficulties involved in getting permission from large mill operators to dispose of such wastes at their facilities. (53)

Response: The staff generally considers that all byproduct materials subject to the proposed regulations should be finally disposed in accordance with the same requirements. However, as indicated in Summary Section 9, in the future it is possible that small quantities of tailings (such as used in connection with research and development) may be exempted or possessed under a general license. Additional evaluations would be necessary before such a determination could be made. Therefore, NRC is inviting comments on this subject and will publish its conclusions at a later time.

> Comment: The State of Texas prohibits transfer of low-level radioactive waste to any tailings impoundment not owned by the transferer. NRC should encourage states to allow such transfers or establish adequate low-level waste disposal facilities. (67)

Response: NRC would encourage states not to prohibit appropriate transfers of byproduct material (e.g., small quantities of uranium tailings) to approved tailings impoundments, as well as to establish low-level waste disposal facilities as practicable and needed. However, within their jurisdictional purview, the states are not constrained to follow NRC advice.

> Comment: Offsite disposal of heap leach residues, and similar wastes produced by small operations, is completely impractical due to the marginal economics involved. (77, 85)

Response: The staff considers that operations with insufficient revenues to provide for adequate environmental protection should not be conducted. With respect to heap leaching of low grade ores, some previously viable operations may indeed be sacrificed. A very small fraction of uranium is produced by heap leaching and the loss of part of this supply will not significantly affect the overall availability or price of uranium product. Offsite disposal is not, however, uniformly required. The staff's final regulations, as discussed in Section 12.5, allow for consideration of involved circumstances, such as costs.

> Comment: The words "shall preferably" in Criterion 1 are confusing and should be replaced. (77, 84)

Response: The staff concurs with this comment and an appropriate change has been made.

> Comment: NRC should not require transport of solution mining or other extraction residues to larger licensed disposal sites. Such materials are of low activity, but frequently are contained in saline slurries or precipitates which are extremely difficult to handle and transport over long distances to licensed sites. Besides the high cost, we believe such transportation would create greater risk and hazard to the public from inevitable accidental spills than would impoundment and isolation at the project site. (85, 86)

Response: The staff has not uniformly required offsite disposal of such wastes, due to the reasons mentioned (see Section 12.5). The staff considers, however, that offsite disposal of solid wastes, which remain after the evaporation of solutions, by aggregation with other solid wastes, be conducted unless demonstrated to be impracticable, or when the advantages of onsite disposal clearly outweigh the benefit of reducing perpetual surveillance obligations.

> Comment: The proposed plan to put high specific activity surface residues from in situ mining in large tailings impoundments is a very dangerous precedent, full of unknown possibilities. The high radium and total curie content of such materials could completely alter needed tailings management practices. (109)

Response: Such transfers would not occur without the knowledge and consent of the NRC (or Agreement State licensing authority), under present licensing practices and requirements. The appropriateness of such transfers would be reviewed as necessary to assure soundness from engineering and environmental perspectives. The staff does not expect such transfers to present significant problems to the receiving disposal site, due to the relatively low volumes of waste involved.

> Comment: Byproduct material from in situ operations should be required to be disposed of at large existing sites. There is no reason to allow the proliferation of small disposal sites. (115)

Response: The staff's regulations (i.e., Criterion 2) are worded so as to assure consolidation of waste materials to the fullest practicable extent (see Section 12.5). However, the staff considers that the relative costs and benefits of offsite disposal are so site-specific, and that potential transportation difficulties and environmental impacts are so large, that offsite disposal cannot be appropriately required in all cases. In view of this, the staff has established requirements for adequate final disposal of all byproduct materials, whether from in situ operations or otherwise.

6.9.9 Monitoring Requirements

> Comment: Facilities for down-gradient monitoring of groundwater should be included in the design of any disposal facility for uranium mill tailings and wastes. (72)

Response: This is a routine requirement (see Section 10.2 and Appendix V).

> Comment: Permanent groundwater monitoring to assure long-term isolation should be required at every tailings disposal site; the GEIS should discuss the costs and benefits of such an alternative. (74)

Response: As discussed in the text, long-term groundwater monitoring may or may not be required, depending on need (see Section 10.3 and Appendix R). The staff sees no reason to require monitoring that is not needed, but maintains the ability to require such monitoring, if appropriate. However, as discussed in Section 12.3.5, seepage is not expected to be a long-term problem. In the semiarid regions where milling is currently conducted, there will be virtually no driving force for seepage after the impoundments dry.

> Comment: We agree that appropriate monitoring is needed to help analyze effects of milling operations on the site and the immediate environment. Any preoperational monitoring should be carried on concurrently with licensing preparation and application. It should not be necessary for a separate period of preoperational monitoring after licensing, but before construction could begin. (86)

Response: Criterion 7 requires only that one full year of preoperational monitoring be conducted before any major site construction. Time between the conclusion of this preoperational program and the initiation of construction is not addressed. In fact, such preoperational monitoring normally occurs, as suggested in the comment, either before submittal of a formal license application, or during the license review process.

> Comment: Criterion 7 does not make clear what NRC's role will be in monitoring compliance with the law and regulations. Will companies be allowed to do their own monitoring, with no NRC inspections? The NRC role should be better defined. Also, quality control must be provided. (115, 134)

Response: Criterion 7 stipulates that preoperational and operational monitoring programs be conducted by the applicant/operator (also see Chapter 10 and Appendix V). It is not meant to define NRC's role in assuring compliance with applicable requirements. The NRC does conduct periodic onsite inspections, and also provides for adequate verification, replication, and quality assurance of monitoring programs through normal licensing procedures and regulatory guidance. Specific guidance concerning monitoring programs is contained in Regulatory Guide 4.14 "Measuring, Evaluating, and Reporting Radioactivity in Releases of Radioactive Materials in Liquid and Airborne Effluents from Uranium Mills," and Regulatory Guide 4.15 "Quality Assurance for Radiological Monitoring Programs."

6.9.10 Embankment Slopes

> Comment: To specify that slopes must be flatter than 5:1 or 10:1 can be unreasonably conservative. Analysis indicates that to make slopes flatter than 6:1 does not decrease erosion rates significantly whereas it greatly increases the amount of material required

> for construction. Consequently, specific slope steepness criteria should not be stated. Instead, the slope and surface stabilization plan should be designed on the basis of the properties of the materials to be used to construct the slopes. Slopes should be designed to accommodate the site into the natural slopes of the surrounding environment. (55, 77, 85, 86)

Response: When slopes are small, erosion is generally proportional with steepness of slopes. However, research indicates that when slopes become steeper than a particular threshold value, the potential for gullying or wind blowout is greatly increased (Schumm, 1977). As those threshold values are not well defined, the flattest practicable slopes should be utilized.

In some cases, such as where mine waste or tailings trench overburden is placed on top of the tailings, slopes flatter than 10:1 or more can be economically constructed. Consequently, although making slopes flatter than the value 6:1, as noted in the comment, may not be significant with regard to wind and water sheet erosion, it would significantly decrease the potential for localized erosion, which can lead to the development of more serious conditions such as gullies.

The regulations provide for flexibility in this matter. The slopes specified in the technical criteria must be considered to represent guideline values. Any slope design must accommodate the impoundment into the natural slopes of the site and surrounding areas, and must provide for the stability of such slopes against long-term localized or sheet erosion. When gentle slopes are impracticable, there must be compensating factors and conditions which make steeper slopes acceptable.

> Comment: Criterion 4c implies that if slopes flatter than 5:1 are impractical, steeper slopes may be used. However, if steeper slopes are allowed, or if facilities are located in areas of naturally steep terrain, stability problems may result. Also, the potential hazard from dispersion of tailings is increased. Therefore, if the terrain is steep or if steep slopes are utilized in the reclamation, the engineering analysis should consider the worst case. Facilities should not be located in an area where natural slopes are steeper than 10:1. (72, 74)

Response: Although slopes on embankment surfaces flatter than 5:1 are desirable, this is not always practicable. When limitations on space exist, or where flatter slopes would extend the toe of the slope into areas subject to concentrated runoff flows, it may be necessary to utilize steeper slopes. In such cases the slope design, surface stabilization techniques, and factors of safety incorporated in the design, can and must provide reasonable assurance that long-term isolation of tailings will be accomplished, to prevent dispersion by natural forces. Note also, that the final regulations have been revised from the proposed version to clarify explicitly the need to consider, in siting and design of impoundments, the effects of surrounding terrain and geomorphic process on long-term stability.

> Comment: Technical Criterion 4c states that to provide stability for above-grade impoundments of the same magnitude as would be achieved with below-grade impoundments "would for example, lead to slopes of about 10 horizontal to 1 vertical (10h:1v) or less steep..." This is inconsistent with the next sentence in Criterion 4c which says that slopes should be flatter than 5:1. (61)

Response: The wording in question has been changed to state that to provide stability"... could, for example, lead to slopes of about 10 horizontal to 1 vertical...". The objective is to minimize slopes and, therefore, the potential for erosion.

> Comment: Tailings areas should not be reclaimed in such a way as to be so large so that, with some uneven settling, surface ponding occurs. This might provide a source of water for promoting continued seepage of tailings contaminants to groundwater. Some slight sloping should be utilized to direct surface water away from the underlying tailings. (105)

Response: The staff is aware of this potential problem and is in full agreement with this comment. This is one of the many factors which must be considered in design of the tailings management system. Stabilization and reclamation program plans will have to demonstrate that differential settlement will not significantly and adversely affect isolation performance in any of several ways, including the enhanced potential for surface ponding.

6.9.11 Land Ownership, Use, and Transfer

> Comment: Criterion 11 needs to specify how and when land transfers will be effected and when use of the surface and/or subsurface estates of such land will be permitted. (47)

Response: Criterion 11 has been revised to clarify provisions concerning the implementation of ultimate land ownership and future use requirements. Generally, at any site where long-term surveillance will be required, the applicant or operator must demonstrate a serious effort to obtain title to the land, including any interests there. However, as discussed in Section 13.4, ownership of certain severable subsurface interests may be determined to be unnecessary to protect the public health and safety, and the environment. In the event that certain subsurface rights cannot be obtained, the applicant or licensee will be required to provide notification, in local public land records, of the the fact that the land is being used for disposal of radioactive wastes, and is subject to the NRC prohibiting the disruption or disturbance of such wastes.

> Comment: How will the land transfer requirement be applied to existing facilities (i.e., how much weight will be given to the status of ownership.)? (47, 135)

Response: The land ownership situation at each of the existing facilities must be evaluated on a case-by-case basis. A serious effort on the part of the licensee to obtain ownership of the site must be demonstrated. (See the discussion of this issue in Section 12.3.11.)

> Comment: Deep well disposal sites where mildly radioactive waste water has been injected should not be subjected to the ownership transfer requirements. (48)

Response: In order to address this issue, one needs to define what is meant by deep well disposal. Generally, deep well disposal involves the placement of wells 5,000 feet or more beneath the surface. In addition, wastes would be injected into an aquifer which is already determined to be unusable. These are conditions which would necessarily be examined before licensing of such a disposal operation. Under such a situation it would probably not be necessary to transfer ownership of the disposal site to a government agency, since annual inspections to determine compliance with long-term stability and groundwater protection criteria would be determined to be unnecessary at the time of initial licensing.

> Comment: Criterion 11 implies that in all cases, government land ownership will be desirable or necessary. The regulation should allow flexibility in order to permit NRC to make determinations about the necessity for long-term government land ownership, as described in the UMTRCA. (55)

Response: It was intended that the NRC have flexibility regarding the necessity for the long-term government land ownership requirement. However, although some flexibility exists, the Commission considers, as indicated in Sections 12.3.11 and 13.4, ultimate long-term government land ownership to be a prudent added measure of institutional control in most cases. Discretion will be exercised, particularly regarding the necessity for subsurface ownership.

> Comment: Criterion 11 which indicates that government land ownership would be required in probably all cases is inconsistent with the intent of the UMTRCA. A broad requirement for government ownership is not adequately justified. Provision should be made for circumstances which provide such a high degree of isolation that government land ownership is deemed unnecessary. (55)

Response: NRC does not consider Criterion 11 to be inconsistent with Congressional intent. Moreover, the Congress specifically directed the Commission to require transfer of title to tailings disposal sites unless a determination could be made that such title transfer was "not necessary or desirable to protect the public health, [and] safety...." Criterion 11 contains some flexibility regarding the necessity for the land ownership requirement in order to permit a determination that long-term institutional control is unnecessary. In fact, Section 12.3.11 of the draft GEIS cites acceptable deep mine disposal as an example of a situation in which such a determination could be made.

> Comment: In order to reserve the right to reprocess tailings, Criterion 11 should specify that the transfer of land ownership occur "upon or immediately prior to the expiration or other termination of the license." (77)

Response: It was the intention of the NRC staff that transfer of title to the lands on which tailings are disposed would take place at the time of termination of the license. Under such an arrangement, the licensee would retain the right to reprocess tailings throughout the entire period of the license, with NRC approval. Criterion 11 has been clarified to reflect the intended timing of the land ownership transfer requirement.

> Comment: Section E of Criterion 11, which applies to licenses in effect in November 1981, is very broad and could be interpreted to require lands in addition to those used for tailings disposal to be transferred to a government agency. Words should be added to indicate that such a situation will not arise which would result in the licensee or another private party being unduly deprived of any potential future uses of such lands. (77)

Response: It was the NRC's intention that only lands on which tailings are disposed and which, therefore, cannot be completely decontaminated, shall be considered for restricted use. All other lands, including the mill site and associated areas, must be completely decontaminated and decommissioned to allow unrestricted use upon license termination. As discussed in Sections 12.3.11 and 9.4.2, under the provisions of the UMTRCA, the Commission can envision some cases in which future uses of tailings disposal areas may be possible, and provision has been made for this possibility.

> Comment: Criterion 11 establishes a broad rule for government ownership of tailings disposal sites which is not justified under the authority of the UMTRCA. The Act requires NRC to make a determination concerning the necessity of title transfer to protect the public health and safety. If ownership of all lands must be transferred and then the government decides that use of the surface or subsurface is permissible, some property owners may suffer an unnecessary hardship. (86)

Response: The Commission has determined that in most cases government ownership of tailings and tailings disposal sites (particularly surface rights) will be necessary or desirable as a prudent measure of control. The Congressional intent is clear that, given this Commission determination, title transfer should be required. Congress further indicated that following such transfer, if the Commission determines that certain uses of the surface and/or subsurface estates can be permitted, the transferee should be given the right of first refusal with respect to such uses. The title transfer requirement must be viewed as a business expense. Procedures established in Criterion 11, which follow the provisions of the UMTRCA regarding possible future uses of disposal sites, are an attempt to minimize any unnecessary hardships. (See Section 12.3.11.)

6.9.13 Daily Pond Inspections

> Comment: Criterion 8(A) should be revised to require only weekly inspections for in situ above ground waste ponds because such ponds are generally far superior to conventional uranium tailings impoundments, are much smaller, and contain only relatively small quantities of waste materials. (48, 67)

Response: While the staff agrees that the need for daily inspections may be reduced, it does not consider that requirement to be so burdensome as to not be worthwhile. Considering the potentially severe and long-lasting impacts of impoundment failure, even for in-situ waste storage ponds, the staff considers daily inspections to be a prudent and practicable protective measure.

> Comment: Criterion 8(A) should be deleted because any failure sufficient to be detected during inspection would be obvious in any case, and any problem that is not obvious would not likely be detected by such inspections. (53)

Response: The staff cannot agree with this comment, and continues to consider daily inspections to be amply warranted. The staff believes that this procedure, if it had been implemented, might have prevented, and would surely have provided advance warning of, the recent Church Rock dam failure in New Mexico.

6.9.14 Dust Mitigation

> Comment: The need for ore pad wetting or stabilization should be evaluated on a site-specified basis and not imposed as an inflexible regulatory requirement. Site-specific factors, such as local

> climate, location of the ore pad in relation to the mill structure and prevailing winds, and physical characteristics like ore moisture content may make control of ore pad emissions unnecessary. (59)

Response: The staff agrees with this comment. Neither the proposed regulations nor the regulations to be implemented require specific actions to be taken to reduce dusting from ore storage areas. What is called for are written procedures tailored to the specific mill. In any case, however, such releases must be kept as low as reasonably achievable, with respect to cost and other factors.

6.10 Implementation Impacts

6.10.1 General Economic Impacts

> Comment: The GEIS should discuss the effects of the increased cost of development of domestic uranium supplies from U.S. sources, as compared with foreign production with similar controls not imposed. (13)

Response: It is the opinion of the staff, based on available information, that the proposed NRC regulations are not greatly different from those now imposed or being considered by the other major uranium-producing countries, in terms of incremental production costs. Production cost differences can and do exist for numerous reasons, apart from costs for environmental protection. The staff considers the production cost impacts of the new regulations to be slight compared to other, unassociated cost/price influences, and thus to have no significant impact on import/export uranium market balances. As discussed in Section 12.3, the environmental protection measures required by the staff's regulations will constitute only a small fraction of total product price in any case.

> Comment: An important national interest consideration is the inevitable loss in future uranium reserves which must be left unmined because higher costs of additional regulation have made them uneconomic. (86)

Response: Such a loss, if any, cannot be regarded as "inevitable." Some temporary deferral of mining may occur, but market forces will eventually result in the exploitation of lower grade reserves in the future, on an as-needed basis. Much ore being mined currently would have been considered "uneconomic" a few years ago. However, the overriding consideration is that the requirements established by these regulations are considered to be the minimum necessary to protect the public health and safety and the environment.

6.10.2 Impacts on Existing Facilities

> Comment: Misleading omissions occur in discussing financial matters. One omission is a clear and unavoidable statement of the simple fact that it is the consumer who will pay for all milling costs, eventually, either by direct price increases or by taxes to provide government subsidies. Another is the absence of recognition of the long term nature of uranium marketing arrangements. It does a mining company little good if it must pay today for increased regulatory costs with price increases that cannot be imposed for two, or four, or ten years. (53)

Response: The staff acknowledges that, in the case of uranium, costs of mining, milling, fuel preparation, etc., will be borne by the consumer of the energy ultimately generated from the uranium. The staff attempted to put this aspect in perspective by means of Table 11.12 of the draft GEIS. In this table, cost components of the various alternatives were expressed in $ per unit of U_3O_8 and in mil/kwhr so that the reader could relate tailings management costs to the cost of U_3O_8 or electric energy, or even MT of tailings managed. The staff could not consider it appropriate to postpone the imposition of adequate, cost-effective regulatory controls until all production contracts could be revised to reflect the costs of environmental protection. (See Section 12.4 also for a fuller discussion of financial impacts at existing sites.)

> Comment: It seems apparent that the NRC Staff has decided, either consciously or unconsciously, to condemn to premature death some current lives and an unknown but potentially enormous number of future lives, for the purpose of continuing to allow the uranium milling industry to operate in the manner to which it is accustomed. (54)

Response: The regulations being implemented seek to reduce health risks to levels which are as low as reasonably achievable, all factors being considered together. Reduction of residual risks to zero is not considered to be either practicable, appropriate, or even possible (see Section 12.3.4).

> Comment: By Executive Order number 10233, it is mandated that agencies review the economic impact of proposed regulations. Based on the proposed regulations of 2 pCi/m^2-sec of Rn-222 flux from reclaimed tailings disposal areas, in addition to the idea that cover material not include mine waste or rock that contains "elevated levels of radium," an enhanced financial burden on the uranium mining industry is foreseen in hauling cover material. It is, therefore, necessary that NRC thoroughly justify and identify the economic impact of this proposed control, since it is used in a proposed regulation. (55)

Response: The staff considers the costs of proposed controls to be adequately identified and justified (see Section 12.3.4).

> Comment: The regulatory requirements proposed in Section 12 of the GEIS were developed primarily for prospective milling operations. It is not clear to what extent the proposed regulations, if promulgated, would apply to existing operations. Current operations account for 25% of the operating mills predicted by the year 2000. The impact of new regulations on such a large sector of the industry should not be treated lightly. (59)

Response: The proposed regulations have been revised to clarify the issue of applicability to existing operations, a matter which the staff has seriously considered. A full discussion is presented in Section 12.4.

> Comment: The draft GEIS fails to give sufficient consideration to the impact of its recommendations upon existing mill sites and the environment, and fails to adequately consider self-insurance by mill operators as a satisfactory long-term surveillance surety arrangement. (60)

Response The staff disagrees with this comment in all respects (see the Summary, Chapters 6, 9, 11, 12, and 14, and Appendices G, K, P, R, T, and U).

> Comment: The draft GEIS fails in several respects to meet specific requirements for environmental impact statements. The draft GEIS fails to make any attempt to evaluate the potential economic impact on existing disposal sites that would result from the various regulatory measures studied and recommended by the Commission staff. It merely attempts to estimate the average monetary costs that a "model" uranium mill would sustain in complying with the various regulatory alternatives. (60)

Response: The staff has evaluated compliance costs in detail with respect to the model mill and has considered reasonable variations as well (see Chapters 11 and 12, and Appendis K). On all decisionmaking matters discussed in the GEIS, the staff has considered the full range of costs of meeting specific requirements that could occur under varying conditions (for example, see Section 12.3.4). The cost impacts of meeting requirements at existing disposal sites are covered in Section 12.4 and Appendix K-9.

> Comment: An important factor omitted is that substantial amounts of existing tailings were generated when uranium sold at prices well below the $30 per pound figure used in the draft GEIS. At certain mill sites, the tailings are a mixture of those produced when the AEC was purchasing uranium at prices as low as $4.62 per pound and tailings produced under more recent sales contracts. However, this year, 1979, DOE reports an average U.S. purchase price of only $21.80 per pound. Thus, it may be several years before the average price reaches the draft GEIS figure of $30 per pound. It is difficult to readjust future sales prices under long-term commercial contracts. Thus, contrary to the staff's assumptions, the flexibility to adjust prices of future sales to pay for new tailings disposal requirements is very limited. (77)

Response: The staff selected an illustrative price of $30 per pound when spot prices of U_3O_8 were over $40 per pound. The fact that costs of complying with the new regulations were not incorporated in previous product prices is explicitly recognized in Chapter 12, and has been duly considered in determining applicability of the new regulations to existing tailings. (See Section 12.4 concerning the financial impacts of regulations at existing sites.)

> Comment: The GEIS does not recognize the special circumstances of existing mills where site selection and tailings disposal cannot meet stringent standards for decommissioning and reclamation. It also does not consider the issue of "commingled tailings" where UMTRCA assigned to DOE primary responsibility for carrying out remedial actions. We believe it is inappropriate to require operators of such mills to bear the financial burden for decommissioning and reclamation of existing licensed sites to these stringent new standards. (86)

Response: The staff considers the applicability of the new regulations to existing sites to be appropriate with respect to any such special circumstances, given the requirements and purposes of the UMTRCA, the associated legislative history of that Act, and the need for the levels of environmental protection provided. (See Section 12.4.)

> Comment: In the draft GEIS, except for the price impacts on both U_3O_8 and electricity for alternative disposal methods, there is no evaluation of the economic and social impacts that are expected to result from the proposed NRC regulation changes on present or fuure uranium milling operations in the U.S. Although it may be difficult to implement the proposed NRC regulation changes at active uranium mills (as described in Section 12.4), it does not mean that an analysis of the adjustments required to meet the proposed NRC regulation changes cannot or should not be carried out at active uranium mills. In the case of prospective uranium mills, an evaluation of the effects of the proposed NRC regulation changes on the construction and operation of future uranium mills is needed. Without these effects, an economic and social impact analysis of the proposed NRC regulation changes cannot be carried out. (99)

Response: The staff could not, within the context of a generic statement, analyze the impacts of tailings management in a manner that would be specifically applicable for all mills now operating, or which would operate in the future. For this reason, impacts were estimated for the model mill. The data from which the impacts are derived are presented in such a way that they can be used to estimate impacts in particular instances. This applies to cost data as well. The staff has analyzed compliance costs in sufficient detail to adequately support the new regulations being implemented, and to establish the fact that such costs will be only a very minor component of the total cost of producing uranium. Such a minor perturbation is insignificant in relation to other factors directly influencing product costs and prices, such as supply and demand, general economic conditions, and similarly important and variable circumstances.

> Comment: It is our understanding that the Nuclear Regulatory Commission intends to impose all of these criteria on all existing operations, when the rules are adopted. If this procedure is followed, the results will be an imposition of completely unjustified cost burden on Atlas Minerals. (106)

Response: See Section 12.4 regarding implementation of regulations at existing sites. The staff has carefully considered applicability of the revised regulations to existing operations; such applicability has been determined to be appropriate and justified, to the extent necessary to assure adequate protection of the public health and safety and the environment.

6.10.3 Environmental Impacts

> Comment: The GEIS recommends that substantial earth cover be placed over uranium tailings disposal areas, a recommendation that has been adopted by the Commission in the form of Criterion 6 in Appendix A to the proposed new 10 C.F.R. Part 40. Many, if not most, uranium milling plants, are located in states where there simply is not a great deal of available earth cover. For those plants, earth cover sufficient to meet the standard recommended by the GEIS could as a practical matter, be obtained only by "strip mining" the neighboring terrain. However, the draft GEIS contains no mention whatever of the environmental damage that might result

> from efforts to meet the GEIS recommendations. In that respect, the draft GEIS clearly fails to conform to Section 102 of NEPA because it does not assess all environmental impacts of any proposed major federal action affecting the environment. (60)

Response: The potential environmental impacts of obtaining earth cover for final reclamation are discussed in new Section 9.3.8.4. In that section, an evaluation of a worst-case situation is provided, wherein it is assumed that cover material must be obtained by strip-mining a thin layer of available soil (1 meter thick) and then hauled 10 miles to the tailings disposal site. As evaluated in Section 9.3.8.4, the impacts of obtaining cover material are very likely to be substantially less than those for the assumed worst-case situation. Impacts from such a worst-case situation, however, would be comparable to those stemming from mill construction. With proper reclamation of the borrow area, impacts would be mostly temporary and there would be no significant permanent impacts.

> Comment: Costs imposed by regulatory action will affect current and future production of uranium and the cost to consumers of electricity, now and in the future. Beyond economic costs, consideration of the social and environmental costs of the proposed regulatory action is essential and mandated by federal law. (85)

Response: The economic costs of measures required by the proposed regulations are discussed in Chapters 11 and 12, with details given in Appendix K. The incremental costs per unit of product and energy are presented in Table 11.12. Social and environmental costs are considered in Chapters 9 and 12.

> Comment: We submit that proposals and recommendations under the draft GEIS must be carefully considered not only in terms of reducing exposure risk and minimizing additions to operating and capital cost, but also in terms of cost to the national economy as measured in the irretrievable expenditure of fossil fuels which would be used to implement many of the recommendations. For example, our calculations indicate nearly 300,000 gallons of diesel fuel could be consumed in merely hauling and dumping enough material to add 10 feet of cover to a typical tailings pile. This is enough fuel to operate a typical 18-wheel, over-the-highway truck more than one million miles. We must now ask ourselves if the reduction in risk is worth the lost energy resources. (86)

Response: Consumption of hydrocarbon fuel, along with many other factors, has been taken into consideration by the staff in evaluating the reclamation plans discussed in Chapters 8, 9, and 12, and costed in dollar units in Chapter 11 and Appendix K.

> Comment: Except for the price impacts on both U_3O_8 and electricity for alternative disposal methods, the draft GEIS did not evaluate for economic and social impacts that are expected to result from the proposed NRC regulation changes. Specifically, only a hypothetical local economy in which a typical uranium mill operates has been evaluated. There was not any analysis of the economic and social impacts on either the hypothetical local economy or the present and future of uranium mining and milling operations in the U.S. We feel that an economic and social impact analysis of the proposed NRC regulation changes should be carried out. (99)

Response: The analysis of the impacts of the operation of twelve mills in the model region (Sec. 6.3.7) may well represent the local and regional social and economic impacts of the uranium milling industry, if no additional regulatory controls are imposed. The analysis of the impacts with the proposed controls is given in Sec. 9.3.7. The difference represents the socioeconomic effects of the proposed NRC regulatory program. This difference is admittedly small, for the social and economic impacts result from those aspects of the industry that are not subject to NRC regulation. An analysis of the national impacts was deemed to be impracticable because the uranium milling industry represents such a small part of the national economy that its effects cannot be traced beyond the immediate vicinity of its operations; nevertheless, some aspects of the nationwide socioeconomic impacts are discussed in Chapter 12.

6.11 Decommissioning

> Comment: Item 9 of GEIS Section 12.2, requiring cleanup of contaminated surfaces and land in accordance with previously issued regulatory guidance, amounts to evasion of normal regulatory procedures. Reference to this regulatory guidance should be deleted from the final document and the proposed regulation. (59)

Response: The staff emphatically disagrees with this comment. The proposed regulation does not reference the subject regulatory guidance; the regulations require cleanup to levels permitting unrestricted use without specifying numerical criteria. Applicable numerical criteria will be promulgated by EPA under the UMTRCA; EPA has issued interim criteria which are presented here, in Appendix J.

> Comment: The decommissioning goals specified in the GEIS as Target Criteria are far, far too stringent, being at levels where it will be difficult, if not impossible, to distinguish mill-related contamination from natural background. "Background" concentrations should be taken to be background levels existing at the time the regulations become effective, not natural background existing prior to when operations began, since operations conducted to that point did not incorporate cleanup costs in product prices and did not contemplate the need to reduce contamination to such low levels. Also, the GEIS should analyze a range of alternative cleanup criteria rather than merely stating criteria to be met, and selected Upper Limit Criteria should apply to all mill sites. The basis presented in the GEIS for the criteria given is unsound and inadequate. (77, 85, 86)

Response: The staff's interim land cleanup criteria, presented in Appendix J of the draft GEIS, have been replaced with interim criteria developed by EPA under Title I of the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA, PL 95-604). These criteria were developed by EPA for application at inactive tailings disposal sites subject to remedial action under Title I. The staff expects future EPA cleanup criteria for active sites to be substantially the same as those now in effect for inactive sites, and has elected to not duplicate EPA efforts in this area. For this reason, the staff's proposed and final regulation changes do not include numerical cleanup criteria. In the interim, the staff has elected to adopt the presently available EPA criteria for purposes of regulatory guidance. The staff will adopt and enforce cleanup criteria for active sites developed pursuant to Title II of PL 95-604 by EPA, as mandated by that legislation.

> Comment: We suggest the proposed regulations should provide for the alternative for the mill site to be decommissioned to less stringent standards if the operator should choose to transfer ownership of the combined mill site with the tailings into a single parcel to be conveyed to the government. (86)

Response: PL 95-604 does not allow for government acquisition of other than final tailings disposal sites. The staff considers that cleanup of areas not used for final tailings disposal to levels allowing unrestricted use as prudent and practicable, regardless of eventual site ownership.

> Comment: The surety provided for decommissioning costs should be based on then-current best estimates provided by the operator, on the basis of a general plan for decommissioning drawn up at the time of initial licensing. The surety amount could be revised periodically at the time of license renewal to accommodate changes for inflation, modifications of the plan, and allowance for any work already performed. Decommissioning plan details should be left to a final plan to be approved as a condition for permission to terminate the license. (86)

Response: As indicated in Sections 12.2.2 (item 1) and 14.2, the staff is in general agreement with these comments. However, the staff could not approve of any surety arrangement which would not provide full coverage of decommissioning costs at all times. Therefore, the staff will perform independent reviews to assure that cost estimates which are provided are indeed adequate, and that a sufficient margin exists to assure full coverage until surety amounts are reevaluated and revised.

6.12 License Fees

> Comment: Structure fees to recognize and justify differences in scope of new complete milling licenses, byproduct material licenses only, and renewals. (52, 53, 55, 67)

Response: There appears to be a substantial misunderstanding concerning the proposed fees published in the August 24, 1979 Federal Register notice (44 FR 50015). The proposed fees in the subject notice applied only to byproduct material licenses as would have been applicable, for example, to a tailings system in an Agreement State. The fees covering a complete milling operation (i.e., both the mill and tailings in a non-Agreement State situation) are already contained in Category 2 of §170.31 of 10 CFR 170. The amounts of the fees in the proposed Category 4.D of §170.31 were based on the required staff effort to evaluate the health and safety aspects of byproduct material disposal; an effort in scope of nearly the same magnitude as evaluating a complete milling activity. Thus, the proposed fees were structured as recommended and would not have resulted in a two-fold increase in cost as inferred. Additionally, the renewal fee of $14,800 in category 4.D(3) was corrected to read $4,800 in a September 19, 1979 Federal Register notice (44 FR 54307). In any case, the amendment to the Uranium Mill Tailings Radiation Control Act in November 1979 precludes dual licensing jurisdiction in Agreement States, and the fees proposed in the August 24 notice are no longer applicable.

> Comment: Require license fees in Agreement States in sufficient magnitude to provide additional staff to expedite licensing based on independent assessments. (120)

Response: The NRC has no authority to establish licensing fees in Agreement States. The NRC must, however, determine that an Agreement State's program is compatible with NRC requirements in general and is equivalent to, or more stringent than, NRC requirements insofar as materials licensed under the UMTRCA are concerned. This includes ensuring that licensing actions are based on independent assessments. The staff has prepared and issued revised criteria for evaluating Agreement States' programs adequacy for the November 1981 amended agreement review and all subsequent reviews. These criteria specifically address resource levels.

7. MINOR TOPICS

7.1 Editorial and Miscellaneous

> Comment: Continued surveillance of mill tailings disposal sites as recommended is not in agreement with tailings management performance objectives asking for elimination of ongoing monitoring and maintenance. (26)

Response: Fulfillment of the performance objectives mentioned will assure, by definition, that no ongoing active maintenance will be needed. Limited periodic surveillance, (for example, annual visual inspections) is called for as a prudent supplementary measure of control. (See Sections 10.3 and 12.3.11.) Significant monitoring, such as physical measurement of radioactivity concentrations and/or radon fluxes, will not normally be required.

> Comment: To contend, as on page 1-2, that this document has produced estimates of the "worst case" is an unquestionable distortion. (46)

Response: The words "realistic worst case" were used on the stated page, with reference only to the density of uranium milling occurring within the region of the model mill cluster.

> Comment: Appendix S is incorrectly labeled as a sensitivity analysis, since this Appendix does not represent a full-blown sensitivity analysis in the true sense. (54)

Response: The staff does not consider this title inappropriate, even though it has not been possible within Appendix S to analyze the entire spectrum of possible variations in all the parameters used in this document. The scope of the evaluation is clearly stated in Appendix S.

> Comment: The inspection and monitoring scenarios in Appendix R are not described as to the length of time such efforts must be continued, or what the response would be if dangerous conditions are found. (54)

Response: The staff envisions a perpetual requirement for site surveillance on an annual basis. Specific monitoring requirements, including types and frequencies of measurements, would vary from site to site on the basis of need. The staff would require redress of dangerous conditions if identified, and as appropriate to protect public health, safety, and the environment.

> Comment: It is stated in Appendix S that tailings volume is inversely proportional to ore grade, but this does not account for the variation of the recovery rate which would decrease as the ore grade decreased. (54)

Response: Variation of the uranium recovery rate with decreasing ore grade is a mild, second-order perturbation on the volume of tailings generated. The staff does not expect the uranium recovery rate to vary more than a few percentage points from the assumed value of 93 percent (for 0.10 wt % U_3O_8 ore), even for minimum ore grades economically processed via conventional milling. Generally enhanced recovery technology may even increase recovery rates in the future.

> Comment: Many assumptions upon which the GEIS is based are buried in the text, inherent in the methods of calculations, or are contained in the data abstracted from reference sources. These assumptions should be listed in the GEIS or in its appendices. (85)

Response: Stringent efforts have been made to appropriately identify significant assumptions made by the staff in performing the evaluations contained in this document. The staff does not consider that a full display of every underlying assumption in this, or other similar evaluations, is either customary or appropriate.

> Comment: The option of no more milling should be evaluated, as should the impacts of the yellowcake product's eventual processing and use. (69, 88, 92, 97)

Response: The alternative of no more milling is not explicitly addressed within the context of this programmatic statement; nor are the impacts of the subsequent processing and use of the yellowcake product produced by uranium recovery facilities. These evaluations are not within the scope of this effort which is, quite briefly, the evaluation of the need for regulatory controls, and the establishment of an appropriate basis for the necessary regulation changes (see Section 1.2). As an alternative, a regulation prohibiting uranium milling has not been explicitly evaluated because, by its very nature, it is not reasonable. However, site-specific impact statements prepared by the staff in support of proposed licensing actions routinely consider an equivalent alternative, i.e., license denial.

> Comment: The statement in the footnote of Table 2 that uranium mines "will not be significant, continuing radon sources following reclamation" is unsupported. Furthermore, such reclamation is not required in many areas. (74)

Response: The staff considers the comment to be valid and has made an appropriate text change.

> Comment: The discussion in the Summary of the assumed "total failure" of tailings isolation is misleading because local impacts could be severe while only long-range radon exposure is addressed. (74)

Response: The staff agrees that local impacts could be severe, but notes that the "10 percent total failure" assumption was made to obtain an upper bound perspective as to health effect consequences, which derive primarily from long-range radon exposure. (See Chapter 6 for localized impacts without any control, and also Section 9.4.2, regarding maximum exposures to individuals who may intrude into disposal areas over the long term.)

> Comment: Present field studies indicate windblown tailings can be carrried much farther than the "several hundred meters" stated in Summary Section 3.3. (99)

Response: The subject text has been clarified.

> Comment: Contrary to the statement on page 8, there is one mill currently discharging to surface waters with a permit. (99)

Response: The text has been corrected to note this situation.

> Comment: Summary Section 4.3 should include a list of alternatives for treatment of tailings solutions for recycle. (99)

Response: The text of Chapter 8 has been expanded to include a more detailed discussion of alternatives for reducing operational water inventories in tailings impoundments, including those involving solution recycle. The regulations being promulgated emphasize the need for recycle and water conservation.

> Comment: Options for tailings area preparation in the Summary should include: treated clay liner, soil cement, underdraining, and siting over a natural barrier. (99)

Response: Options for tailings area preparation listed in the Summary reflect the staff's consideration of these suggested additions.

> Comment: Recycling of process water is not "standard" practice as stated in the Summary. (99)

Response: The staff considers recycle to be a common enough practice to be described as "standard" but has changed the word to "routine" to clarify the intended meaning.

> Comment: With respect to Section 15.2.1.1, please note that about 47 percent of the uranium mined in 1978 came from open pit mines, as opposed to the assumed figure of 30 percent. (99)

Response: This comment has been incorporated.

> Comment: Nonconventional uranium sources, such as in situ extraction, do not produce relatively small amounts of uranium, as stated in the Summary. (104)

Response: The staff considers that, in comparison to the amount of uranium produced by conventional milling, the amount of uranium produced by nonconventional sources is indeed relatively small.

> Comment: Throughout the GEIS, the word "containment" should be used rather than the word "disposal" wherever reasonable, since containment is the real objective. (110)

Response: The staff does not consider such a change to be necessary to convey the fact that the objective of disposal is containment.

> Comment: Table 6 fails to give a figure for persistent radon releases from uranium mines, and is thus incomplete. (74)

Response: Table 6 is meant to summarize the impacts of uranium milling through the year 2000, as indicated by the title. The figure mentioned it not necessary for Table 6 to be "complete."

> Comment: It should be noted, when discussing mill tailings disposal alternatives, that EPA is required to establish standards for disposal of mill tailings by May 1980, under PL 95-604. (99)

Response: See the discussion of this general issue in Summary Section G, "Timing of Regulations." The staff considers that EPA's responsibilities, as mentioned, have been sufficiently addressed.

> Comment: It would be helpful if recent similar licensing cases were identified, when describing waste management alternatives, in order that more detailed information might be obtained. (38)

Response: Please refer to Appendix T, which tabulates information on presently operating uranium recovery facilities. Recent licensing cases are also discussed in Appendix T.3.

> Comment: The GEIS should make more extensive use of available empirical data and information rather than calculational models. This would provide a more realistic assessment of environmental effects. (59, 92)

Response: The NRC has committed large amounts of resources to the acquisition and use of "real" data (please refer to Appendix G-9). To the fullest extent practicable, this document has employed such data as are available for this generic study.

> Comment: It is stated in Section 6.2.4.2.5 that 60 percent of the liquid in the tailings pond will be evaporated. It should be stated whether or not this figure is based on actual mill data. (99)

Response: The figure represents the staff's considered judgment as to what a typical evaporation rate might be for the semiarid model region, based on all available information, including actual mill data.

> Comment: It would be helpful if the specific sites involved in the tailings spills listed in Table 7.1 were provided. In that way, the circumstances could be understood. (97)

Response: Table 7.1 has been updated, but individual mills have not been identified. The staff does not believe such identification to be appropriate in the context of this generic statement.

Comment: In Section 7.1.1.3, emphasis should be made of the serious consequences of tailings slurry reaching the watercourse, rather than simply referring to Section 7.1.3. (21)

Response: The reader is referred to Section 7.1.3, because that is where the effects of tailings slurries reaching a watercourse are addressed.

Comment: Statements on page 4 of the Summary and on page 6-5 concerning the predicted extent of contamination around the model mill appear to be inconsistent. (26)

Response: These statements have been appropriately revised.

Comment: The referencing in the GEIS is often poor (for example, the Appendix G-1 discussion of particulate resuspension) and this places a great burden on the general public readership. (92)

Response: The staff does not consider unduly copious citations and long bibliographies to be beneficial in promoting general understanding of the scientific basis for this GEIS. The staff has made very deliberate efforts to provide relevant references, as appropriate. For those members of the public who do wish to make their own independent assessment of the methodology and conclusions of the GEIS, there is no alternative but to study the supporting documents and reports.

Comment: Portions of Appendix C concerning radon inhalation should be recast in terms of working level months (WLM) rather than radon concentration, and a discussion of the problems inherent in applying the concept of WLM should be added. (54)

Response: Appendix C is not intended to be a comprehensive treatise on radon inhalation toxicology, but merely to acquaint the general public with the basic concepts and vocabulary of radiation science.

Comment: Published reports show that the uptake of plutonium in drinking water is enhanced by chlorination. The possibility of a similar effect on uranium absorption from public drinking water should be considered. (138)

Response: This observation is of potential relevance to the assessment of radiological impacts resulting from uranium contamination of chlorinated public water supplies. Such public supplies are not considered within the scope of this document, as contamination of such supplies does not occur within the model region. This assumption is consistent with actual milling operations and regions. Furthermore, the staff's final regulations will assure that such contamination does not occur.

Comment: An EPA study showed that arsenic levels are not greater in alkaline mills as stated in Summary Section 3.4; with respect to Appendix B, the practice of discharging process water to an aquifer by deep well injection has been stopped. There are several other ions present in mill solutions in addition to those stated, and there are currently four carbonate leach circuits (including two mills that have both acid and alkaline circuits); the final statement should make use of information from current studies with respect to long-term tailings pile integrity and groundwater impacts; and, second stage precipitation should be discussed in Appendix H. (99)

Response: These comments have been incorporated, to the extent appropriate.

Comment: It is very difficult to adequately evaluate the draft GEIS, because many referenced documents are "in preparation." (26)

Response: That situation has been corrected in this document to the fullest extent possible. All information considered essential to the decisions and conclusions made in this GEIS, and embodied in the final regulations, is either presented here or is contained in available referenced sources.

Comment: The reported extraction efficiencies on pages B-7 and B-9 do not agree with the statement made on page B-13. (38)

Response: A correction has been made.

Comment: Section 8.3.4.3 describes wind induced soil erosion of 25 pounds per acre as insignificant and fails to state the time over which such erosion occurred. (97)

Response: The study referred to measured the stated erosion due to 85 mph winds over a period of three minutes, and is cited only to illustrate the erosion reduction effects of rock covers. The measured erosion is insignificant with respect to what the erosion would have been with no protection.

Comment: The statement that the chemistry of seepage water draining from tailings is difficult to predict (Appendix E) is not consistent with the potential approval of tailings disposal in contact with groundwater. (21)

Response: The staff has considered this issue in depth and has concluded that despite some residual uncertainties, it is not appropriate to completely forbid disposal of tailings in contact with groundwater. Section 12.3.5 contains more discussion of this matter.

Comment: Neutralization of acidic seepage as it advances through subsoils will be accompanied by release of bicarbonate and calcium, and possibly magnesium ions and oxyhydroxides of iron and manganese. This liberation process can intensify groundwater problems. (99)

Response: Although such impacts are possible, they are insignificant in comparison to those which are addressed in detail.

Comment: A more complete assessment of water use alternatives should be made. (99)

Response: Impacts on available water resources are routinely and thoroughly addressed in individual specific licensing cases. The staff does not consider it appropriate to address such impacts in detail, on a generic basis. Nevertheless, Criterion 5 of the final regulations calls for consideration of water conservation techniques and practices.

Comment: A great deal of information on seepage presently exists and should be used in model evaluation. (126)

Response: Please refer to the specific comments on groundwater impacts analysis, in Section 4.5 of this Appendix, for discussions relevant to this issue.

Comment: The description of the CCD washing circuit in Appendix B is confusing. To our knowledge, the circuit described is not commonly used. (38)

Response: Certain information concerning the CCD washing circuit was incorrectly extracted from ORNL-TM-4903. Section 2.2.1 of Appendix B has been revised.

Comment: In Section 2.2 it should be pointed out that the AEC also recommended that the problem (tailings disposal) be approached generically. With respect to Table 2.1 it should be noted that conditions since the Phase I site visits have changed considerably at some sites. In Section 2.3, it should be noted that all of the sites have exhibited wind and water erosion. A more detailed summary should be given of the Phase II studies. Water contamination, for instance, is not even mentioned. The Phase II reports give a better documentation of the present conditions at these sites. (99)

Response: The Phase II studies involved extensive efforts in which conditions at each site were documented in detail. A complete summary of all of this information is not considered to be appropriate for inclusion in this document. Both Sections 2.2 and 2.3 have been substantially rewritten, to reflect the general status of the inactive sites.

7.2 Occupational Radiation Exposure

Comment: The kidney is the critical organ for inhalation of uranium in soluble form. Since uranium in yellowcake dust can have a sizeable soluble component, effects on the kidney should be explicitly discussed. (26)

Response: Because of the presence of highly soluble uranium in yellowcake, worker exposure to yellowcake dust must be limited to prevent kidney damage due to heavy metal poisoning. The exposure limit stemming from the chemical toxicity of soluble uranium is more restrictive than the exposure limit would be if based only on radiation protection considerations. Therefore, worker exposure to yellowcake is limited on the basis of the chemical toxicity of uranium. However, there are no known instances of uranium mill workers suffering kidney damage due to uranium intake. Epidemiological studies of uranium mill workers conducted by Archer, et al., ("Cancer Mortality Among Uranium Mill Workers," Journal of Occupational Medicine, 15, 11-14, January 1973) did not find any excess mortality due to kidney disease.

> Comment: Occupational doses arising from accident situations should be considered. Worst case exposures should be stated. (35,74)

Response: Since inception of the NRC, there have been virtually no mill-related accidents which have resulted in violation of quarterly intake limits. The nature of uranium milling is such that exposures exceeding quarterly limits are simply not observed. Events which could broadly be classified as accidents contribute only very small fractions of career radiation exposure totals. By far, the most serious accidents which occur at uranium mills are typical industrial accidents which do not involve excess radiation exposure.

> Comment: Evidence should be given to support the assumption that mill workers normally rotate assignments over the course of their careers. (74)

Response: Although specific documentation is unavailable, the majority of mills rotate workers on a periodic basis for reasons unconnected with radiation safety. Even at mills which do not routinely rotate workers, employees usually perform many jobs over their careers.

7.3. Slurry Yellowcake Shipment

> Comment: The GEIS should evaluate the advantages and disadvantages of wet versus dry yellowcake as a final product in the mill circuit. Yellowcake drying and packaging operations are major sources of environmental and occupational hazards in and around uranium mills. The NRC should consider requiring the Allied Chemical conversion facility in Metropolis, Illinois, to accept wet yellowcake for processing. (26, 84, 130)

Response: Both the draft GEIS and this document provide detailed evaluations of the effects of wet and dry yellowcake preparation and shipment. The staff agrees that yellowcake drying and packaging operations at individual mills are generally major contributors to the environmental and occupational hazards associated with such mills. However, the staff cannot require wet yellowcake production and shipment, because there is insufficient capacity currently available to process yellowcake in this form (see Section 12.3.7). Of the two operating conversion plants, only one can accept and process wet yellowcake, at a rate representing less than a third of total current yellowcake production rate.

The suggested alternative, to require the Allied facility to accept and process wet yellowcake, is not practicable either from cost, environmental impact, or regulatory perspectives. In order to accept wet product, the Allied facility would have to either install its own product dryers or completely revamp the present conversion process (a "dry" process). Dryer installation at Allied would merely transfer hazards problems from one location to another; it would also likely make it impossible for Allied to operate in conformance with EPA limits for offsite radiation exposure imposed under 40 CFR Part 190. Conversion to a "wet" process would involve complete reengineering, wholesale replacement of major process components, and major reconstruction efforts. The engineering and economic difficulties involved are such that plant shutdown and replacement via new construction is likely to be more practicable. In either case, present regulatory authority is insufficient to take action because the facility currently operates in conformance with all requirements.

> Comment: In the future, shipment of yellowcake in a slurry may become a viable alternative. However, it is our view that the costs of conversion to wet shipment cannot be justified at any time in the near future. Charges for transportation and conversion of wet cake are higher. Also, only 3,000 to 4,000 MT/yr of yellowcake can be processed wet, about 25 to 30 percent of total U.S. production. (59, 86)

Response: The staff agrees with these comments in general (see Section 12.3.7).

> Comment: Cost estimates for slurry transport appear applicable only to new mills. Because of the significant costs involved, retrofitting existing mills and converting facilities to handle

slurry could not be justified any time in the near future. The analysis of potential yellowcake transportation accidents should not serve as a basis for converting from yellowcake transport to slurry transport. (85, 86)

Response: The staff is in general agreement with these comments.

7.4 Environmental Monitoring

Comment: Radon or radon progeny measurements should be allowed, on an optional basis. (43)

Response: Radon air concentration measurements are required as part of the preoperational and operational monitoring programs. However, radon progeny determinations are preferable for evaluating working level concentrations inside structures, as may be required for decommissioning of onsite structures.

Comment: A discussion of the monitoring required to determine compliance with applicable site decontamination, decommissioning, and reclamation criteria is necessary. (47)

Response: Such a discussion is provided in Section 10.3.

Comment: High volume air sampling performed one day per week should be considered as an acceptable substitute for continuous low volume air sampling. (59)

Response: The staff considers periodic high volume air sampling to be inferior to continuous low volume sampling, with respect to monitoring average air concentrations, since such concentrations are extremely variable on a day-to-day basis (see Chapter 10 and Appendix V).

Comment: Air sampling requirements should be flexible enough to allow for compatibility with state air quality monitoring requirements. (59)

Response: Monitoring requirements are established by the staff to achieve certain goals. To the extent that these goals can be achieved by monitoring required for other purposes, the staff will not require duplication.

Comment: Natural gamma radiation levels in many areas are so high that 5 μR/hr is not distinguishable from background. (59, 85)

Response: The staff considers 5 μR/hr from contamination to be readily distinguishable from natural background gamma radiation levels using either pressurized ionization chambers or thermoluminescent dosimeters. However, the staff will adopt decommissioning and cleanup criteria when issued by EPA for active mills (see Appendix J).

Comment: The preoperational monitoring program should not be conducted by the licensee. (63)

Response: Monitoring programs required by the staff are carried out by applicants and/or licensees in conformance with associated documentation and quality assurance requirements (see Appendix V). In addition, the staff reviews reported results in the context of data from other similar measurements and locations to ascertain that no untoward bias is exhibited. If deemed appropriate, the staff can undertake limited independent efforts to verify reported results. Normally, such analyses and reports as are required by the staff are prepared by independent contractors whose operations and reputations are familiar to the staff.

Comment: It is not clear whether background levels of radon emission and gamma exposure are to be determined from baseline, preoperational data, or current data. (67)

Response: Background levels are to be established on the basis of preoperational data.

Comment: High variability of natural soil concentrations of radium together with the limitations of present analytical techniques make it difficult or impossible to ascertain compliance with the proposed cleanup criteria for radium in soil. (85)

Response: The staff considers that present analytical techniques are quite capable of differentiating between routine variations in background and the proposed cleanup criteria in

Appendix J of the draft GEIS. However, the staff will adopt EPA criteria; EPA interim criteria for inactive sites are presented in Appendix J of this final statement. The EPA radium criterion is inclusive of background.

> Comment: Air particulate, surface soil, and sediment samples should be analyzed for Po-210 content. (99)

Response: The staff cannot consider such analyses appropriate as there is very little use for such data in addition to that obtained for the long-lived parent Pb-210. Po-210 is found in levels which are of much less health significance than the other elements which are analyzed for.

> Comment: Groundwater sample analysis should include physical and chemical parameters along with certain heavy metals, including arsenic and molybdenum. Sulfate monitoring should be considered as it might provide an advanced indication of seepage. (99)

Response: The staff considers such requirements on a case-by-case basis, but does not consider generic application to be appropriate, other than as described in Chapter 10 (also, see Appendix V).

> Comment: In the table entitled "Potential Exposures from Radon inside Structures on Contaminated Land" (Appendix J, page J-9, Note 3), the working levels derived from a radium soil concentration of 3pCi/g are not based on the range of values for B and λ as referenced. (85)

Response: The subject table has been deleted. The staff will adopt EPA cleanup criteria; interim EPA criteria applicable at inactive sites appear in Appendix J of this document.

> Comment: At least during the first four years of mill operation, the operational monitoring program should be identical with the preoperational program. Groundwater samples should be taken monthly, until the data indicate a reduced frequency is acceptable. (99)

Response: The preoperational monitoring program (Table 10.1) and the operational monitoring program (Table 10.3) are essentially identical. The air particulate sampling locations are located in the different sectors predicted to have the highest radionuclide concentrations during milling operations and therefore should be able to measure the effectiveness of any interim stabilization procedures. Monthly groundwater sampling and analysis during the first year of operations should provide an adequate data base for the operational monitoring programs which, as shown in Table 10.3, will continue throughout mill operations and until the mill license is terminated.

8. LONG-TERM ISOLATION PERFORMANCE

8.1 Long-Term Surface Erosion Control

> Comment: It is questionable whether or not the technology exists that can provide adequate long-term isolation of tailings. This is reflected in the fact that the evaluation of alternative tailings management plans in Section 9.4.1.3 fails to adequately assess the length of time over which a particular alternative is expected to provide adequate isolation of tailings. Proof should be offered that will provide confidence that the technology will operate safely and as expected over long-term periods. Three meters of cover may not be enough, given the problems of gullying, sheet erosion and differential settlement, together with the possibility of flooding induced by as much as 10 inches of rainfall in 24 hours. (34, 37, 62, 79, 81, 82)

Response: In the evaluation on long-term stability of uranium mill tailings impoundments performed in support of this GEIS, and summarized in Section 9.4.1, particular reference is made to man-made earthen structures and natural landforms that have been seen to remain stable for thousands of years. Consequently, it is evident that earthen structures can provide long-term stability. By drawing upon appropriate disciplines in engineering, as well as in geomorphology and other physical sciences, those factors which can be included in design to provide long-term stability have been defined. Taking those factors into account, the staff's regulations have been developed so as to impose stringent siting and design requirements that will then assure long-term stability under natural weathering forces. (See Criteria 3 and 4).

As discussed in Section 9.4.1, the technology does exist to provide for long-term isolation. In those areas where there are uncertainties in the technology, conservatism in design must be implemented. The staff's regulations are intended to assure long-term stability by requiring the conservative application of currently available technology, such as below grade burial, to the extent practicable. These regulations require reduction of erosion to negligible levels, including erosion induced by potential heavy rainfall.

The staff recognizes, as stated repeatedly in this GEIS, that the initial thickness of tailings cover is not as important over the long-term as assuring erosion control. This is reflected in the regulations by emphasis on erosion control and isolation measures.

The staff has evaluated this problem and developed regulations considering the inescapable fact that the tailings will, in fact, remain hazardous for extremely long periods of time--hundreds of thousands of years. However, attempting to provide absolute assurances that the tailings, which are very large volume, low specific activity wastes, will remain completely isolated for infinite time frames, is impracticable and inappropriate when the potential impacts of other naturally occurring and technologically enhanced, persistent radon sources are considered (see Section 12.3.4.4).

> Comment: A serious deficiency in the GEIS is the lack of information on the long-term integrity of alternative tailings management technologies and the consequent difficulty of selecting the most appropriate plan. There may be alternative technological advances that would provide better assurance of long-term containment. There may also be geomorphic processes or geologic settings that would assure long-term stability. These have not been adequately considered in the GEIS. Consequently, the GEIS does not provide an adequate basis for regulatory action. (34, 37, 82, 92, 97, 99)

Response: The staff, as summarized in Section 9.4.1, has identified the major potential failure mechanisms which can lead to disruption of tailings impoundments over the long term. Considering geomorphological features which have remained stable for many thousands of years, and basic studies performed on erosion control, the staff has identified specific but generally applicable design and siting measures which should be applied in individual cases to account for potential failure mechanisms. The staff considers this evaluation to be adequate support for the criteria relating to long-term stability delineated in the regulations.

As clearly stated in the introduction to Section 9.4.1, it would be impossible and inappropriate to evaluate in detail long-term stability aspects of the alternatives examined in this GEIS because of the highly site-specific nature of the factors that govern that matter. Instead, as discussed above, the design and siting measures which must be observed in individual cases are identified.

With regard to long-term stability, the regulations essentially call for implementation of the best of currently available technology. As indicated in Section 12.7 and other sections, the NRC will continue to sponsor research into the matter of mill tailings disposal, and monitor the research of others. Any important developments will be incorporated into regulations as appropriate.

> Comment: Average erosions rates in North America, based on sediment loads (dissolved and undissolved) carried by North American rivers, show that 44 meters of depth per million years are being lost from the earths's surface. Therefore, it is reasonable to assume that over long periods all minable uranium presently in the ground will eventually be exposed by erosion. With this perspective, it is reasonable to conclude that bringing uranium ore to the surface via mining will have no net long-term effect of contributed radon to the atmosphere. Mining merely shifts the time of release. (85)

Response: While it might be assumed that natural erosion would eventually bring to the surface all uranium and associated radionuclides, mining and milling uranium ore is a voluntary enterprise involving potentially significant and long-lasting environmental impacts. In addition to being required by NEPA, common sense dictates that these impacts be controlled, as appropriate, to levels which are as low as reasonably achievable, irrespective of otherwise naturally occurring impacts.

> Comment: The draft GEIS fails to present any analysis or evaluation of the many factors that affect wind and water erosion and therefore cannot support the need for a minimum three meter cover required. (85)

Response: The staff has considered and evaluated the factors that affect wind and water erosion, as indicated in sections 9.4.1.2(a) and 9.4.1.2(b) of the draft GEIS. The three-meter minimum cover is established primarily for reasons other than isolation of tailings under erosion conditions (see Section 12.3.4.7). The other measures prescribed in the regulations, in Criteria 3 and 4, which are aimed at erosion protection, are of paramount importance in maintaining initial cover thickness.

> Comment: Natural weathering and erosional forces cannot be eliminated and therefore no assurance of long-term, or even short-term containment, can be provided by any above-grade disposal option. (37, 79, 81, 82, 97, 109)

Response: By including those elements which are inherent in stable natural landforms and landscapes in the design of final reclamation plans for above-grade disposal options, as described in Section 9.4.1 of the draft GEIS, the staff feels that long-term stability against erosion and weathering can be attained, and long-term containment assured.

> Comment: Establishment of vegetation on covered uranium tailings piles for erosion control purposes could take decades and adequate erosion protection (wind and water erosion, and gullys) cannot be assured during that period until adequate vegetation is established. Further, it is questonable whether vegetation can provide reliable long-term erosion control in the arid environment typical of Western uranium mining and milling areas. Other erosion control measures, such as rock mulch, may be more suitable for arid regions. (37, 99)

Response: The staff has determined that vegetation can provide adequate short and long-term erosion control on very gentle slopes, when conditions favorable to the growth of a full and self-sustaining vegetative cover can be relied on. However, when such conditions cannot be relied on, then impoundment surface protection with rock cover would be necessary. The regulations have been revised to clearly indicate the need for rock cover where arid conditions, or other factors, make full and self-sustaining vegetative growth unlikely. This is based upon evaluation of the erosion (wind and water) considerations presented in Section 9.4.1.2 of the draft GEIS, and in light of the potential cyclic performance of vegetation.

> Comment: Vegetative covers must be considered with respect to the atmospheric electric current model and the potential for modification of weather patterns. (141)

Response: The staff does not consider this to be a significant concern.

> Comment: Topsoil not usable for bottom liners should be salvaged for later use as dressing for reclamation covers. (105)

Response: The staff would agree that this is appropriate under most circumstances. However, there is not sufficient need to make such action a regulatory requirement, as this issue is more appropriately addressed in the individual environmental assessments discussed in Section 12.3.10.

> Comment: The NRC staff recommends that tailings disposal sites be located in depositional environments. However, consideration must be given in the siting of tailings disposal areas to the long-term stability of the landscape. (26, 55)

Response: The staff recommends that a depositional environment be established on the reclaimed surface of the impoundment, not that disposal areas be necessarily located in depositional environments of the landscape. This however, as discussed in Section 9.4.1 of this GEIS, could enhance the long-term stability of a site.

The staff agrees that the overall landscape stability should be evaluated when selecting a disposal site, and that the potential for changes in current geomorphic processes be considered. This element of site selection and long-term stability is also discussed in Section 9.4.1 of this GEIS and is explicitly addressed in the final regulations.

> Comment: Areas of deposition demonstrate higher seepage rates due to the collection and containment of water. For this reason, depositional environments could adversely affect groundwater quality because of high leaching of contaminants into groundwater. (26)

Response: Incorporation of features that will encourage deposition on the surface of tailings impoundment areas is only one of several design considerations. For a site in an arid climate with a small upstream drainage area, and very gentle slopes, the amount of water and duration of retention on the tailings impoundment surface would be small, and any enhanced infiltration that could result would be small and temporary (with infiltrated moisture being removed by evaporation or evapotranspiration). Generally, no impact on groundwater due to this condition would be anticipated because the increased infiltration of precipitation moisture into cover materials would still be insufficient to cause percolation down through the tailings. (See Section 13.3.5 concerning long-term seepage.)

> Comment: To design a reclamation plan to provide a depositional environment, while a desirable feature, could confound or adversely affect other design features, such as storm runoff diversion structures, due to aggradation of sediments. (55)

Response: The development of a depositional environment is only one criteria of the reclamation plan. The other performance criteria must also be considered and a plan compatible with all must be developed. The staff has, as part of its performance objectives, concluded that the need for ongoing maintenance must not be part of a reclamation plan. Therefore, aggradation and filling of diversion structures due to the development of a depositional environment would not be compatible with this performance objective, and would therefore not constitute an acceptable design plan. Reliance on diversion structures, as mentioned, would also be unacceptable, unless it could be demonstrated that they would be reliable over the long term.

8.2 Other Isolation Performance Issues

> Comment: Criterion 4 of the proposed rules has the objective of developing tailings management plans, and reclamation plans that will not require ongoing maintenance and monitoring or other active control measures to preserve isolation. Whereas this is a worthy objective, it is questionable whether it is realistic to expect that no long-term monitoring and maintenance will be required. Furthermore, if some level of monitoring and maintenance is required, long-term institutional capability to provide control cannot be reasonably assured. (34, 90, 99)

Response: The staff is requiring reclamation as necessary to assure that no ongoing active maintenance will be needed. In some cases, monitoring may be required as part of continuing post-operational inspections. The staff does not consider it practicable or necessary for high volume, low specific activity wastes such as mill tailings, to require disposal such that even periodic surveillance would not be appropriate. This would require absolute assurances about complete confinement of tailings, into the indefinite future, that simply cannot be provided by any existing reasonable tailings disposal alternative. Thus, the staff has developed regulations which minimize reliance on institutional controls to the maximum practicable extent. (See Sections 12.3.4.2 and 12.3.11.) Refer to Sections 9.4.2 and 12.6 concerning the residual risks that will exist over the long term, under conditions resulting from implementation of the regulations being promulgated. The staff's conclusion is that these residual risks are acceptable.

> Comment: The only effort to assess the effects of a breach with no remedial action has been the postulation that 10% of all impoundments will fail within long-term periods. This assumed number of failures is too low. Also, it is unacceptable to express the impact in terms of the percentage of natural releases of radioactivity. (34)

Response: To expect to be able to predict, with any certainty, the number of impoundments that will fail within long-term periods, is not realistic. Loss of reclamation cover on 10% of all reclaimed impoundments was an assumption made for illustrative purposes, not an estimate based on any quantitative analysis. The assumption that ten percent of all impoundments were failed at one time is considered to be very conservative, especially considering that remedial action would be taken as required to prevent or correct such failures. Similarly, the impact is expressed as a fraction of that due to natural background for purposes of perspective. Also, see the discussion in Section 12.6 on the matter of what should be considered an upper bound with respect to long-term failure scenarios.

> Comment: It is likely that a clay cap will crack from dessication and erode before the toxic period of the tailings has passed. (37)

Response: In an arid environment, it is possible that a clay cap could crack from dessication if not protected by sufficient earth cover over the clay cap. This additional cover material will also provide radon attenuation in the event that the clay cap does crack. To rely entirely upon a moist clay to provide adequate radon attenuation is not appropriate. A minimum cover requirement, fully explained in Section 12.3.4.7, has been established to avoid this problem. Neither clay or soil alone can provide adequate erosion protection. Regulations (Criterion 4) require that full, self-sustaining vegetation be established, or that rock covering be employed, to provide adequate surface erosion protection.

> Comment: Differential settlement of sands and fines in tailings will cause rupture of the liner and cap, disruption of decant lines and drains, slumping of exposed slope faces and disruption of concrete spillways. (37)

Response: The staff's regulations are such that no long-term reliance can be credited to liners, dewatering systems, or concrete spillways. Thus, differential settlement occurring after reclamation would be of concern only with respect to any installed clay radon barrier, and general surface erosion protection. Although excessive differential settlement of sands and fines in tailings could cause some faulting of the reclamation cover, differential settlement can be predicted, and allowed for in design on the basis of engineering tests. Proper design of the impoundment must take into account the potential for differential settlement.

> Comment: A study on the migration of salts in inactive uranium tailings disposal sites concludes that radioactive and nonradioactive constituents will migrate upward, due to osmotic pressure, through significant cover thicknesses. This migration would result in the liberation to the environment of potentially toxic and radioactive constitutents as well as cause elevated levels of radon to occur. Furthermore, this upward movement would cause the destruction of vegetation established on the cover. On the basis of this information, it is questionable whether a cover of any thickness can assure containment of radon or other potential contaminants held in tailings. (47, 56)

Response: The conclusions reached in the referenced study about potential upward salt migration in tailings, and through reclamation covers, is of serious concern to the staff. However, the conclusions are questionable and need to be supported by additional documentation and verification. At this time, the staff considers that it would be premature to base regulations upon the results of this single preliminary study by a single investigator. However, it is in light of uncertainty with respect to this and other concerns about long-term tailings cover performance, that a minimum cover requirement has been prescribed. (See Sec. 12.3.4.7.)

> Comment: The effect of low pH seepage from tailings impoundments must be considered as it will affect the stability and hydraulic conductivity of clay liners and the ion exchange capacity of natural foundation soils. (38, 99)

Response: The ion exchange capacity of natural foundation soils and the effect of low pH conditions on liners are currently the subjects of considerable research (Crim, Shepherd and Nelson, 1979; ongoing research at Battelle Pacific Northwest Laboratories, NUREG/CR-1494, 1980). The regulations conservatively require that seepage control measures be incorporated in tailings disposal system design, to minimize seepage rates to the maximum degree reasonably achievable. Added conservatism results from geochemical factors that inhibit migration of radionuclides. To date, the staff has received no information which would invalidate the position taken in the draft GEIS, that clay bottom liners can be relied upon to effectively retard seepage for time periods greater than the operating lifetimes of uranium mills. The staff would not consider it appropriate to place long-term reliance on clay bottom liners, although this may indeed be the proper interpretation. Results of the above mentioned research on liner performance under acidic conditions are somewhat mixed. Some changes in permeabilities have been observed, but no significant deterioration has occurred.

> Comment: The consequences of burrowing animals and potential root penetration should be disclosed and discussed. (74, 92)

Response: Whicker (1978) presented a review of existing data on the interaction of burrowing animals with covered, reclaimed uranium tailings disposal sites. He concluded that no definite prediction of radioactive uptake or dispersal was possible based on his review. Further, the short natural life span of the animals investigated does not allow study of long-term radiation or toxicity effects on the animals involved.

Burrowing by animals would not be expected to significantly affect the structural integrity of a reclaimed tailings disposal facility. However, radon exhalation could be enhanced by the establishment of direct channels to the surface. This effect would be localized and small unless infestation was widespread. For this and other reasons, as discussed in Section 12.3.4.7, the staff has determined a minimum tailings cover thickness should be established. (See Criterion 6 of the final regulations.)

> Comment: Part 40, Criteria 2 should include a statement that the tailings should be located so that no upstream catchment structure is necessary. (92)

Response: The statement in the technical criteria that the tailings should be located in areas that are not susceptible to flooding over long-term periods precludes their location at any place where an upstream catchment structure may be necessary. Note also that there was a typographical error in the Federal Register version of the proposed regulations, where the subject criterion stated upstream catchment areas should be "utilized" instead of "minimized" as was intended.

> Comment: Because it is likely that reglaciation may occur over the period when containment of tailings must be maintained, glaciation should be discussed under Section 9.4.1.2.

Response: It is the staff position that it is not reasonable or realistic to require extreme steps today to isolate tailings in such a fashion that they are immune to such distant and uncertain events as glaciation, or other effects associated with extreme climatic change.

> Comment: Fixation of tailings by cement or asphalt to assure long-term containment should be given more emphasis and consideration as a disposal option in the GEIS. (47, 82)

Response: Section 12.3.3.3 does consider the fixation of tailings by cement or asphalt as a disposal option. The staff's position, that fixation is not currently a practicable disposal option, is based on the information presented in this section. The staff considers the levels of emphasis and consideration given to fixation alternatives to be adequate.

> Comment: Alternative milling processes, such as a nitric acid leach of ores, should be given serious consideration as a disposal option, and not rejected in the GEIS in a perfunctory manner. (47)

Response: Section 12.3.3.3 presents the staff's evaluation of alternative milling processes, and the basis for rejecting alternative processes as viable options. Alternative milling processes have not been considered in a perfunctory manner, and in fact, have not been rejected. Because of cost and other consideration, the staff has merely determined that they should not be required.

> Comment: Long-term seepage problems, in terms of groundwater impacts, may make the objective to achieve disposal that will eliminate the need for long-term monitoring and care difficult to attain. (26, 99)

Response: Section 12.3.5 provides the basis for the staff's position that tailings disposal options can be developed for site-specific conditions, including seepage, that will achieve the performance objective that no long-term maintenance be necessary to preserve isolation. Continued seepage to groundwater, in the regions in which uranium mills are now located, is not expected. This is because evaporation rates generally far exceed precipitation rates, and precipitation moisture will not normally percolate downward through the cover and tailings to reach underlying aquifers. Any long-term seepage that does occur, will occur only infrequently and in small amounts.

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APPENDIX B. URANIUM MINING AND MILLING OPERATIONS

1. DESCRIPTION OF MINING OPERATIONS

Uranium mining and resource development is estimated to account for about 40% of the production cost or uranium concentrates.[1] The two most commonly used methods of mining uranium ores are surface or open-pit mining and underground mining. A third method, solution or in situ mining, finds limited application. The choice of mining method basically depends on the relative mining costs for a given output and is influenced by such factors as the size, shape, grade, depth, and thickness of the ore deposits.

1.1 Open-Pit Mining

Open-pit mining is used where deposits are shallow and where the overburden consists of loosely consolidated soil or detritus. It is usually the preferred method for ore deposits covered with overburdens no thicker than 90 m (300 ft) although some ore deposits have been surface mined to depths of more than 150 m (500 ft).[1] Equipment used for stripping overburden includes tractors with rippers, rubber-tired scrapers and tractor-pushers, diesel power shovels, and large truck fleets.[2] 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 often are not necessary and shallow ores are mined in single-bench pits. In larger operations using high-capacity equipment, mining is conducted in multiple-bench pits. Compared with the mining of other types of minerals, the ratio of overburden to ore in uranium mining is unusually large, ranging from 8:1 to 35:1.[3]

To control intrusion of groundwater during open-pit mining, a trench several feet deep may be dug around the periphery of the pit floor. The groundwater drains into the ditch and then can be pumped from the mine. The trench is dug deeper as the ore is removed to the original level of the ditch. The water may be used for the milling process or discharged to the surface.

In 1976, surface mining contributed about 51%[4] of the 8 million MT (9 million ST) of uranium ore produced in the United States.[5] However, because of their relatively lower grade, surface-mined ores accounted for only about 40%[4] of the total annual uranium concentrate production, estimated at 12,000 to 12,200 MT (13,000 to 13,500 ST) of U_3O_8.[5]

1.2 Underground Mining

Deeper ore deposits require underground mining. A variety of techniques are used because of differences in the shape, size, altitude, and grade of the ore bodies.[1] For small ore deposits, a number of mines employ simple adits or inclined entries driven into a canyon wall or sloping ground. Mining is done by open-cast methods supported or unsupported by roof bolting; in wider spaces, pillar supports may be used. Ore is recovered by hand mucking and tramming and with the use of such equipment as front-end loaders and mucking machines. For larger deposits, most mines require a vertical shaft entry sunk to ore-bearing formations at depths of from 185 to 430 m (600 to 1400 ft). Typically, the shaft is circular, compartmented, concrete-lined, and up to 4.3 m (14 ft) in diameter.[2] From the shaft, stoping, or the driving of various levels or tunnels, is performed to gain access to the ore deposits. The mining techniques used include the room-and-pillar, longwall retreat, and panel methods. The mining method selected for each ore body depends on the stability of the ground, the size and shape of the ore body, and the cost of extraction. Depending on ground stability or the permanency of the tunnel, steel plates, timber, or concrete is used to support tunnels extending from the shaft.[3] The ore is drilled, blasted, and often transported by slushers to the ore pass. Underground haulage may be either by track, electric or diesel locomotive, or trackless rubber-tired equipment.[2] New tunnels are driven until the ore deposit is depleted.

Groundwater intrusion is a problem with underground mining and dewatering is often required. The volume of water pumped from mines may range from 0.75 to 11 m^3/min (200 to 3000 gpm). The water is usually used as process water in the mill.

Mines are required to have proper ventilation to prevent the build-up of radon-222 gas (a uranium daughter product) to concentrations hazardous to the miners' health.[3] 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 which enters the shaft.

In 1976, underground mining contributed roughly 49% of the total uranium ore produced in the United States. However, underground-mined ores on the average were of a higher grade than surface mined ores and their milling accounted for about 57% of the total annual concentrate (U_3O_8) production.[4]

1.3 Solution Mining

Solution, or in situ, mining (Fig. B.1) is employed to recover uranium from lowgrade ores not economically recoverable by conventional mining methods.[2] Essentially, the process consists of introducing suitable leaching solutions into the underground ore body to solubilize the uranium minerals and then recovering the enriched solution by pumping it to the surface for further processing.[3] Advantages of this method include the elimination of hazards associated with normal underground mining and elimination of the need for handling large quantities of material and disposing of solid waste products. Possible objections to undesirable open pits and structures are also eliminated, a consideration of special importance when the mine is near populated areas.

A number of requirements must be satisfied before solution mining can be applied:[6]

1. The uranium ore must lie in a generally horizontal bed underlain by a relatively impermeable stratum instead of badly fractured or channeled structures. This condition will avoid serious losses of leaching solutions.

2. The ore must be located below the static water table.

3. The direction and speed of regional water flow must be known.

4. The uranium minerals in the ore must be amenable to the proposed leaching process.

5. The ore deposit must be extensive enough to justify the cost or uranium recovery.

Solution mining is usually carried out by drilling inflow wells into the ore body upstream of a production well based on the direction of groundwater flow. Salt solutions of ions, such as sulfate, bicarbonate, carbonate, and amonium known to form stable aqueous complexes with hexavalent uranium, are pumped to the inflow well, and simultaneously, there is a withdrawal of a slightly greater volume of water from the production well. A solution of oxidant ($NaClO_3$) may be added to increase leaching efficiency. The inflow of solution is continued until the leach zone is depleted, as indicated by a decrease in uranium concentration in the leach solution. The selected location and spacing of wells is based on the fact that interflow between wells and an aquifer having regional flow 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.[3]

In 1976, solution mining accounted for around 2% of the total uranium concentrate (U_3O_8) production in the United States.[4]

Discussions of potential environmental impacts, primarily those to groundwater, from solution mining may be found in References 7-9.

2. DESCRIPTION OF MILLING OPERATIONS

During the milling process the uranium values are recovered from the crude ore and concentrated to yield an intermediate, semirefined product called yellowcake [U_3O_8, $(NH_4)_2\ U_2O_7$, or $Na_2U_2O_7$]. The milling process involves the following basic steps: (1) ore handling and preparation, (2) mill concentration, and (3) product recovery.[1] Ore handling and preparation include such processes as ore blending, crushing, fine ore storage, grinding, and possibly drying or roasting to improve handling or solubility properties. In newer mills, use of wet, semi-autogenous grinding eliminates the need for dry crushing operations. Ore handling and preparation utilizing dry crushing operations are described in Section 2.1; semi-autogenous grinding is evaluated as an alternative to the dry crushing process and is described in Chapter 8. Mill concentration consists of hydrometallurgical extraction or leaching techniques, using either dilute sulfuric acid or alkaline carbonate solutions[1] as lixiviants, followed by further concentration of leached uranium by ion exchange or solvent extraction. The product is recovered from solution by chemical precipitation, followed by drying and packaging for shipment.[3]

2.1 Ore Handling and Preparation

2.1.1 Ore Blending

For most uranium mills in the United States the ore must be blended either at the mine or at the mill to ensure that the feed has uniform physical and chemical characteristics. A uniform feed

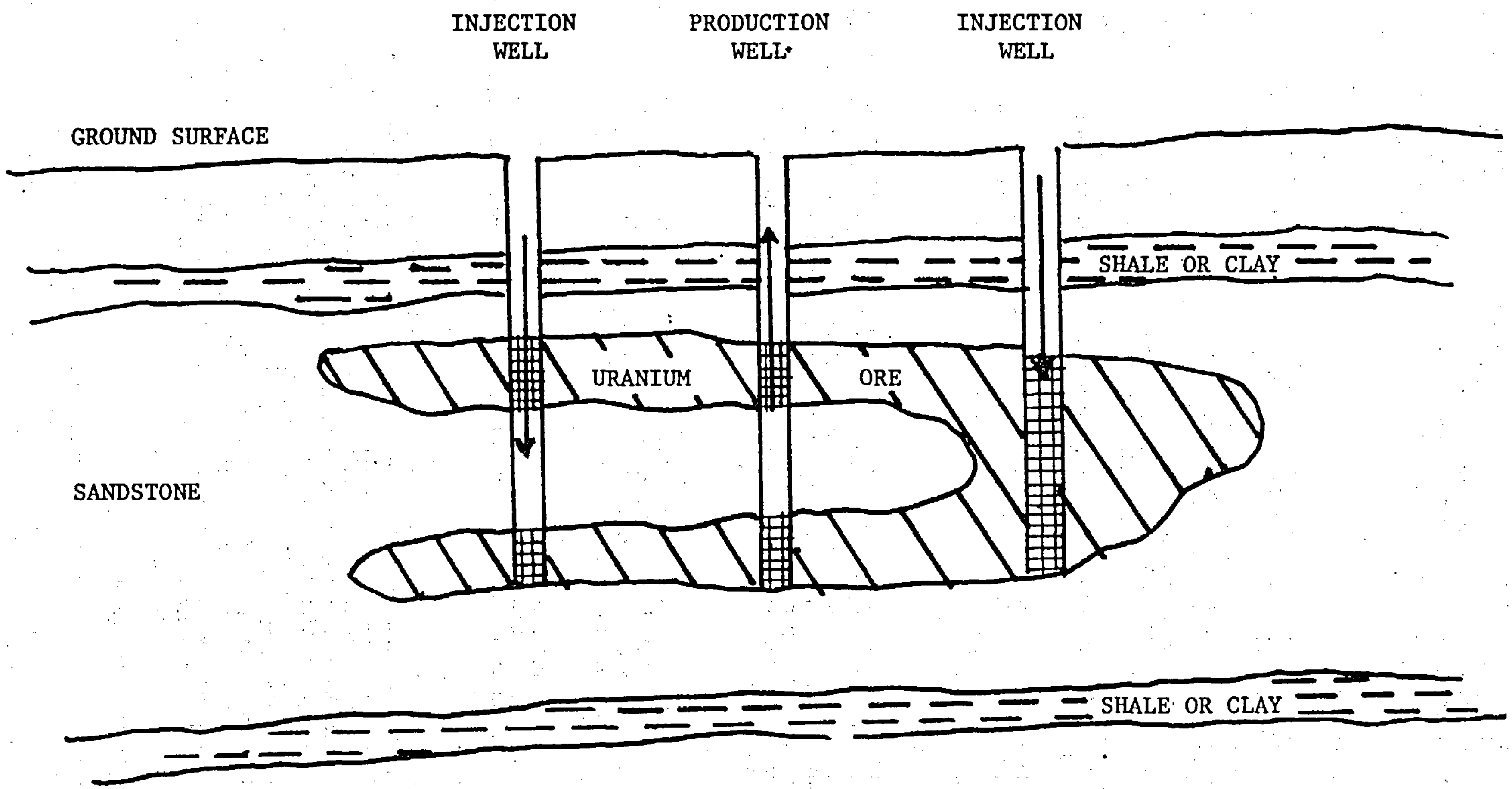

Fig. B.1. Diagrammatic Vertical Section of a Roll Front Uranium Deposit Showing Hypothetical Placement of Injection and Production Wells for In-Situ Mining. (From J. N. Frank, "Cost Model for Solution Mining of Uranium," ERDA Grand Junction Office Conference on Uranium, October 1976.)

in terms of U_3O_8 content is important to smooth out plant operations and to achieve full capacity potential in the operation of various mill circuits for ion exchange, solvent extraction, and uranium precipitation. Blending promotes a smooth operation and eliminates extremes in the form of hard ores which limit the capacity of the grinding circuits, slimy ores which interfere in ion-exchange circuits, sandy ores which cause settling problems in tanks and pipelines, and ores high in molybdenum or organic matter which may cause fouling or poisoning in ion-exchange circuits.[7]

2.1.2 Ore Crushing

The ore is moved from the mill stockpiles to the crushing plant feed by means of front-end loaders, bulldozers, or by trucks to receiving bins which are vented to the atmosphere through dust collection equipment (e.g., orifice dust collector). Jaw crushers, used as primary units, range in size from 38 by 61 cm (15 by 24 inches) to 76 by 155 cm (30 by 40 inches). Fine ores or undersized material bypasses the grinding circuit through the use of a scalping grizzly (bar screen) and are sent to storage bins. For effective dust control, air exhaust hoods are located on the crusher, at the screens, and at each ore transfer point. The exhaust air passes through a dust collector before discharge to the atmosphere through a roof vent. Depending on ore hardness, two crushing stages may be required, employing impact-type and cone or gyratory crushers. There are wide variations in crushing plant capacity, with ranges from 70 to 320 MT (75 to 350 ST) per hour, depending on ore characteristics. Mine-run ores are reduced to a size between minus 1.9 and minus 3.8 cm (minus 3/4 and minus 1-1/2 inches).

Excessive moisture content in the ore can have adverse effects on ore handling characteristics in the crushing plants and in fine ore storage. Natural drying or kiln drying may be required to reduce the moisture content to 5% or less during winter months or to 10% or less during the other seasons of the year.[3]

2.1.3 Fine Ore Storage

Mills usually have fine ore storage capacities equal to or up to double the rated daily mill capacity. Flexibility in ore blending is provided by extra, multiple-bin storage capacity. The largest problem associated with the operation of ore storage facilities is that of moist or sticky ore hanging up or freezing in the bins during winter, resulting in large decreases in live storage volume. This operational problem can be alleviated by improved bin design, providing heated enclosures for ore bins or placing steam coils around the bin bottoms, and preheating ore in dryers.

2.1.4 Ore Roasting

In a few cases, uranium ores may undergo roasting to increase the solubility of valuable constituents and to improve the physical characteristics of the ore. As examples, ores are roasted to enhance vanadium extraction, to improve the ore settling and filtration characteristics by alteration of clay minerals in the ore and to remove organic carbon which can cause problems in the leaching circuits.

Ore from the crushing circuit is fed through a rotary kiln operating at a termperature not exceeding 340°C (650°F) and thereafter returns to the grinding circuit. When not needed, the roasting circuit is bypassed and the ore goes directly from the crushing to the grinding circuit.

2.1.5 Ore Grinding

Ore characteristics and the leaching process used dictate the degree to which ore must be ground. For the acid leaching of sandstone ores, the ore is ground to liberate the natural grain size. Alkaline leaching is more selective and much finer grinding is required to expose the uranium values. From the crushing circuit, the ore is conveyed to the grinding circuit by belt-type feeders at the desired feed rate. Samples are taken at points between the crushing and grinding circuit for routine laboratory analysis. Rod and ball mills are usually employed to effect a size reduction of the ore to approximately 28 mesh for the acid leach process or to 200 mesh for the alkaline leach process. The ores are wet ground (water added), resulting in a pulp density of 50 to 65% solids with the aid of classifiers, thickeners, cyclones, or screens which size the ore and return coarser particles for further grinding. Water consumption is reduced by recirculating mill solutions or recycling the clarified effluent from the grinding circuit thickener. As noted above, where a semi-autogenous grinding mill is utilized, ore sizing, normally done by crushing operations (Sec. 2.1.2), is done in the grinder.

2.2 Mill Concentration and Product Recovery

The uranium content of ores that have been crushed and ground is recovered by hydrometallurgical leaching techniques coupled with concentration and purification steps such as ion exchange, solvent extraction, or the Eluex process. Low-grade ore can also be subjected to heap leaching. Various processes commonly employed are described in detail below.

2.2.1 Acid Leach Process

As of 1976, mills employing the acid leach process represented 82% of the total concentrator capacity in the industry.[8] Acid leaching is preferred for ores with low lime content (12% or less). Those with high lime content require excessive quanitites of acid for neutralization and are best extracted by alkaline leaching for economic reasons. This leaching or extraction process is compatible with any of the concentration and purification processes, including ion exchange, solvent extraction, or a combination of both processes known as the Eluex process. (A representative flow diagram for the acid-leach solvent-extraction process is shown in Fig. B.2.) After crushing and grinding of the ore, the resulting slurry (50 to 65% solids) is discharged from the ball and rod mills into the leaching circuit, which consists of several tanks mechanically agitated in series, for a total residence time of around seven hours. Enough sulfuric acid is continuously added to maintain pH between 0.5 and 2.0. This translates into a free acid concentration of from 1 to 90 grams of acid per liter during the contact period for dissolution, depending upon the type of uranium minerals present. For ores treated exclusively for uranium extraction in the United States, the acid consumption ranges from 20 to 60 kg of sulfuric acid per MT (40 to 120 lbs/ST) of ore.[3] An oxidant, either $NaClO_3$ or MnO_2, is also continuously added with the sulfuric acid to increase leaching efficiency by the oxidation of any tetravalent uranium present in the ore to the hexavalent state. Iron, however, must be present in solution for $NaClO_3$, or MnO_2 to be effective oxidants for tetravalent uranium. Either oxidant acts to oxidize ferrous iron (Fe^{++}) to the ferric (Fe^{+++}) state, and the ferric iron in turn oxidizes the uranium as represented by the following reactions:

$$6Fe^{++} + NaClO_3 + 6H^+ \rightarrow 6Fe^{+++} + NaCl + 3H_2O$$

$$2Fe^{++} + MnO_2 + 4H^+ \rightarrow 2Fe^{+++} + Mn^{++} + 2H_2O$$

$$UO_2 + 2Fe^{+++} \rightarrow UO_2^{++} + 2Fe^{++}$$

The quantity of iron, which serves as an intermediary, required in the oxidation reactions need not be stoichiometric since it is alternately oxidized and reduced in a continuing cycle. Minimum reported requirement for free ferric iron is about 0.5 grams per liter in the presence of $NaClO_3$ or MnO_2.[9] The overall reaction with H_2SO_4 providing the hydrogen (H^+) ions is therefore:

$$3UO_2 + NaClO_3 + 6H^+ \rightarrow 3UO_2^{++} + NaCl + 3H_2O$$

or

$$UO_2 + MnO_2 + 4H^+ \rightarrow UO_2^{++} + Mn^{++} + 2H_2O$$

Ore leaching proceeds at atmospheric pressure and a little above room temperature. Most of the uranium content of the ore is dissolved, together with some other materials present in the ore, such as some radionuclides (uranium daughter products), iron, aluminum, and other impurities.

After ore leaching is completed, the pregnant leach liquor containing the dissolved uranium is removed from the tailings solids in a countercurrent decantation (CCD) circuit. In this operation, the slurry is first sent to hydrocylones (liquid cyclone separators) which separate the coarse sand fraction as an underflow and the sand fraction is subsequently washed in a series of classifiers. The overflows from the classifier and the hydrocyclone are combined and the slimes are washed in a series of thickeners (5 or more stages). Flocculants are added to promote settling of the suspended solids. The solids are washed with fresh water and recycled (barren) raffinate from the solvent extraction circuit. After thorough washing, the sands and slimes are pumped as a slurry to a tailings pond. The dry weight of the tailings basically accounts for the total weight of the processed ore, with the exception of the very small weight of the uranium values that were extracted.

Typical dry tailings composition is 70 to 80% sands and 20 to 30% slimes.[3,10] The waste solution accompanying the sands and slimes to the tailings pond is around 1-1/2 times the weight of the processed ore.[10]

After solid-liquid separation in the CCD circuit, the leach solution is sent to the solvent extraction, or alternatively, to the ion-exchange process. Several extraction tanks in series (e.g., four stages) are used where uranium is recovered from the leach liquor (aqueous phase) by countercurrent contact with an organic solvent (organic phase). This organic solvent may be either a 6% tertiary amine solution in a kerosene diluent with isodecanol as modifier to improve phase separation and increase extraction efficiency (Amex process), or a 4% alkyl phosphoric acid solution in kerosene with tributyl phosphate added as a modifier (Dapex process).

Uranium forms a complex with the organic solvent, and in an excess of the solvent this complex is so soluble that the uranium is almost quantitatively extracted from the aqueous phase. The

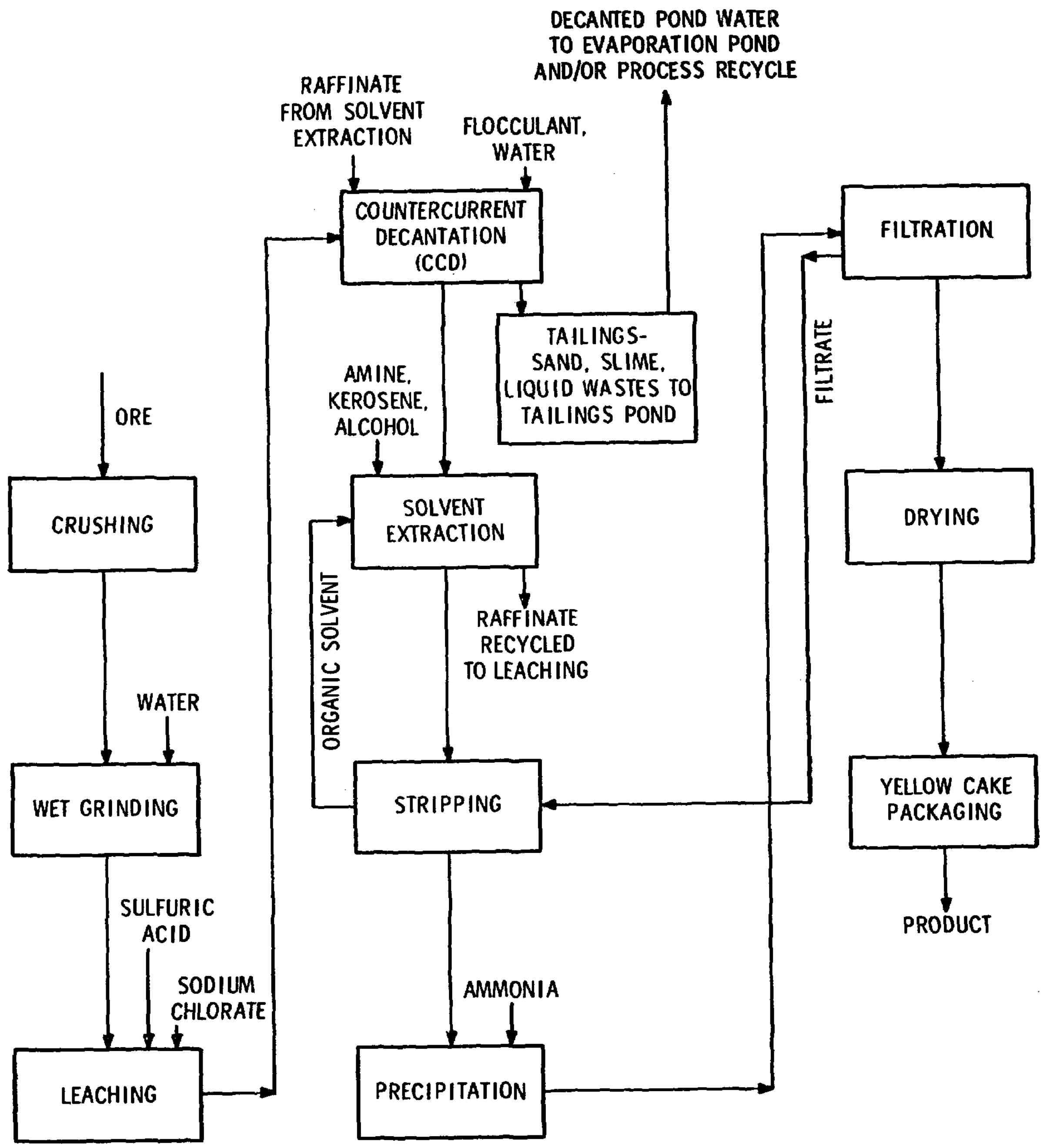

Fig. B.2. Flow Diagram for the Acid-Leach Process. (Modified from "A Study of Waste Generation, Treatment and Disposal in the Metals Mining Industry," Midwest Research Institute for U. S. Environmental Protection Agency, EPA No. 68-01-2665, October 1976.)

immiscibility of the solvent in water aids separation. Other constituents and impurities in the leach liquor remain in the aqueous phase. After mixing to ensure adequate contact, the mixture of solutions is conveyed to a settling tank for phase separation; the lighter uranium-loaded organic layer rises to the surface and is separated by decantation, while the aqueous raffinate is recycled to the countercurrent decantation process.

The uranium-loaded organic phase is then treated in a stripping operation to separate the uranium from the organic solvent. Stripping is performed in several stages with an aqueous ammonium sulfate solution for the Amex process at a controlled pH of 4.0 to 4.3 to eliminate sodium impurities. For the Dapex process, a sodium carbonate solution is used as stripping agent. In either case, the stripped organic phase is recycled to the solvent extraction circuit for reuse.

The uranium that has been transferred from the organic phase to the aqueous strip solution is precipitated from solution by addition of gaseous ammonia, sodium hydroxide, hydrogen peroxide, or magnesia in several stages, with the pH properly controlled. In most mills, gaseous ammonia is used as precipitating agent. Where a purer product of low sodium content is desired, sodium hydroxide is used to precipitate uranium, the precipitate redissolved in sulfuric acid and the uranium reprecipitated with gaseous ammonia.

The precipitated uranium is dewatered in thickeners and then filtered and washed in drum, plate, or frame filters. The resulting filter cake still contains considerable moisture and is dried in a continuous steam-heated dryer or in a multiple hearth dryer operation at 370° to 430°C (700° to 800°F). The dried product (yellowcake), containing from 90 to 96% U_3O_8, is crushed and screened to required size and packaged in 55-gallon steel drums for shipment. Product weight per drum varies from 300 to 400 kg (650 to 950 lb), depending on the product density.

Dust emission during product drying and packaging is controlled by passing the off-gas from the drying and packaging areas through a dust separation system (e.g., wet impingement dust collector) before discharge to a roof stack.

Overall uranium recovery from the acid leach process is around 91% based on the uranium content of the ore feed, with the remaining 9% lost to the tailings.[10]

2.2.2 Alkaline Leach Process

In 1976, mills employing the alkaline leach process accounted for 18% of the total concentrator capacity of the industry.[8] This leaching process is best suited for ores with high lime content which would require large quantities of acid for neutralization if the acid leach process were used.

Figure B.3 shows a representative flow diagram for the alkaline leach process coupled with caustic precipitation to concentrate the extracted uranium. Solvent extraction to concentrate and purify uranium is currently used to treat only clarified acid solutions. Column ion-exchange or the resin-in-pulp process may be applied in combination with the alkaline leach process, but the leaching process selectively extracts the uranium such that the simpler and cheaper caustic precipitation of uranium is more widely employed.

The ore is first received, crushed, and wet ground to a much finer size (~ 200 mesh). The resulting ground ore slurry, containing 50 to 65% solids, is then leached in a two-stage system, the first stage consisting of a five-hour leach in autoclaves at a pressure of 4.5×10^5 Pascals gage (65 psig) and 93°C (200°F), followed by a second leaching stage for 18 hours at atmospheric pressure and 85°C (185°F). The leach solution contains 40 to 50 grams of Na_2CO_3 per liter and 10 to 20 grams $NaHCO_3$ per liter. The bicarbonate prevents reprecipitation of the dissolved uranium through reaction with the hydroxyl ion. In practice, leaching time can vary from 23 to 72 hours, depending on ore characteristics and operating conditions. The pressure leaching (first stage) prior to atmospheric leaching (second stage) is designed to increase the rate of leaching in a number of milling circuits. Circular tanks around six m (20 ft) in diameter and 12 to 18 m (40 to 60 ft) deep are used with air bubbled through the leach solution to oxidize uranium to the hexavalent state. The hydraulic pressure provided by solution depth in the tanks increases the leaching rate. The basic reaction involved is the dissolution of uranium in alkaline carbonate solution to form the soluble $UO_2(CO_3)_3^{-4}$ (uranyl tricarbonate) anion, as represented by the following overall reactions:

$$2\ UO_2 + O_2 \rightarrow 2\ UO_3$$

$$UO_3 + Na_2CO_3 + 2\ NaHCO_3 \rightarrow Na_4UO_4(CO_3)_3 + H_2O$$

The uranium-carrying leach solution is then separated from undissolved solids in a series of countercurrent filtrations (i.e., a sequence of filtering and repulping operations) in which the

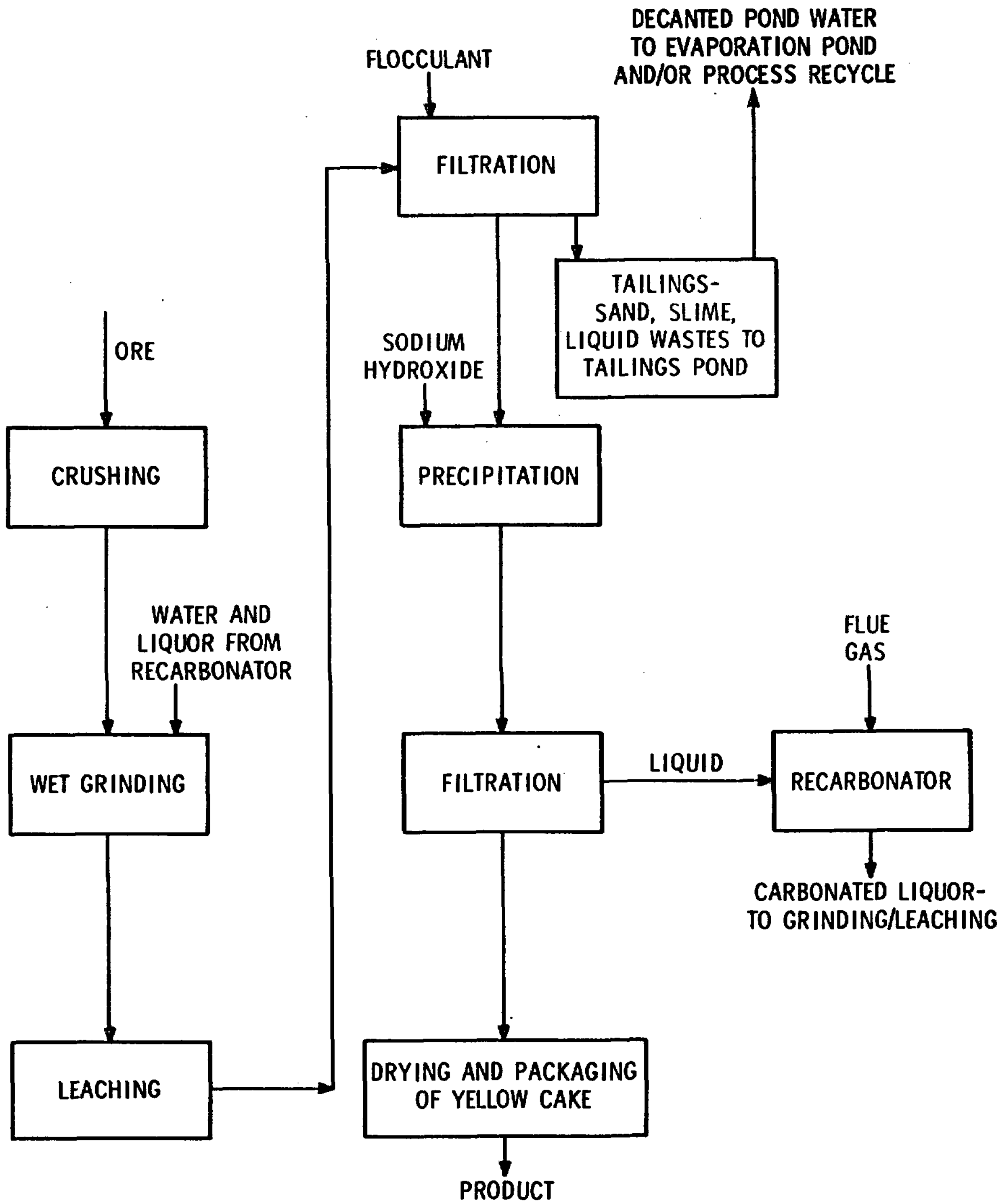

Fig. B.3. Flow Diagram for the Alkaline-Leach Process. (Modified from "A Study of Waste Generation Treatment and Disposal in the Metals Mining Industry," Midwest Research Institute, for U. S. Environmental Protection Agency, EPA No. 68-01-2665, October 1976.)

solids are washed free of dissolved uranium. The resulting filter cake consists of nearly equal parts by weight of sands and slimes; it is slurried in water (~ 50% solids) and pumped to a tailings pond. Uranium is precipitated from the leach solution as the insoluble sodium diuranate ($Na_2U_2O_7$) by addition of sodium hydroxide, according to the following reaction:

$$2\ Na_4UO_2(CO_3)_3 + 6\ NaOH \rightarrow Na_2U_2O_7 + 6\ Na_2CO_3 + 3\ H_2O$$

Precipitation takes place in a series of agitated tanks at atmospheric pressure and 82°C (180°F), with sufficient sodium hydroxide added to elevate the pH to above 12. The barren caustic solution discharged from the precipitation circuit contains Na_2CO_3 and a small amount of NaOH. This can be reused in the leaching process by recarbonation in packed towers where the solution comes in contact with CO_2, typically from boiler flue gas. The CO_2 neutralizes the NaOH and converts some carbonate to bicarbonate.

The precipitated sodium diuranate is filtered, washed, dried, and packaged in 55-gallon steel drums for shipment, similar to the product recovery steps described for the acid leach process. Also, any dust emission problem during product drying and packaging is similarly controlled with the use of dust collectors (e.g., wet impingement dust collector).

Overall uranium recovery from the alkaline leach process is around 93% based on the uranium content of the ore feed, with the remaining 7% lost to the tailings.[10]

2.2.3 Heap Leaching Process

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.[7] Heap leaching is usually used for the treatment of low-grade dumps or when the ore body is small and situated far from the milling facilities. Haulage costs dictate the choice of heap leaching at sites distant from the milling plant because the shipment of a high-grade pregnant solution or a crude bulk precipitate from a point near the mine site is cheaper than hauling low grade ore to the mill.

A typical open heap construction is shown in Figure B.4. The heap leaching pile is constructed by grading the ground at the site area to a smooth sloping surface.[3] To avoid losses, the area is covered by a six-mil sheet of polyethylene. Perforated plastic pipes, 10 cm (4 inches) in diameter, are laid parallel about 5.5 m (18 ft) apart. About 30 cm (1 ft) of gravel is put over the pipes and then the low grade ore is piled on to a depth of 7.6 m (25 ft). The top of the ore pile is graded and divided into sections 90 by 18 m (300 by 60 ft) with dikes made from the ore. The sections are wetted with a 7% to 10% H_2SO_4 solution, which percolates through the pile at a rate of from 12 to 20 L/m^2-hr (0.3 to 0.5 gallon/ft^2-hr). The enriched solution collected from the bottom of the pile contains an average of one gram of U_3O_8 per liter. 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 solution grade is reached. Enriched solutions collected can be processed at the leaching site by ion exchange or solvent extraction and precipitated by sodium carbonate or ammonia, with 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 leach operation, with the enriched solutions being returned to the mill circuit for processing.[7]

2.2.4 Concentration and Purification Processes

Following the extraction of uranium values from the ore by the acid leach or alkaline leach process, the resulting impure and dilute leach solutions have to undergo concentration and purification as a prerequisite to the production of a final, high-grade, uranium product.[7] A number of major techniques are used to effect this stage of the milling process. They are:

a. Ion Exchange. The ion-exchange process can be used for the treatment of both pulps and clarified solutions in either the acid or alkaline circuit.[7] Strong and intermediate base anionic-type resins are used which preferentially adsorb the uranium anion complexes present in the solution and which exclude metallic cations, resulting in a high degree of purification. The resins are loaded from either a sulfuric or a carbonate leach feed solution and subsequently stripped by eluting with a chloride, nitrate, bicarbonate, or an ammonium sulfate-sulfuric acid solution. Four types of ion exchange circuits are employed by uranium mills. The fixed-bed type consists of stationary columns packed with resin. The leach solution is fed to the columns and uranium is sorbed on the resin. The resin is washed and the uranium desorbed. The moving-bed column circuit consists of stationary columns with the resin transferred to different columns for the loading, washing and eluting operations. In the continued resin-in-pulp process, a series of tanks is used for contacting the resin and process solutions to effect sorption, washing and desorption. The resin and solution flow countercurrently in the tanks and are separated by screens, with forced air used for agitation. The basket resin-in-pulp process consists of a series of resin-filled cubical baskets that are jigged up and down in the process

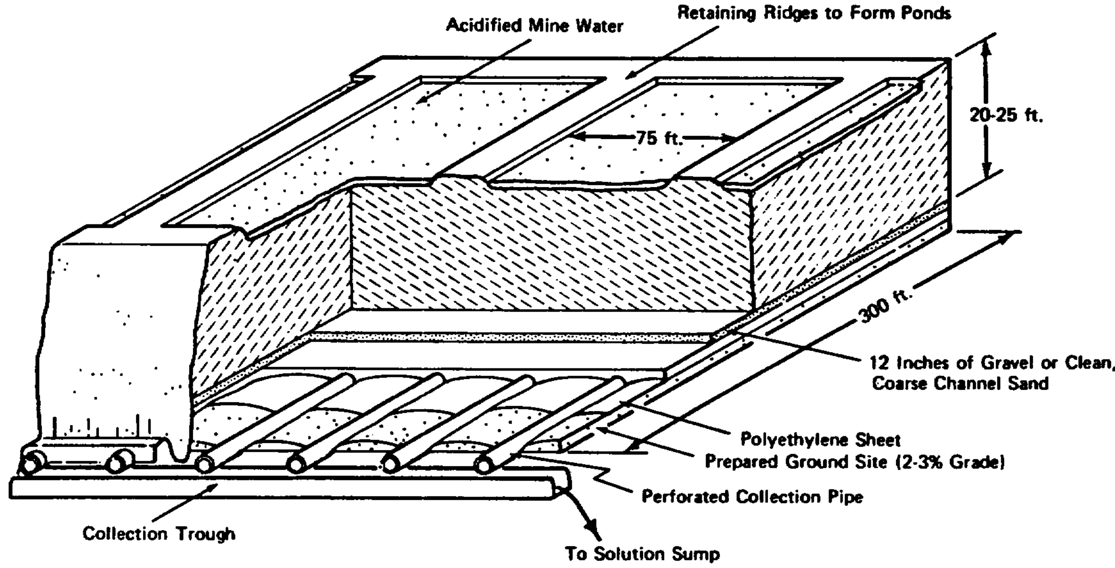

Fig. B.4. Schematic Diagram of Typical Heap Leach Pile. (After R. C. Merritt, "The Extractive Metallurgy of Uranium," Colorado School of Mines, Research Institute, 1971.)

solution contained in tanks. Uranium is extracted by circulating the feed slurry, eluant, and wash solution within the tank.[3] The two latter processes can tolerate high solids content in the feed solution in 1976, around 21% of the total annual ore production was processed in mills using column ion exchange for the concentration and purification of uranium.[5]

b. Solvent Extraction. At present, solvent extraction is used to treat only clarified acid solutions, although attempts have been made to develop alkaline circuit and acid solvent-in-pulp applications. Anionic and cationic solvents are in use and either is able to achieve good concentration and purification efficiency. The uranium in the clarified feed solution is extracted into the organic phase and subsequently stripped into an aqueous phase. The solvent extraction circuit usually consists of a series of extraction tanks with the feed solution and the organic solvent flowing countercurrently. Two processes, the Dapex and the Amex, are extensively used. In the Dapex process, the extractant used is a 4% solution of di(2-ethylhexyl) phosphoric acid (EHPA) in kerosene with tributyl phosphate added as a modifier.[7] The modifier improves phase separation and the extraction efficiency. Sodium carbonate solution is used to strip uranium from the organic phase, which is subsequently recycled to the extraction circuit. In the Amex process, a 6% solution of tertiary amine, such as almine-336, in kerosene is used as the organic extractant with isodecanol added as modifier. Stripping of uranium is accomplished with ammonium sulfate, chloride, or sodium carbonate solutions.[3] Mills that processed 43% of the annual ore production in 1976 used solvent extraction for the concentration and purification of uranium.[5]

c. Eluex Process. The Eluex process is a combination of ion-exchange and solvent-extraction processes. Uranium is adsorbed by the ion-exchange resins, the resins then eluted with sulfuric acid and the resulting eluate fed to either the Dapex or Amex solvent extraction process. Advantages derived from this process are the attainment of a purer end product and the elimination of the requirements for nitrate and chloride reagents, thus avoiding potential problems associated with them.[3] Approximately 18% of the annual ore production in 1976 was processed by mills employing the Eluex process.[5]

d. Improved Eluex Process. An improvement of the existing Eluex process has been developed and its main feature is that a stage of uranium solvent extraction is coupled with each stage of resin elution instead of the elution and solvent extraction operations being conducted separately. A reduction in the number of stages, retention time, and resin inventory to about one-fourth or one-fifth of that in existing circuits can be achieved by the improved system. This favorable improvement in circuit design may influence the process design for mills constructed in the future.

3. MILL WASTES AND EFFLUENTS

The processing of uranium ore in concentrating mills generates wastes and effluents that are both radioactive and nonradioactive. Solid, liquid, and gaseous effluents are released to the environment to a greater or lesser extent, depending on the process control and waste management measures instituted by the mill operator. The following paragraphs describe these mill wastes and effluents generated by the acid and the alkaline leach processes both qualitatively and quantitatively, based on data compiled from recent surveys of operating mills,[11] on information available in the literature, recent field studies performed by the Argonne National Laboratory at current operating mills, and from environmental impact statements for new or relicensed mills, as well as from calculations made to establish material balances around milling facilities.

In a study, a group of nine operating mills (located in New Mexico, Wyoming, Utah, and Colorado) processing (as of 1976) more than 18,000 MT (20,000 ST) per day were surveyed to characterize milling wastes based on actual reported data. The combined capacity of these nine mills in 1976 represented more than 71% of the total milling capacity (25,800 MT, or 23,400 ST) of all conventional uranium mills operating in the United States.[11] Grades of ore processed averaged around 0.16%.

The tailings represent the bulk of the wastes originating from the uranium mill and with the exception of the recovered uranium and process losses, account for practically all of the ore solids and the process additives, including water. As discharged from the operating mill, the tailings consist of a mixture of solids and solutions varying in chemical and physical compositions depending on the nature of the ore and the process used. The fractions comprising the tailings are: (1) the sand, consisting of solids greater than 200 mesh (+75 micrometers, or μm), (2) the slimes, consisting of solids less than 200 mesh (-75 μm), and (3) the liquids, which are solutions of chemicals, dissolved ore solids, and water.

About 10% of the uranium and virtually all of the other members of the uranium series in the original ore are discharged with the tailings. The only significant exception is thorium, up to 5% of which may be retained in the uranium concentrate, depending on the mill process.[10] Current average assay of ores is 0.16% by weight of U_3O_8 (1.35×10^{-3} g U-238/g ore). This is equivalent to 450 pCi/g ore for each of the nuclides U-238, U-234, Th-230, Ra-226, and Pb-210 in the case of secular equilibrium, which may be assumed as a first approximation.[12] The concentration of U-235 in natural uranium is 0.71%, but compared with the U-238 decay series, the U-235 series contributes negligibly to the quantity of radioactivity dispersed. The dry tailings therefore theoretically contain about 450 pCi/g each of U-238 and U-234 and 450 pCi/g each of Th-230, Ra-226, and Pb-210. Because of differences in ore grades or compositions and variations in milling processes, data from the survey of operating mills do not agree closely with the preceding values. The following discussion reports the findings of the above survey, which attempts to characterize mill wastes and effluents.

3.1 Acid Leach Process

3.1.1 Total Tailings

The tailings in slurry form are usually discharged into a tailings impoundment at an average 1:1 ratio, by weight, of solids and solutions. For economy in water use, and depending on the final extraction processes, up to 70% of liquids from the tailings pond may be recycled. On a dry basis, the tailings consist of 20 to 37% slimes, with 29% as the average for the mills surveyed.

3.1.2 Sands

The sand component of the tailings consists of particles from 38 mesh to 200 mesh (75 to 500 μm). The chemical composition varies, but consists largely of silica (SiO_2) with minor amounts of complex silicates of Al, Fe, Mg, Ca, Na, K, Mn, Ni, Mo, Zn, U, and V. Also present are minor quantities of sulfates, phosphates, and chlorides. The radiological content of the heavy sands varies with the type of process and characteristics of the ores and ranges from 26 to 100 pCi/g of Ra-226 and from 0.005 to 0.01% of U_3O_8. Information on other radioactive isotopes is very limited and only thorium-230 has been measured (with questionable results). Concentrations of thorium in the range of 70 μCi/g to 600 pCi/g have been reported; the lower values are probably more reliable.

3.1.3 Slimes

The slime component (-200 mesh) makes up approximately 29% of the total solid tailings. The size distribution of the slime material consists of approximately 30% from 200 to 325 mesh (-75 to +45 μm) and 70% less than 325 mesh (-45 μm). The slime material consists of various silica complexes of Al, Fe, Mg, Ca, Na, K, Mn, etc., that are clay-like. The slimes also show higher concentrations of the radioactive elements, with uranium values almost double that of the sands. For example, in a tailings where the U_3O_8 concentration in the sand is 0.004%, the slime concentration of U_3O_8 is 0.007%. This also generally holds true for the radium concentrations.

Radium concentrations range from 150 pCi/g to 400 pCi/g. Thorium-230 is reported from 70 pCi/g to 600 pCi/g. Information on other radioactive isotopes is limited and the concentrations are not available.

3.1.4 Liquid

The liquid portion of tailings currently produced is equal in weight to the solids and is used in the tailings system as a medium to transport the sand and slimes to the final place of deposition. Depending on the process and nature of the liquid, recycling varies from 0 to 70%. One mill used to discharge liquid (after filtering) to a disposal well in an aquifer of poor quality. The quantity of tailings solutions decreases due to evaporation and seepage. The solutions contain various concentrations of $SO_4^=$, NaCl, NH_4^+, and $PO_4^{\equiv}$, with minor amounts of flocculants, kerosene, and other organics used in the process. Ions of Cu, Mo, U, V, Zn, Mg, Ca, Be, Al, Ni, Sb, and Fe are present in the solutions. Concentrations of other metallic ions, such as those of As, Ba, Cd, Cr, Mn, and Pb, are generally less than 0.01 ppm. The pH of the solutions varies from 1.2 to 2.0 and total dissolved solids may approach 1%. Radium analysis of the liquid portion varies from 20 pCi/L to 7500 pCi/L. Thorium-230 assays vary from 2000 to 22,000 pCi/L. Uranium concentrations vary from 0.001 to 0.01%. Analyses for other isotopes of the uranium decay series are not available.

3.2 Carbonate Leach Process

3.2.1 Total Tailings

Presently four carbonate leach mills are operating, including two that have both acid and alkaline leach circuits. The physical properties of alkaline leach tailings are similar to those of acid leach mills. Slimes make up approximately 35% of the total solids. Tailings are deposited in the tailings area at about the same pulp density and are 50% liquid by weight. Liquids used in a carbonate leach can be recycled at almost a 100% return, with the only losses due to evaporation and seepage during the decant process.

3.2.2 Sands

The sand component of the tailings consists of sand from +200 to -48 mesh (75 to 300 μm). The chemical components are 99% silica, with various small amounts of U (0.010%), Mo (0.001%), and Se (0.002%). Radiological analyses have not been separately performed on the sand and slime fractions; the total content is approximately 600 pCi/g each for radium-226 and thorium-230. No measurements were reported for the remaining daughters of uranium.

3.2.3 Slimes

Slimes are less than 200 mesh (75 μm) and generally consist of silica (SiO_2) and various complex silicates of Na, Ca, Mn, Mg, Al, and Fe. Also present are minor amounts of sulfates, chlorides, and carbonates. Very little information is available on the radiological content of the sand and slimes separately. Reports indicated the ratio is about the same for radium and uranium as found in the acid leach processes.

3.2.4 Liquid

The nature of the carbonate leach process allows more of the liquids to be recycled, although recovery of uranium is not as high as with the acid leach process. The chemical concentrations (grams per liter) of various substances in solution are: $CO_3^=$, 7.00; HCO_3, 100; Se, 0.04; $SO_4^=$, 7.60; Cl^-, 0.70; Mo. 0.08; V_2O_5, 0.04; and U_3O_8, 0.04. The pH varies from 10 to 10.5.

Analysis of the radiological content of the liquids shows radium-226 to be approximately 200 pCi/L. Since thorium is insoluble in the carbonate leach process, its concentration in the liquid portion of the tails is nill.

3.2.5 Other Radioactive Emissions

In addition to the mill tailings, radioactive materials are emitted from other processing areas in the concentrator plant, the amount of emissions depending on the process control equipment used. These sources of emissions and the associated emission rates, adjusted for a typical mill processing 1800 MT (2000 ST) per day of ore containing 0.10% U_3O_8, would be essentially the same as those calculated in Appendix G-1 for the base case model mill, despite the assumption of an acid leaching process for the model mill. These release rates are presented in Chapter 5, Table 5.5.

3.2.6 Nonradiological Emissions

During uranium milling, small quantities of a number of airborne chemical (nonradioactive) contaminants are also released to the environment. The products of combustion from the burning of fuel (e.g., natural gas) in the process and heating boilers release CO_2, nitrogen oxides, and water vapor. Sulfur dioxide and sulfuric acid fumes are released from the leach tank vent system, generally in very low concentrations. Vaporized organic solvents, mostly kerosene, are released in varying amounts from the solvent extraction ventilation system.

Data from several environmental impact statements for uranium mills[13-15] giving typical emission rates have been adjusted for a mill processing 1800 MT (2000 ST) of ore per day. Emission of organic solvents (92% kerosene) ranges from 0.5 to 76 kg (1 to 170 lb) per day. Typical release rates of sulfur dioxide (including sulfuric acid fumes) from leach tanks range from 0.2 to 1.5 kg (0.5 to 3 lb) per day. The burning of fuel oil instead of natural gas can result in the emission to SO_2 and NO_2 at rates of around 22 kg (50 lb) per day and 5 kg (10 lb) per day, respectively. The emission of H_2O and CO_2 as combustion products are of minor importance.

3.3 Nonconventional Leachates

Landa (23) summarized the results of several studies on the leachability of radium from uranium ores and mill tailings. The following generalizations resulted:

1. Radium in uranium ore is only slightly soluble in H_2SO_4, but highly soluble in HCL and HNO_3.

2. Radium in acid processed tailings is leachable with EDTA, HCL, HNO_3 and distilled water. The solubility in distilled water is highly dependent upon the liquid to solid ratio used in the test, suggesting a limiting solubility product or suspension pH effect. Data presented suggest that uranium mill tailings in the environment may constitute a long-term source for radium contamination of contacting surface and groundwaters. Tailings which have been exposed to weathering forces for several years have apparently shown evidence of radium depletion.

3. Variable results were obtained when extraction of radium from tailings was attempted by use of various salt solutions.

4. Some of the chemical properties of groundwater that appear to favor the transport of thorium (high concentration of sulfate, low concentration of calcium, and low ionic strength) may inhibit the groundwater transport of radium.

5. At lower pH's, thorium becomes more soluble. Acid-leach milling may dissolve from 30 to 90 percent of the thorium in the ore. The solubized thorium can be subsequently precipitated if the acidic effluent is neutralized, either by contact with natural media, or by process additions of lime and/or limestone to the waste solutions.

6. Soils and related materials have been shown to sorb significant quantities of uranium. The sorption of uranyl ions by such natural media appears to be reversible. Uranium must be reduced to U^{4+} by a soil related substrate or a mobile phase, such as H_2S.

Recent studies performed by Oak Ridge National Laboratory[24] have indicated the following:

1. It becomes more difficult to leach radium from ore with HNO_3 as the leaching proceeds. Very little further leaching of radium occurs after about the 10-pCi/g level is reached.

2. Three molar HNO_3 was an effective leachant for tailings, while 0.5 molar HNO_3 was not.

3. Nitric acid-leached ore whose radium content has been decreased to less than 10 pCi/g will not leach significant amounts of radium with water.

4. Progressive leaching of tailings from the sulfuric acid leach process with HNO_3 and water will require further study.

5. It appears that thorium and uranium can be extracted from leach solutions by tri-n-butyl phosphate (TBP), and that radium can be carried on $BaSO_4$. It also appears that chelating agents such as EDTA and DTPA are effective leachants for removing radium from uranium tailings.

Leaching of ore or tailings to remove radium and thorium can be beneficial for environmentally sound disposal of tailings. However, removal of these radioactive materials by leaching with nitric acid or other leachants may be only a partial solution to the problem. Available studies do not indicate if leaching to remove radioactive materials (such as radium or thorium) from ore or tailings will also remove other pollutants normally associated with tailings. While radium and thorium cause much of the environmental hazard associated with tailings, further treatment may be necessary to remove other metals, sulfates, arsenic, and other pollutants to ensure environmentally safe disposal of tailings.

4. MILL TAILINGS MANAGEMENT

The primary aspects of mill tailings management and disposal are described in Chapter 8 and Appendix K. Several aspects of mill tailings management are now described in more detail.

4.1 Dewatering of Tailings -- Belt Filter

Mill tailings slurry can be dewatered into a relatively dry solid by the use of a belt vacuum filter.[16] The equipment consists of a slotted or perforated endless elastomer belt supporting a filter fabric which is also in endless-belt form and traveling across a suction box. The tailings slurry is pumped and evenly distributed onto the filter at one end. Wash liquor, if desired, may be applied at one or more points along the path of belt travel. The filter cake is discharged at the other end where the support belt and the filter medium are parted to be directed along separate lines of pulleys beneath the filter. The filter medium may be washed on its return journey to the head of the filter where it rejoins the drainage belt.

Advantages in the use of horizontal-belt vacuum filter include complete cake removal and the opportunity for effective washing of the filter medium. A disadvantage is that fact that half of its filtering surface is always idle. Effective filtering areas can range from 0.2 to 61 m^2 (2 to 655 ft^2). A typical configuration of a horizontal-belt vacuum filter equipped with a number of wiping dams to separate filtration and washing zones is shown in Figure B.5. The use of a belt filter to dewater uranium tailings can be expensive for many uranium ores. Its applicability for a variety of ore types needs to be confirmed with actual experience.

4.2 Dewatering of Tailings -- In Situ System

Mill tailings slurry can be dewatered after placement by a system of underdrains piped to central sump pits. Water which collects in the sumps can then be pumped back to the mill for reuse. Specific elements of this control method might include:

1. Provide a well-constructed impermeable bottom clay liner placed above the regional water table.

2. Provide stub clay side liners continuing part way up the pit side wall to form a continuous saucer-shaped bottom and side liner for the pit. The greatest potential for seepage out the sidewalls exists at the lower part of the wall where a saturated zone will form within the tailings above the liner. Seepage from the sidewalls above the saturated zone will be minimal, because unsaturated hydraulic conductivities are much less than saturated conductivities, and the hydraulic driving head and innundation times associated with the upper part of the wall are much less than for the lower side walls. Reference 22 illustrates this phenomenon. Therefore, a full sidewall liner may not be necessary. The liner would appropriately extend up the sidewall a sufficient distance to capture seepage which can occur below the saturated zone (for example, on the order of 1/4 to 1/3 total sidewall height), the specific height being determined based on the conditions of tailings and site-specific conditions.

3. Install a network of perforated gravity drain pipes and pumping sumps with the drain pipes in the tailings sufficiently above the bottom clay liner to provide effective drainage of the tailings. These drains would be covered by about 1-foot thickness of coarse filter gravel, to prevent clogging of the drainage pipes. To reduce the possibility of sedimentation and clogging in the drain pipes, the pipes and the clay liner should be sloped toward the pumping or collection sumps. In individual cases, specific filter criteria must be delineated, and minimum slopes established that will assure, for the tailings involved, that drains will not be blinded or become clogged.

4. Pump the tailings drainage effluent from the sumps during filling of the pit with tailings and as required for the first few months after the filling is completed. Thereafter, if the sumps do not remain dry, they should be periodically dewatered until drainage of the tailings is completed.

Features of this method of in situ dewatering of tailings are shown in Figure B.6. It is important that the underdrain piping, sumps, pumps, and transport piping for the leachate or drainage material be constructed of corrosion resistant materials. Also, coarse tailings and slimes should be uniformly distributed throughout the tailings disposal volume to promote best possible drain---

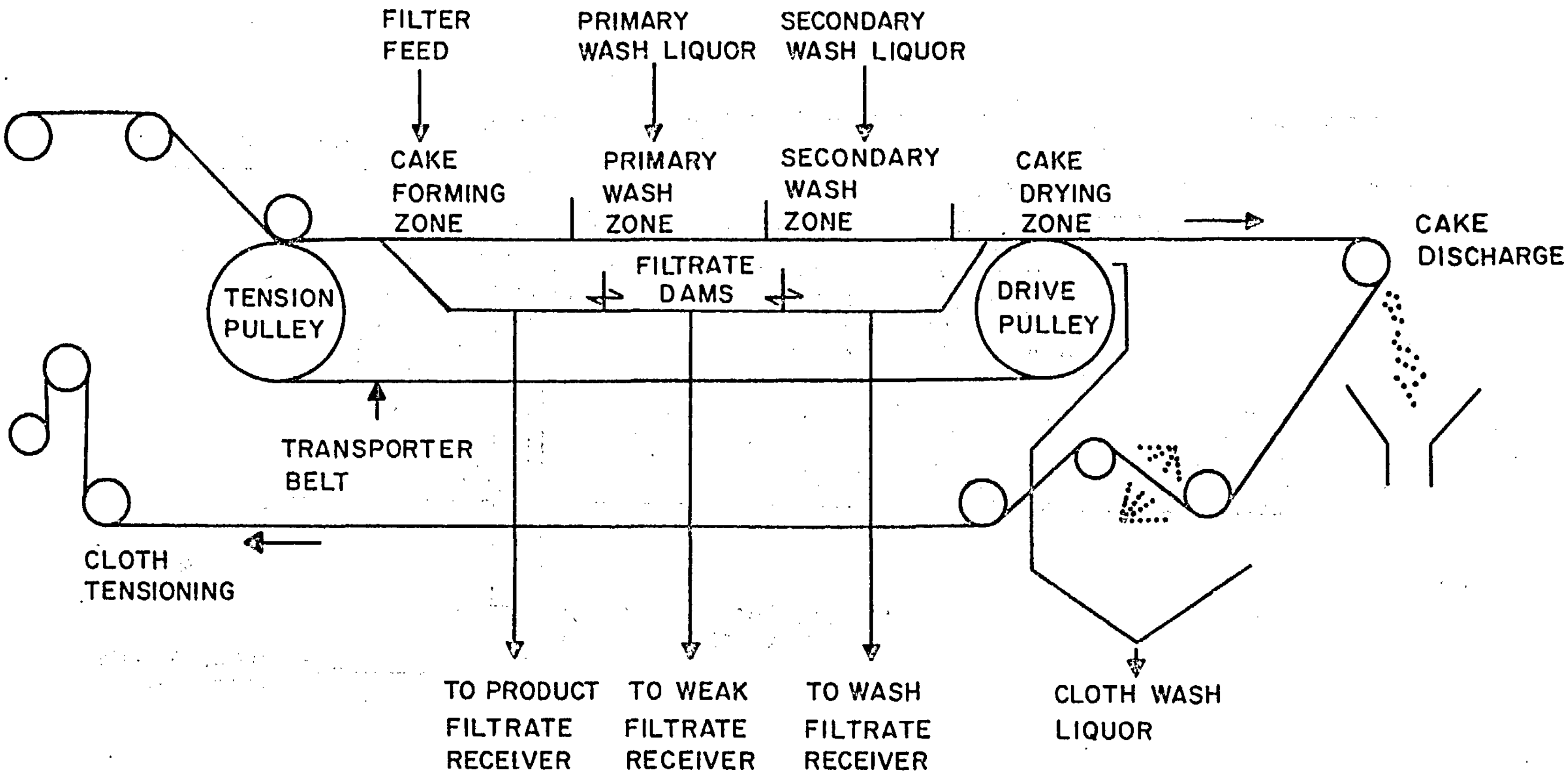

Fig. B.5. Horizontal Belt Vacuum Filter [Based on Enviro-Clear (a Division of Amstar Corp.) General Catalog No. EC-77.]

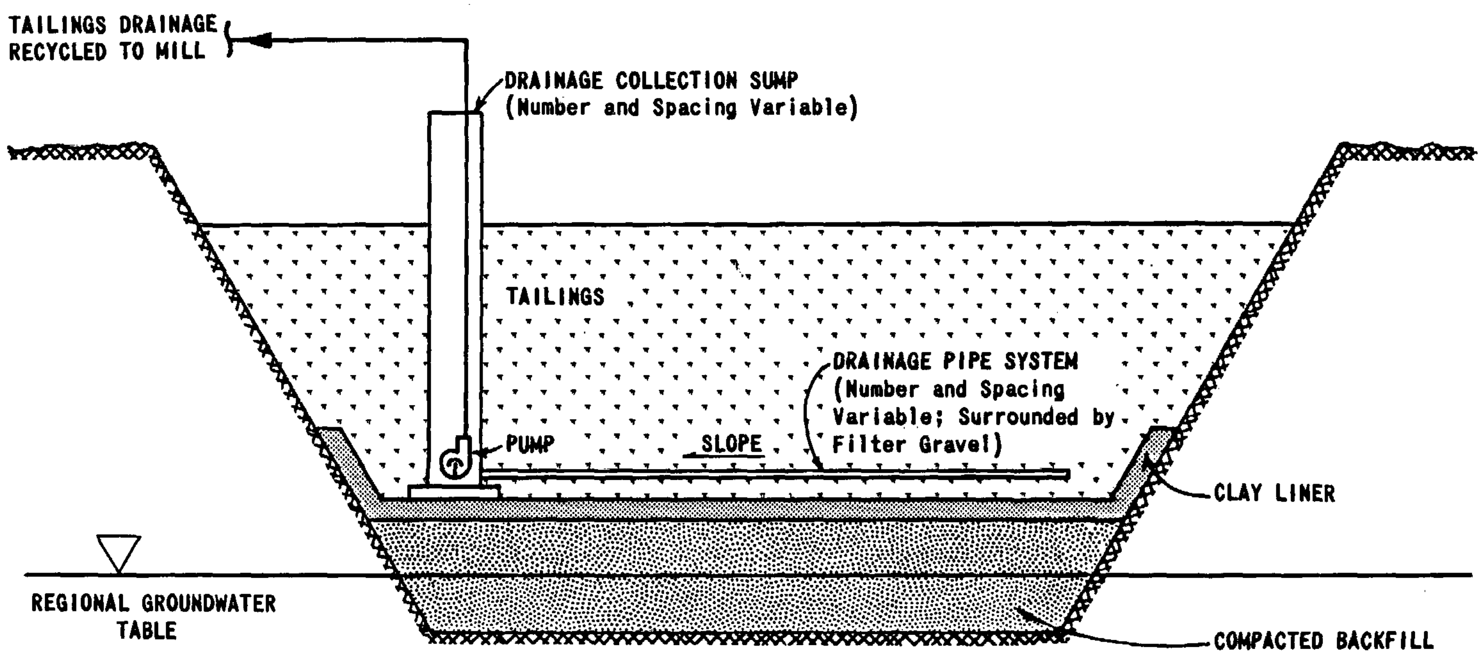

FIG. B.6 In-Situ Dewatering

Drain spacing and the size of piping should be designed to assure rapid draining of the tailings. Factors controlling sizing and spacing of the underdrain system include the following:

1. Porosity of the tailings.
2. Conductivity or permeability of the tailings (typically between 10^{-4} and 10^{-3} cm/sec).
3. Time available to drain the tailings (typically six to eight months).
4. Rate of tailings deposition per unit area of the disposal pit plan area.
5. Moisture content of the tailings as initially deposited (typically in the range of 50 percent).

Rate of flow of leachate or drainage from the tailings will be relatively low. However, the diameter of collection pipes should be sized conservatively to minimize the possibility of clogging.

Spacing of the underdrain system based on drainage hydraulics is difficult. The problem is similar to design of drains for controlling groundwater levels for highway and other construction, and agriculture. The subject has been extensively treated in civil and agricultural engineering literature, and by several texts. To minimize potential for leakage of tailings drainage outside the stub clay side liner, drainage piping should be placed near the stub clay side liner at the outside perimeter of the tailings disposal pit.

4.3 Lime Neutralization

Lime neutralization of uranium mill tailings has been required of Canadian mills since the early 1960s. Generally, uranium milling in Canada occurs in relatively wet or nonarid areas, and tailings liquid overflows directly to water courses from tailings disposal areas. To obtain the best possible tailings liquid quality for discharge to water courses, it may be necessary to raise the pH to the range of 8.0 to 10.0, and sometimes even as high as 11.0.

At the higher pH values, the solubilities of many of the heavy metals are of somewhat greater than the minimum which would occur at slightly lower pH. However, solids-liquid separation occurs primarily by settling, and higher values of pH often increase settleability of precipitated solids, thereby providing maximum total removals. Also, higher pH often increases the driving force of oxidation reactions.

In the case of the model mill, neutralization would be employed to precipitate most radioactive and other heavy metallic cations, along with some anions, such as sulfate. During leaching, solids-liquid separation occurs primarily by the mechanism of filtration. Therefore, it should not be necessary to raise the pH sufficiently to obtain optimum settleability of the precipitated solids, as is current Canadian practice.

For the model uranium mill, the radioactive metals radium 226, thorium 230, lead 210, plutonium 210, and bismuth 210, along with the nonradioactive arsenic, cadmium, copper, iron, lead, manganese, mercury, possibly molybdenum, selenium, sulfate, possibly vanadium, and zinc would provide the most potential for pollution of groundwater or surface water by leaching.

The various heavy metals present in uranium mill tailings which can cause pollution problems by leaching are somewhat site specific. The pH for precipitation is somewhat different for each of these heavy metals. If lime neutralization is to be employed, the heavy metals present in tailings should be investigated for the specific mill. The optimum pH for best precipitation of most of the heavy metals will depend on chemical equilibria conditions and solubility products of the various heavy metals present. Actual laboratory, bench scale, or pilot scale studies may be necessary to optimize the neutralization pH. It is expected that the optimum pH for lime neutralization will be in the range of 8.0 for most mills.

The location of a usable source of limestone in close proximity to a given uranium mill will have a large effect on feasibility of lime neutralization of tailings. Deposits of limestone are generally available in the western areas of the United States where uranium mills are located. However, many of these deposits consist of dolomitic limestone (having a high magnesium content). Dolomitic limestone may not be acceptable for lime neutralization if the magnesium content is greater than five percent. The high calcium limestone required for neutralization is presently in short supply in Arizona, Colorado, New Mexico, California, Wyoming, Idaho, and Montana. In addition, many industries, such as sugar companies, have purchased lime deposits for their own uses in the western United States. Therefore, an investigation to determine continuing availability of an acceptable lime source would be necessary before lime neutralization could be implemented at a specific uranium mill.

Three forms of lime are available for neutralization of tailings. These are limestone ($CaCO_3$), quicklime (CaO), and hydrated lime ($Ca(OH)_2$). Limestone is much less expensive than hydrated lime or quicklime on a weight basis. However, the calcium carbonate in limestone generates carbon dioxide, which forms carbonic acid thereby suppressing further increases in pH, after an initial small increase in pH. In addition, calcium carbonate itself acts as a buffer which tends to suppress increases in pH after the initial increase. Therefore, limestone is practical only to raise the pH from the initial 1.5 to 2.0 up to the range of 3.5 to 4.0 although further small increases may be feasible with air stripping of CO_2.

When limestone is used for neutralization, it is necessary that it be very finely ground. Two hundred mesh particle size has been used, although 325 mesh particle size is now recommended. Fine grinding is required to minimize build-up of calcium sulfate on the particle surfaces, which would prevent the required chemical reaction.

Quicklime (CaO) is approximately the same price on a weight basis as hydrated lime ($Ca(OH)_2$). Quicklime must be slaked to produce hydrated lime before it can be used for neutralization. However, hydration adds water molecules to the quicklime, and decreases the available chemical for neutralization on a weight basis. Therefore, purchase of quicklime, with slaking at the mill site will be generally more economical (to minimize shipping charges), than use of hydrated lime. On the basis of shipping weight, hydrated lime has only about 75 percent of the neutralizing power of quicklime, which has been hydrated or slaked on site.

A schematic diagram of the lime neutralization process is shown on Figure B.7. This is a two-stage process, employing limestone and quicklime. Limestone is used to raise pH to approximately 3.5 to 4.0. This would be accomplished in a rapid mix tank with a minimum 10 minutes detention time. This tank would be of fiberglass reinforced plastic, rubber-lined steel or lined concrete construction, and would contain a mechanical mixer of alloy construction or rubber-covered. The rapid mix tank would be aerated to strip CO_2, thereby enhancing the ability of the more economical limestone to raise the pH as high as possible. Limestone would be fed from a storage bin through a dry feeder to a slurry tank. Water would be introduced to the slurry tank with an authomatic batching system. Concentration of the slurry would typically be 5 to 10 percent limestone. Slurry would be fed by centrifugal pump in a continuously recirculating pipe loop controlled by a three-way valve to bleed limestone into the rapid mix tank. Lime feed from the recirculating slurry loop would be controlled by a closed loop system operating as a function of the pH of the rapid mix tank and metered slurry flow into that tank.

The second stage of the system would employ quicklime to raise the pH from 3.5 to 4.0 up to approximately 8.0. Quicklime would be fed from a storage bin through a dry feeder, into a slaker where it would be hydrated, and into a lime slurry tank. The slurry feed system and control would be similar to the limestone slurry feed system. A minimum detention time of five minutes would be required for the quicklime rapid mix tank. Identical construction materials would be required as for the limestone feed system.

To reduce the problem of gypsum ($CaSO_4$) buildup in the pipeline to the tailings disposal area, it may be desirable to provide a total detention time of up to 2 hours in the rapid mix tanks. This should be considered especially if the pipeline is long. The larger tanks would cause only a minor increase in estimated capital costs, since costs of those tanks are small compared to the total lime feed system.

Limestone could be hauled to the millsite by railroad hopper car or trucks. Trucking costs are generally about double the costs of shipping by rail on ton/mile basis.

It should be emphasized that pilot studies would be required to determine lime use quantities and required rapid mix tank detention times for a specific mill. These depend on properties of the uranium ore, specific process methods employed in acid leaching, and to a certain extent on the limestone and quicklime to be used. The lime quantities will be quite variable for specific mines.

As an additional alternative for lime neutralization, it may be economical at some mills to calcine limestone to form quicklime. By this process, finely ground limestone is processed in a rotary kiln at high temperature to produce quicklime.

To determine lime quantities required (for cost estimating purposes at the model mill), experiences at several Canadian and French uranium mills, and one U.S. mill were investigated. Present practice in the United States is to recycle some of the water from the tailings disposal area back to the uranium mill. Due to the calcium sulfate ($CaSO_4$) produced by lime neutralization, recycle of this water from the tailings disposal area would often be undesirable or infeasible. Therefore, it is important to recycle this water before the neutralization process occurs. Recycling before lime neutralization will produce an additional benefit in that substantially less lime will be required for neutralization.

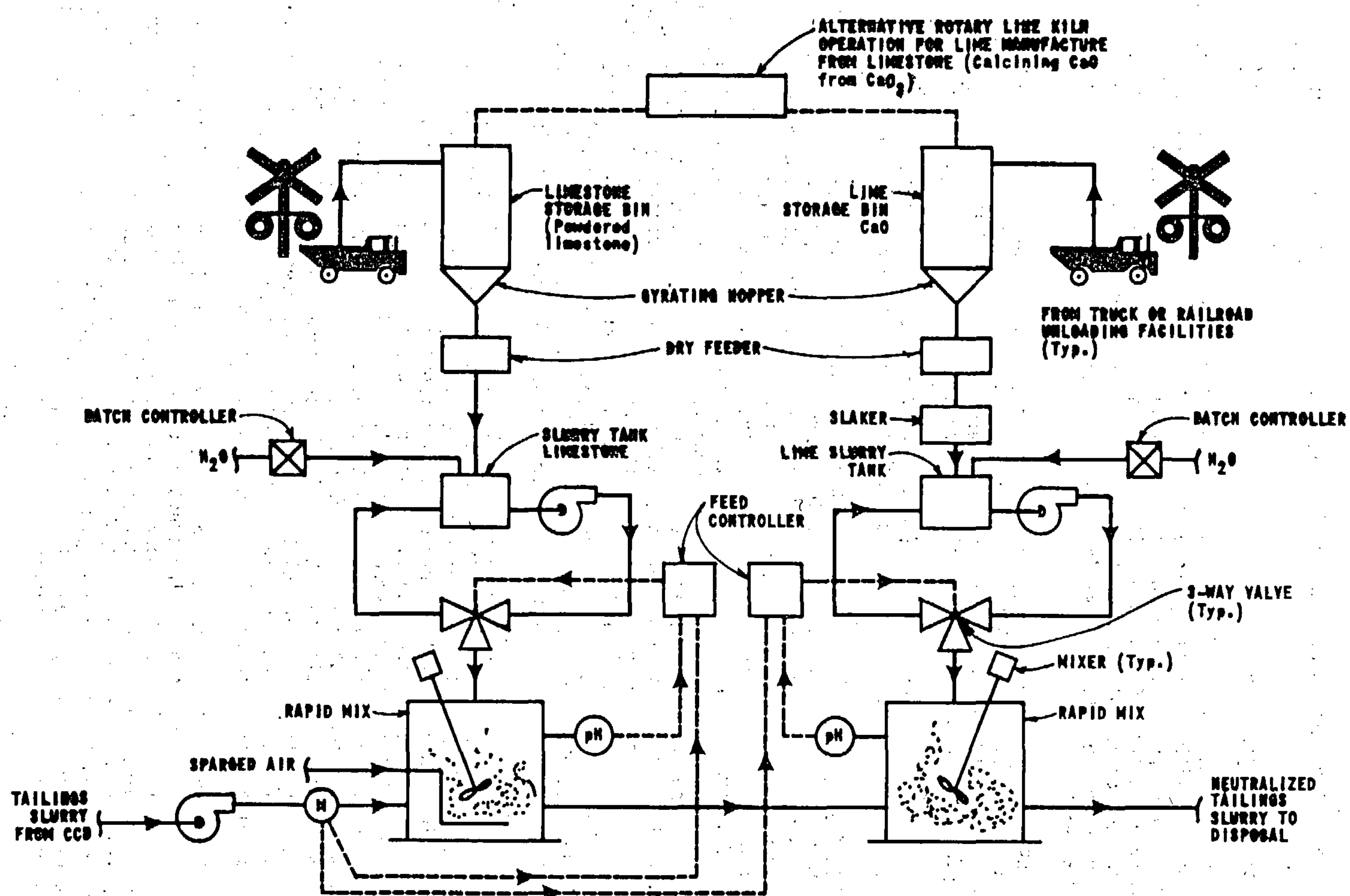

FIG. B.7 Schematic Diagram of Lime Neutralization Process

The following lime quantities are estimated for the model uranium mill of 1800 metric tons per day capacity:

Limestone use = 25 kg/mt or 45 metric tons per day.
Quicklime = 9 kg/mt or 16.2 metric tons per day.

The preceding quantities of lime are very substantial. Feasibility of this process is highly dependent on location of a suitable source of limestone near the mill site, to minimize the substantial shipping costs which would occur.

Costs for lime neutralization of uranium mill tailings for the model mill are discussed in Appendix K-2.

4.4 Impoundment Construction

As part of the uranium mill licensing process, the NRC reviews the design and construction details associated with the tailings retention system to assure that they result in a safe impoundment where disposal of tailings is above grade. To assist the applicant in meeting NRC design requirements, the NRC has made avilable Regulatory Guide 3.11, entitled "Design, Construction, and Inspection of Embankment Retention System for Uranium Mills." This guide elaborates on the NRC position concerning embankment design and is the basis for NRC review of submitted designs.

The current NRC position favors: (1) the downstream method of construction when staged construction is the preferred alternative, (2) the use of imported fill material for construction, and (3) the employment of a seepage-reducing "impermeable" layer. All designs should be based on sound geotechnical and hydrologic engineering principles.

Where a tailings dam is constructed in stages, one of the following three methods has been used: (a) upstream method, (b) downstream method, or (c) centerline method (Fig. B.8).

Upstream Method. The upstream construction method, Figure B.8(A), is the oldest used by the mining industry and is a naturally developed procedure for disposing of the tailings as economically as possible. An initial starter dike is constructed at the downstream toe of the ultimate dam with borrow materials. The crest of the dam is raised by placing fill materials in successive dikes located on the upstream side of the initial starter dike. The centerline of the embankment crest is shifted toward the upstream pond area as the height of the dam increases. The downstream toe of each subsequent dike is supported on the top of the previous dike, with the upstream portion of the dike placed over finer tailings (slimes) within the impoundment. These slimes, placed hydraulically, have a relatively low shear strength and remain in a loose and saturated state for many years after deposition.[17] As the height of the dam increases, the potential failure is located at an increasingly greater distance from the downstream face and through the slimes. As a result, the outside shell contributes less to stability as the height increases. The retained slimes are sufficiently loose and saturated that they could be liquefied to cause the failure of the dam if subjected to seismic shock or blasting.

Downstream Method. With the downstream construction method, Figure B.8(B), an initial starter dike is constructed at the upstream toe of the ultimate dam. The crest of the dam is raised by placing fill materials in successive dikes located on the downstream side of the starter dike. The centerline of the dam crest is shifted downstream as the dam is raised. Each subsequent stage of dike construction is supported on the top of the downstream slope of the previous section. All of the embankment section lies outside the boundaries of the sediment tailings. Materials incorporated in subsequent stages of the embankments may consist of the coarse mine waste or borrow materials from nearby pits. Downstream construction permits controlled placement and compaction to achieve high shear strengths. It also permits the incorporation of drainage facilities to control the piezometric pressures within the embankment. Thus the dam can be designed and subsequently constructed to whatever degree of competency may be required, including resistance to seismic and blasting shocks.

Centerline Method. The centerline method, Figure B.8(C), is intermediate between the previous two construction methods. The crest of the embankment is maintained in approximately the same horizontal position as the embankment is raised to its final height. The dam is raised by spreading and compacting successive layers of materials on the crest, on the upstream shoulder and on the downstream slope. The centerline method permits the downstream half of the tailings dam to be designed and constructed to conventionally acceptable engineering standards; however, certain portions of upstream slopes rest over the slimes and are therefore vulnerable to slope failure and seismic liquefaction.

These three construction methods lead to substantially different embankment cross sections and produce different embankment material characteristics. Consequently, the embankment stability conditions are affected. In the upstream and centerline methods of construction, the stability

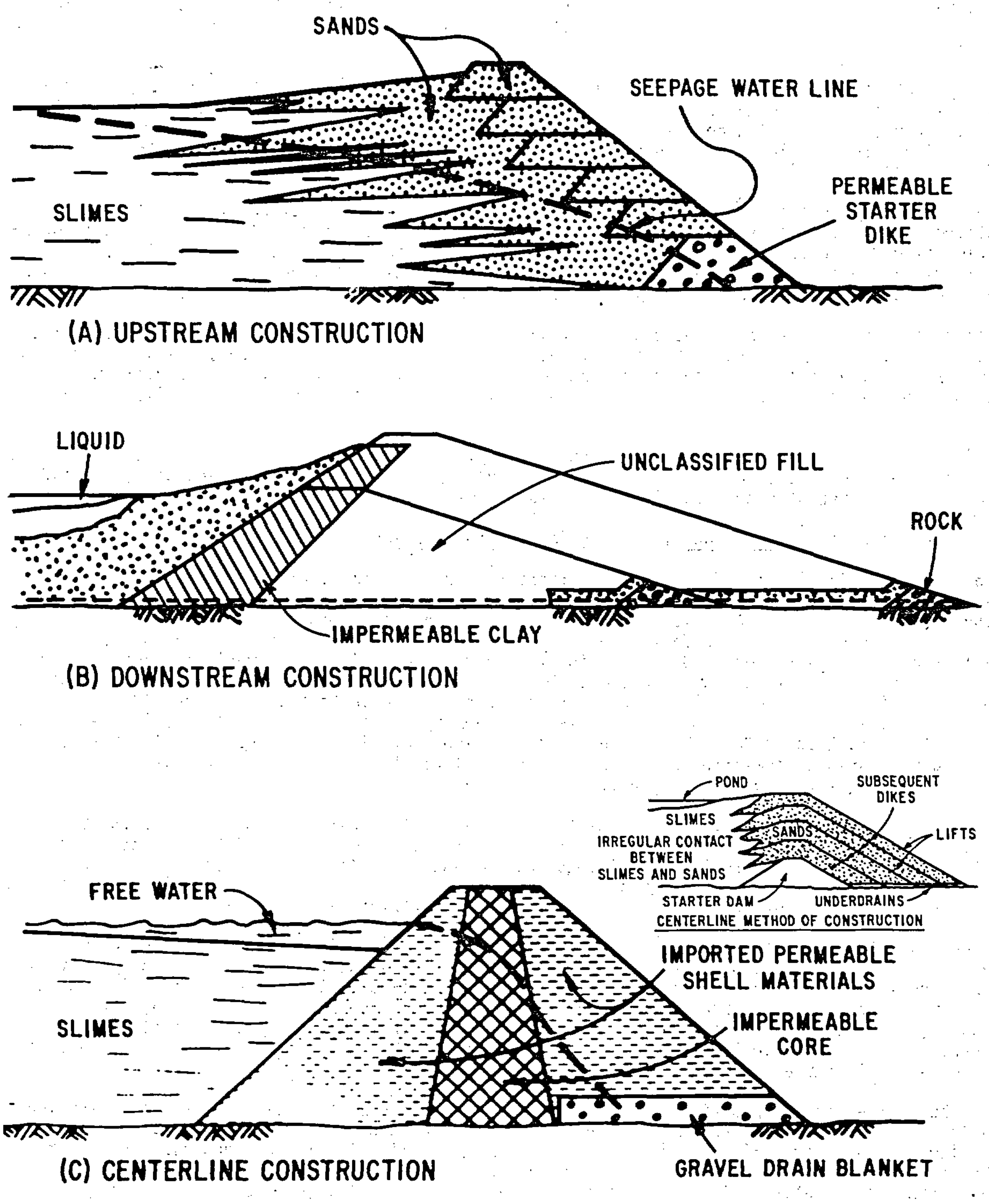

Fig. B.8. Basic Methods of Tailing Embankment Construction. (Modified from "Tailings Disposal Today," Proceedings of the First International Tailing Symposium, Miller Freeman Publications Inc., 1973.)

of the ultimate dam is dependent, to a large degree, on the shear strength characteristics of tailings deposited upstream of the dam. The shear strength is governed by the gradation and density of the solids, the consistency of the slurry, and the distribution of the pore water pressures within the deposit. When initially deposited, the tailings have very low shear strength.

The strength theoretically increases with time as drainage and consolidation take place under the weight of overlying materials. However, because of the very fine gradation of the tailings and the random nature of deposition, large variations in permeability and pore water pressure exist within the tailings, and the strength may not increase adequately to ensure the stability of the final slope.[18]

Downstream construction is the only method wherein all embankment sections lie outside the tailings boundaries, thereby permitting controlled placement and compaction of fill and incorporation of drainage facilities. Thus, for a given height and a given downstream fill slope, a tailings dam constructed using the downstream method will have a higher factor of safety than a tailings dam constructed by either the upstream method or the centerline method.

Because the most important purpose of the tailings dam structure is to contain the radioactive waste materials and because of the unsatisfactory performances of the hydraulically constructed dams and tailing dams,[19-21] the downstream method appears to be the best stage construction methods to ensure the safety function of the tailing dams, especially in seismically active areas.

It is noted that the coarse tailings fraction can provide a sound structural fill for embankment construction. However, to eliminate problems of blowing of radioactive particulates, the NRC does not favor use of coarse tailings for this purpose.

4.5 Rock Cover for Protection of Exposed Impoundment Surfaces

Erosion protection is one of the most important requirements in assuring long-term stability of tailings impoundments. Section 9.4.1 includes a discussion of the factors which control both wind and water erosion. As illustrated by predictive models for estimating soils loss caused by wind and water erosion, these factors are complex and interrelated. However, based upon evaluation of these factors and considering the natural geologic and climatic processes which determine the shape of natural landforms, the staff established certain criteria which should be adhered to in order to control erosion. These are presented in Section 9.4.1 and 12.2 and have been incorporated into regulations being issued. An important element of these criteria is the provision of rock cover to stabilize the final tailings covering; more specifically, this is necessary in arid to semiarid areas, where good, full vegetative cover is not likely to be self-sustaining for thousands of years.

Sizing and design of rock cover to prevent wind erosion and water erosion is difficult, because it is not possible to accurately predict climatic, traffic, and other conditions that might influence erosion of the reclaimed tailings impoundment side slopes and cover over the long term. Therefore, sizing and design of the rock cover for a particular tailings impoundment must provide a strong measure of conservatism, given the uncertainties that exist.

In general, the rock cover must be one which will not be susceptible to undercutting or piping and will not be dislocated by human and animal traffic or by natural forces (for example, very large precipitation events). The following describes an illustrative rock cover design which attempts to address these broad requirements. Because the side slopes are most susceptible to erosion, they require a more substantial rock covering. The side slope design includes two layers, a large particle layer supported by a well-graded bedding layer, on very gentle slopes (as close to 10h:1v as is practicable).

For the gentle side slopes (for example, 8h:1v, as described in the illustrative case described in Appendix K-9), a 15 cm (6-inch) thick layer of angular crushed rock (coarse aggregate) is applied over a 15 cm (6-inch) thick layer of bedding material (medium aggregate). The 15 cm (6-inch) layer of bedding material (medium aggregate) would consist of particles approximately one-fifth the diameter of the dominant coarse aggregate particle, would be fairly well graded (uniformity coefficient of at least 6.0) to provide stability, and less than 5 percent of the material particles would pass a No. 16 (1,190 μ) sieve. The crushed rock would be of a median size of 8 cm (3 inches--that is, as a minimum, about cobble size) or larger, and the thickness would be approximately double the median size selected. The rock would be fairly well graded to allow adequate keying and interlocking of the rock particles. The placement of the bedding and the specification on grading of material are intended to assure there is no piping or undercutting of the rock cover. The method of installation would be by dumping from trucks and spreading, placement, and compaction with a bulldozer.

To prevent wind and water erosion on the flat top surface of the tailings cover, a 5 cm (2-inch) thick layer of the medium aggregate (same as bedding material for the side slopes) might be adequate for occasional animal or human traffic, and should be able to withstand very infrequent encroachment by light vehicles. One method of applying the medium aggregate to provide maximum stability upon installation would be to apply it in several layers. The first layer would be mixed with soil (in the outer surface of the cover) and compacted by roller. The second would be compacted on top of this. This design assumes that significant differential settlement or subsidence will not occur because the underlying tailings have been dried or dewatered sufficiently, and that the tailings have been covered, as required, to provide a stable foundation.

The individual rock fragments are dense, sound, and resistant to abrasion, and are free from cracks, seams, and other defects that would tend to increase their destruction by water and frost actions. Weak, friable, or laminated aggregate are not used nor should shale, stones laminated with shale, or cherts.

The following are soundness and quality specifications for rock fragments that would be applied:

1. ASTM C-88; loss not to exceed 10 percent with sodium sulfate, when subjected to 5 cycles of the soundness test.
2. ASTM C-127; bulk specific gravity not less than 2.5.
3. ASTM C-131; abrasion loss not to exceed 50 percent of weight after 500 revolutions.
4. ASTM C-33 for coarse aggregate, except that blast furnace slag is not to be used.
5. AASHTO T103; loss from freezing and thawing not to exceed 10 percent after 25 cycles.

In general, some guidance on uniform, surface-sheet erosion protection can be obtained from literature on erosion control practices developed for short-term applications such as that which has been developed by the National Research Council for highway construction[25] or by the U.S. Department of Agriculture, for a wide range of open-land situations.[26,27] The guidance given in such literature must be taken as the extreme lower bound of what must be provided, given the long term uncertainties which are unique to the tailings disposal problem.

The top of the tailings cover is slightly mounded to promote uniform drainage in all directions, without channelizing the flow or otherwise causing high surface water runoff velocities. Where the area of the top of the cover is very large [for example, exceeds 80 ha (200 acres)], directing runoff into channels paved with concrete, or covered with riprap of adequate size to prevent erosion, may be necessary. The rock cover design described above is intended to protect against sheet flow where no more than runoff from precipitation on the impoundment itself is of concern. In any area where there may be any concentration of flow, riprap must be sized based on the maximum quantities and velocities of water which might occur (that is, flows occurring as a result of the probable maximum precipitation event) in the channelized flows.[28] Given the large uncertainties that exist, particularly with regard to the climatic factors that determine the size of the probable maximum flood (PMF), an overall factor of safety is called for in riprap design. For example, a minimum of 1.5 times the boundary shear force expected from the PMF would be appropriate in sizing riprap.

Costs for rock cover are discussed in Appendix K-6, Section 1.5.

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APPENDIX C. BASIC CONCEPTS AND TERMINOLOGY OF RADIOLOGICAL HEALTH AND BACKGROUND RADIATION

1. INTRODUCTION

The word "radiation" in a general sense refers to energy emitted in the form of waves or particles. It includes sound, elastic, and electromagnetic waves. The latter category includes many well-known forms such as X ray, ultra-violet, visible light, infrared (heat), and radio, which differ from one another in wave length (or the related parameter, frequency). In this document, "radiation" is used in a more restricted sense to mean "ionizing radiation." Ionizing radiation is any electromagnetic or corpuscular (i.e., particulate) radiation sufficiently energetic to ionize, directly or indirectly, the atoms of the material through which it passes. In the process of ionization, sufficient energy is transferred from the radiation to the media with which it interacts to remove completely an electron from an atom, thereby creating an electron-ion pair. The effects that ionizing radiations produce in matter are usually attributed to the ability of such radiations to ionize and, to a lesser extent, to excite target atoms.

The ionizing radiations present in the natural environment and with which all living creatures are bombarded continually may be classified as follows:

(a) Electromagnetic--conventionally referred to as either X rays or gamma rays according to the mechanism by which they are produced. Relative to their interactions and the effects they produce, an X ray and a gamma ray of the same energy are identical.

(b) Corpuscular

(1) beta rays - these are energetic charged particles emitted by atomic nuclei in the process of radioactive transformation or decay. Their mass and charge are equal in magnitude to that of the electron.

(2) alpha rays - these are heavier charged particles which may be emitted by certain radioactive nuclei. They have the same mass and charge as a helium nucleus, which means they have twice the charge and about 7300 times the mass of a beta particle.

Because of the basic, physical dissimilarity of these forms of ionizing radiation, it is to be expected that their ability to penetrate matter is quite different. Typically the gamma rays emitted in radioactive decay will travel 5 to 25 cm (0.2 to 10 inches) in living tissue before any interaction occurs. In contrast, corpuscular radiation will interact strongly and lose energy along its entire path through tissue. As a result, the maximum distance of penetration for beta particles characteristically ranges from 0.1 to 1 cm (0.04 to 0.4 inch), while the range of alpha particles from naturally occurring emitters is much shorter still, typically 0.005 cm (0.002 inch).

Forms of ionizing radiation in addition to those listed above also contribute to the natural background exposure. These include a variety of mesons, heavy particles, and neutrons which are present in the cosmic radiation discussed in Section 2 of this appendix. However, the alpha, beta, and gamma rays are important in the evaluation of the radiological impacts from the uranium milling industry.

Another common way to classify radiation depends on whether its source is outside the human body (external) or inside (internal). External sources include cosmic radiation and radiation from rocks, soil, building materials, and the surrounding air. Internal sources are radioactive materials present within the body. A small fraction of certain elements which are essential components of living tissue, such as hydrogen, carbon, and potassium, are naturally radioactive. Therefore, a significant internal exposure to radiation is unavoidable. Because of its great penetrating ability, gamma radiation is the major contributor to the external exposure of most human organs. In contrast, alpha particles from naturally occurring emitters cannot penetrate the outer dead layers of the skin and, therefore, constitute no external hazard. Alpha emitters must gain access into the interior of the body in order to cause a harmful exposure.

The word "exposure" has already been used several times to mean subjecting a target (usually living tissue) to radiation, or causing it to be irradiated. Throughout this document "exposure" will be used in this general sense, although the word has another very specific meaning in the field of radiological physics (related to the amount of electric charge produced by ionization in a unit mass of air by X rays or gamma rays and often measured in units of roentgens). It is important to understand that indirectly ionizing radiation such as gamma rays can pass through matter without interacting and, therefore, without causing any effect. It is only when interaction occurs and energy is transferred to the absorber that any change can occur in the material. The commonly used index of energy absorption is the quantity called the "absorbed dose" (often simply referred to as the dose), which traditionally has been measured in units of "rads." An absorbed dose of one rad is equivalent to the absorption of 100 ergs of energy in a mass of one gram. Under the International System of Units (SI) the unit of absorbed dose is the "gray" or Gy, equal to 1.0 joule per kilogram (or 100 rads).

In analyzing the effects of irradiation, the absorbed dose has proved to be a very useful quantity. This is not surprising, since one probably would expect the effect to be proportional to the amount of energy deposited in a given amount of material. Early biological experiments with ionizing radiation, however, soon revealed that equal doses of radiation from, for example, gamma rays and alpha particles did not produce the same biological response. Numerous experiments were performed to determine the relative biological effectiveness (RBE) of various forms of radiation. Usually, the RBE of the radiation was measured relative to X rays of a specified wave-length, and the RBE was expressed as the ratio of the absorbed dose of each radiation necessary to produce a specific biological effect in a particular organism or system. Thus, if 10,000 rads of X ray were required to kill a microorganism, but only 1000 rads of alpha rays were needed, the alphas would have an RBE of 10.

In radiation protection work it is useful to have a quantity whose magnitude is proportional to the expected biological effect, regardless of the form or type of ionizing radiation which produces the effect. Also, in protection work one is concerned with a specific organism (the human being) and usually with long-term effects, such as cancer induction from low doses of radiation. From the available data, organizations such as the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP) have defined a "quality factor" (Q) for each radiation which is proportional to the relative effectiveness of that radiation in causing damage to human beings. Knowing the quality factor it is possible to define a new quantity, the "dose equivalent," as the product of the absorbed dose times Q (and, in some circumstances, other modifying factors as well). When the dose is expressed in rads, the dose equivalent is in units of "rems" (when dose is given in grays the dose equivalent is expressed in "sieverts," or Sv). Presumably a dose equivalent of 100 rem from either alpha, beta, gamma, or other forms of ionizing radiation will produce the same biological effect if an appropriate value is chosen for the quality factor. In the interest of brevity, but at the expense of technical accuracy, the term "dose" frequently is used in this document rather than the correct, implied term "dose equivalent." It should be understood that whenever a "dose" is expressed in units of rems, it is a dose equivalent.

Another factor that is important in determining the effects of irradiation is the distinction between dose or dose equivalent and dose rate (or dose equivalent rate). Both the total dose equivalent delivered to an organism and the rate at which it is delivered are important in determining the effect. Since the human body apparently is able to repair, at least to some extent, the effects of beta and gamma irradiation at low dose rates, it cannot be ruled out that the risk at very low dose rates may actually be zero. In contrast, it is generally assumed, based on the available evidence, that the effects of alpha particles remain proportional to the dose even at low dose rates.[1] Much more careful scientific study will be required before the effects of low doses of all types of ionizing radiation can be predicted with certainty and, in the meantime, predictions will continue to be based on assumptions which are generally, but not universally, considered to be conservative. The dose rates to the general population evaluated in this document are very low compared to the dose rates at which effects actually have been observed.

Another factor that is important in addition to the rate of delivery in determining the effect of a given dose is the portion of the body that is irradiated. In radiation therapy for cancer using X or gamma rays, patients may receive doses that are many times larger than the lethal dose to the whole body. These treatments are not lethal because the volume of tissue irradiated is carefully restricted. Certain tissues or organs are more radiation sensitive and more important to normal body functions than are others. For this reason, in radiation protection standards or guidelines different MPDs are usually recommended for various parts of the body.

Although the concepts of absorbed dose (rads) and dose equivalent (rems) are quite simple in principle and applicable to all ionizing radiation, the unique problems associated with the dosimetry of radon gas has led to the development of another unit of measure--the "working level" (WL). Because radon and its radioactive progeny are the major contributors to the total radiological impact from mining and milling, a discussion of the working level concept is warranted, even though it is restricted in its use to these radionuclides. To understand the definition of working level, one must be aware of the relationship among radionuclides in a decay chain. There are three series of radioactive elements that occur naturally in the earth's crust. Each begins with an isotope whose half-life is at least of the same order of magnitude

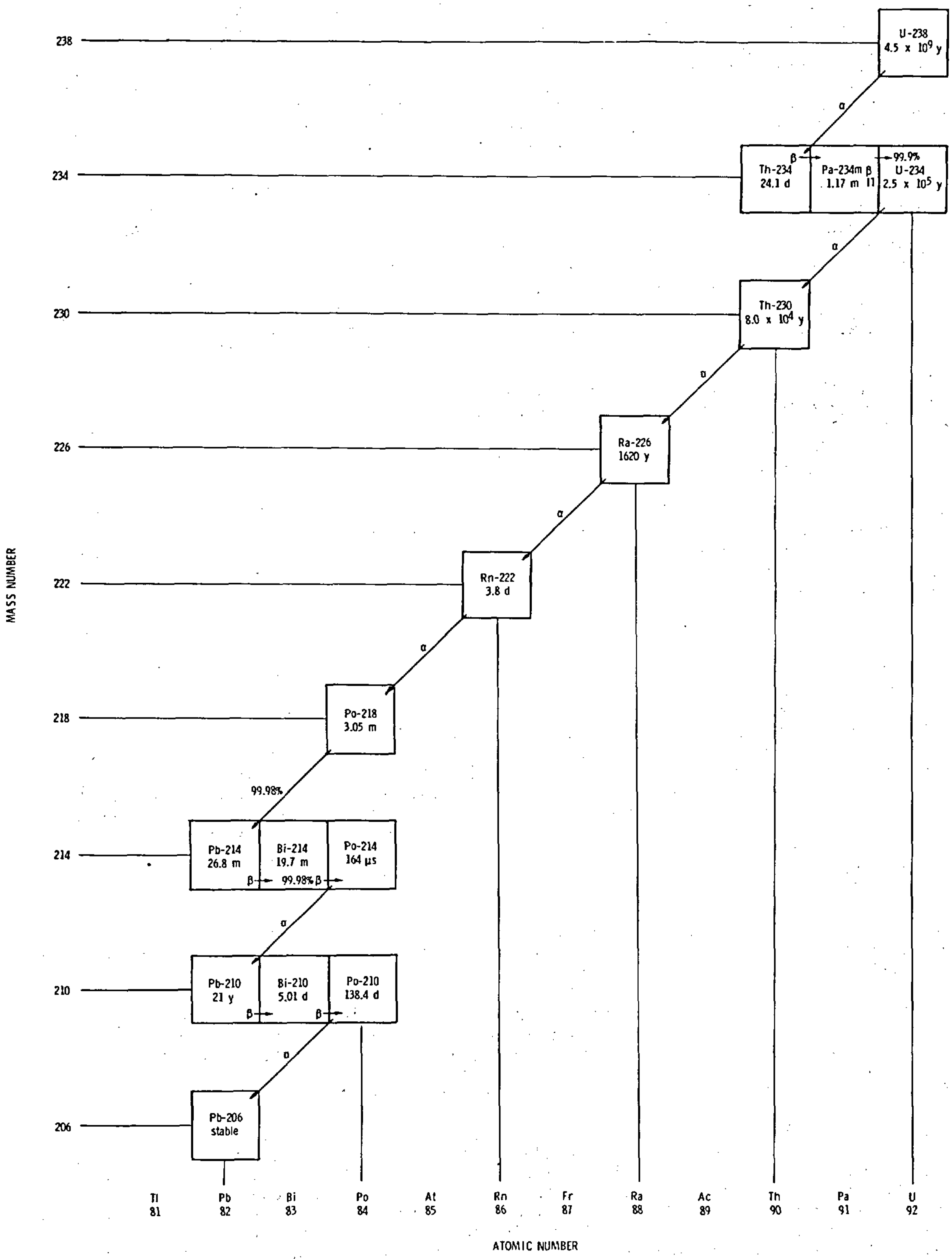

Fig. C.1. The Uranium-238 Decay Series.

as the age of the earth (otherwise the series would have disappeared by now). The so-called thorium series has thorium-232 (half-life of 1.4×10^{10} years) as its parent or first member. The other two parents, uranium-238 (half-life 4.5×10^{9} years) and uranium-235 (half-life 7.1×10^{8} years) both occur in natural uranium. The U-238 isotope is by far the more abundant (99.3%) and its series contributes essentially all of the radiological impact associated with the milling industry. This series is depicted schematically in Figure C.1. Not including the two minor branches in the decay scheme, the U-238 supports 13 lineal radioactive decay products traditionally referred to as daughters (suggesting the presence of female chauvinists among the early nuclear scientists). The chain terminates in stable (nonradioactive) lead-206.

In ore bodies which have been undisturbed for many years there are equal amounts of radioactivity of each radionuclide. The common unit of quantity of activity is the curie (Ci), defined as 3.7×10^{10} disintegrations (or decays) per second (the SI unit is the becquerel, or Bq, equal to one disintegration per second). In ore containing 0.1% natural uranium (U_3O_8) there are 2.8×10^{-7} Ci of U-238 (10,000 disintegrations/second) per kilogram of ore. If nothing has occurred to remove any decay products, a condition known as secular equilibrium exists and there would also be present 2.8×10^{-7} Ci each of Th-234, Pa-234, U-234, Th-230, and Ra-226 per kg of ore. This does not imply that an equal weight of each isotope is present per unit weight of ore. The mass, or number of atoms, per curie is inversely proportional to the half-life.

In Figure C.1, the disintegrations, or decays, by alpha particle emission are those which result in a decrease of 4 in mass number and 2 in atomic number (such as Po-210 to Pb-206) and are indicated by a line directed down and to the left at a 45° angle. These nuclides represent a negligible radiological hazard as long as they remain outside the body, but are serious health hazards once inside the body.

It may be seen from the figure that radium-226 decays by alpha emission to radon-222. Radon, being an unreactive gas with a 3.82-day half-life, may escape from its immediate environment, whether that environment is an ore body, a tailings pile, or a bone in which radium has deposited. If a significant amount of radon escapes, then the decay chain will not be in a state of secular equilibrium from that point onward.

Radon does escape into the atmosphere continually and outdoors is present in concentrations ranging from about 0.1 to 1 picocurie per liter of air (pCi/L). Radon is inhaled with each breath, but it is likely to be exhaled again without irradiating the respiratory tissues. When radon undergoes alpha decay, there follows within a short time a series of four more decays (two by alpha emission) before relatively stable Pb-210 (half-life of 21 years) is reached. The longest half-life among the intervening nuclides is only 27 minutes. The radon daughters are not gases, but heavy metals, and rapidly become attached to available surfaces, usually to small airborne particles or aerosols. These aerosols, unlike radon gas, are easily deposited when breathed into the respiratory tract. Experience has shown that the bronchial epithelium (the lining of the bronchi) is an especially critical tissue, and that the total concentration of radon daughters, rather than the concentration of radon itself, is the parameter which best predicts the potential hazard. For this reason, in 1957 the U. S. Public Health Service introduced the concept of working level. One WL is any combination of short-lived radon daughters (meaning Po-218, Pb-214, Bi-214, and Po-214) in one liter of air that will result in the ultimate release of 1.3×10^{5} MeV of alpha ray energy.[2] This amount of energy is the amount that will be released by the daughters in secular equilibrium with 100 pCi of radon. Unfortunately, radon and its daughters are almost never found in equilibrium, so a simple measurement of radon concentration will not reflect the potential inhalation dose.

When originally proposed, 1 WL was considered to be an acceptable maximum concentration for miners working a normal 40-hour week (170 hours per month). Exposures were described in "working-level months" (WLM). Thus 17 hours in an airborne concentration of 10 WL constitutes an exposure of 170 WL-hours or 1 WLM. The current EPA recommended maximum occupational exposure limit is 4 WLM per year, or 40 hours each week in a concentration of 1/3 WL.

Because the dose to lung tissue depends on respiratory parameters as well as on WL concentration and duration of exposure, it is not appropriate to determine continuous, nonoccupational exposure in WLM per year simply by multiplying WL by (24 × 365/170) to give about 52 WLM/year at a concentration of 1 WL. Instead, in this document it is assumed that a concentration of 1 WL yields 25 WLM/year for exposure that is continuous and nonoccupational. This reduction by about a factor of two reflects the difference in respiratory parameters appropriate for a worker engaged in physical activity and these parameters averaged over periods which include rest and other sedentary activity. To convert WLM of exposure to dose equivalent to the bronchial epithelium, it is necessary to make a number of assumptions about which there is not complete agreement among scientists. In this document a factor of 5 rem/WLM, based on the BEIR report, has been used in calculating doses and developing risk estimators (Appendix G).[3]

2. COSMIC AND TERRESTRIAL RADIATION

The term "cosmic radiation" is used here to refer to both the primary radiation of extraterrestrial (solar and galactic) origin that enters the earth's atmosphere and the secondary radiation that results from the interactions between the primary radiation and the earth's atmosphere. The intensity of, and radiation dose from, the primary radiation field at a point on the earth's surface is affected by solar activity and the geomagnetic latitude and elevation of that point, with elevation having the most effect.[4] Cosmogenic radionuclides, so called because they are formed by the interaction between cosmic radiation and nuclides in the earth's atmosphere, also contribute to the dose to man when they are ingested with food. Of the approximately 20 known cosmogenic radionuclides, only carbon-14 delivers a significant dose to man.[5]

The model region has an elevation of about 1000 m (3000 ft). Computations have been made for the annual doses in each state based on the average elevation and the populations of those states for the year 1960 (Ref. 6, Vol. 1, p. 96). Klement et al. have also made dose estimates for each state using similar methods (Ref. 7, pp. 7-13). By taking a weighted average of the populations and doses in the states within the appropriate physiographic provinces, the staff has estimated the cosmic ray dose in the model region to be about 54 mrem/year per person, including a 10% dose reduction due to shielding afforded by housing (Ref. 8, p. 108).

Carbon-14, a cosmogenic nuclide formed by the interaction between cosmic-ray neutrons and nitrogen in the atmosphere, is assimilated into living tissue by normal biological processes. In the 1972 UNSCEAR report,[5] a specific activity of 6.1 pCi of C-14 per gram of carbon and an average human body carbon content of 18% were assumed. The average dose to the whole body was then estimated at 1 mrem per year.

Terrestrial radiation (mostly gamma rays) originates from K-40, Rb-87, and the radioactive decay series of U-238 and Th-232. The uranium-producing area has a somewhat higher external terrestrial radiation background than the U.S. average; surveys conducted to measure the radiation background in the United States indicate that the outdoor background in this area is about 60 to 90 mrem/year (Ref. 7, pp. 7-13; Ref. 9, p. 317). The walls of houses and office buildings afford some degree of shielding from background radiation. To allow for this shielding, a factor of 0.8 was used, based on the estimates of Oakley[10] and the UNSCEAR report.[5] The background radiation from external terrestrial radiation at the model site is thus estimated at 62 mrem/year to the whole body. The dose to bone is further reduced by body shielding and is estimated to be 50 mrem/year.

Internal terrestrial radiation is due mainly to K-40 and the nuclides of the U-238 and Th-232 series that are ingested with food and drinking water. The amount of radionuclides in food is essentially independent of geographic location, primarily because of the dispersed food production and distribution points that exist in the United States (Ref. 7, p. 11). Potassium is under homeostatic control in the body so that the dose from K-40 is largely independent of variations in diet. The dose from ingested nuclides is therefore uniform throughout the United States. For the whole body the internal dose is estimated to be 21 mrem/year; for bone surfaces the dose is about 52 mrem/year; and for dense bone it is 115 mrem/year.[5,7,8]

3. RADON INHALATION

The concentration of Rn-222 at ground level depends on its rate of emanation from the ground and on the stability of the air near the ground. The emanation rate is extremely variable and is highly dependent on soil characteristics and meteorological conditions. The concentration of the parent Ra-226 and the grain structure and porosity both of the soil and of the cover material all affect the rate of radon emanation from soil. Barometric pressure has been reported to affect the radon flux from soil, a twofold increase in the radon emanation occurring when pressure drops by 1%.[11] Variation within 24-hour periods in Rn-222 concentration near the ground has been observed by many investigators.[12,13] Explanations for the concentration changes include effects of temperature, pressure, humidity, and air movement. However, the most significant cause for the fluctuations has been shown to be vertical exchange through eddy diffusion. Since radon concentration is highly variable, the dose from its daughter nuclides will also vary significantly. The dose values that are summarized here represent average values; the actual, short-term values can be expected to differ from the average.

The weather conditions at the model site are taken to be similar to those found in the western states. The concentration of Rn-222 in open air at ground level has been measured at different locations in the U.S. (Ref. 14 and Ref. 8, p. 79), including a site in New Mexico for which the average concentration over a six-year period was 240 pCi/m^3. Other studies have measured outdoor Rn-222 concentrations in western areas ranging from about 60 pCi/m^3 to over 2000 pCi/m^3.[15,16] A value of 240 pCi/m^3 is thought to be a conservative average value for outdoor Rn-222 concentrations in western regions. The concentration of Rn-222 in buildings is generally higher than in the open, depending on the Ra-226 content of the construction materials and the degree of ventilation of the building. Indoor concentrations as low as 5 pCi/m^3 (Ref. 17) and as high as

4800 pCi/m^3 (Ref. 8, p. 82) have been reported. George and Breslin have measured Rn-222 concentrations in homes in the New Jersey-New York area.[18] They have reported a geometric mean of the Rn-222 concentrations on the first floor of houses of about 830 pCi/m^3. The geometric mean for outdoor concentrations in the New Jersey-New York area is about 180 pCi/m^3. An indoor concentration of about 900 pCi/m^3 for western regions can be derived from George and Breslin's work by substituting the conservative outdoor Rn-222 concentrations for western regions (240 pCi/m^3) for the New Jersey-New York outdoor concentrations (180 pCi/m^3). The average value (900 pCi/m^3) would result in a bronchial dose of 560 mrem/year (based on the dose conversion factor of 0.625 mrem/yr per pCi of Rn/m^3, which is used throughout this document). American Indians living in the region generally inhabit poorly ventilated huts with mud-lined walls. Houses made with sun-dried, unburnt clay have been found to have an indoor Rn-222 concentration of 1760 pCi/m^3.[19] Since the huts are made of similar material, a dose of about 1100 mrem/year to the bronchial epithelium would result.

The air in a trailer-home could be expected to have about the same concentration as the outside air. Thus, an individual living in a trailer would breathe air with a concentration of 240 pCi/m^3 and would receive a dose to bronchial epithelium of approximately 150 mrem/year.

4. TECHNOLOGICALLY ENHANCED RADIATION

The reader is referred to References 20 and 21 for a discussion of technologically enhanced radiation. The study described in Reference 21, which specifically addresses technologically enhanced sources of radon, was funded by NRC in support of developing regulations for the disposal of mill tailings.

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APPENDIX D. FLOW PATTERNS FROM MINE DISCHARGE IN MODEL REGION

The potential discharge of water from uranium mines in the model region is 240 m^3/min (6.3 × 10^4 gpm) [40 mines at 6 m^3/min (1.6 × 10^3 gpm) per mine]. The existing stream channels will provide sufficient drainage capacity; however, aggregations of dewatering operations will change many of these ephemeral channels to perennial streams.* The impact of such a change on water quality and aquatic biota in Middle Reservoir and Tributary River (Fig. 4.1) will depend upon the transport of material (e.g., heavy metals, soluble salts) from the area of active milling and tailings disposal to the river, and upon the extent and rate of utilization and/or colonization of the new aquatic habitat by biota.

In order to assess surface water habitats and impacts thereon in the model region, calculations were made to determine: (1) which sections of the channel of Bone Gulch would become perennial and which would remain ephemeral, and (2) if a continuous flow would be maintained into Tributary River and Middle Reservoir. The following conditions were assumed:

- The direction of the principal axis of the hydraulic conductivity tensor (anisotropic) is independent of the coordinates of the region.
- The dewatering of the 40 open pit and underground mines is continuous, simultaneous, and at the rate of 6 m^3/min (1600 gpm).
- The average velocity (V) in the stream channels (based upon the slope of the region) is 36 m/min (120 ft/min).

It is indicated from the calculations that more than 60% of the stream channel will be changed from ephemeral to perennial. However, under dry conditions, Section BB (stream channel which forms a confluence with Tributary River--see Fig. D.1) will not discharge into the river because the potential water loss in the stream section from infiltration (Q_S) and evaporation (Q_E) exceeds stream input (Q_{in}). Although the streamflow will come within less than 1000 m (3300 ft) of Middle Reservoir, water will not reach the reservoir unless there is sufficient precipitation or snowmelt within the drainage basin to increase the discharge in Section BB (see Sec. 6.2.4.1).

The mine dewatering flows through a given section of the channel (Fig. D.2) are calculated as follows:

Given:	Slope of region	= 0.01
	Substrate hydraulic conductivity for vertical movement	$K_v = 10^{-4}$ cm/s
	Substrate hydrologic conductivity for horizontal movement	$K_h = 10^{-2}$ cm/s
	Equivalent hydraulic conductivity	K
	Total loss	Q_L
	Seepage (infiltration) loss	Q_S
	Evaporative loss	Q_E
	Annual evaporation rate	4.0 × 10^{-6} m/min
	Length of stream section	L
	Stream dimensions	(see Fig. D.2)
	Cross-sectional area of channel based on estimate of Q_{in} and V	A
	Water input	Q_{in}
	Wetted perimeter of stream bed	B

*There have been actual instances of uranium mining operations converting streams from ephemeral to perennial (see Refs. 1 and 2).

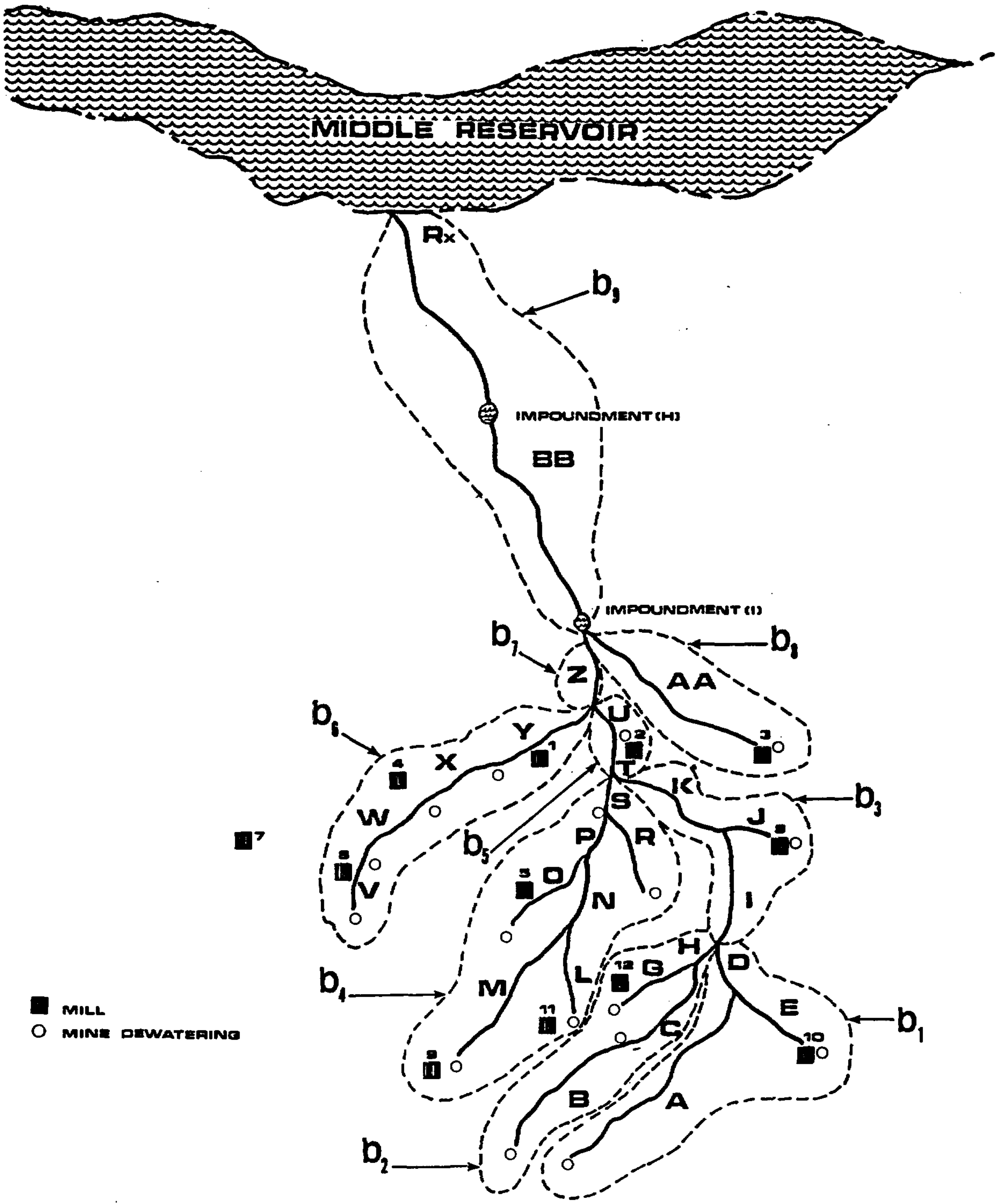

Fig. D.1. Principal Drainage Systems Affected by Mining and Milling Operations.

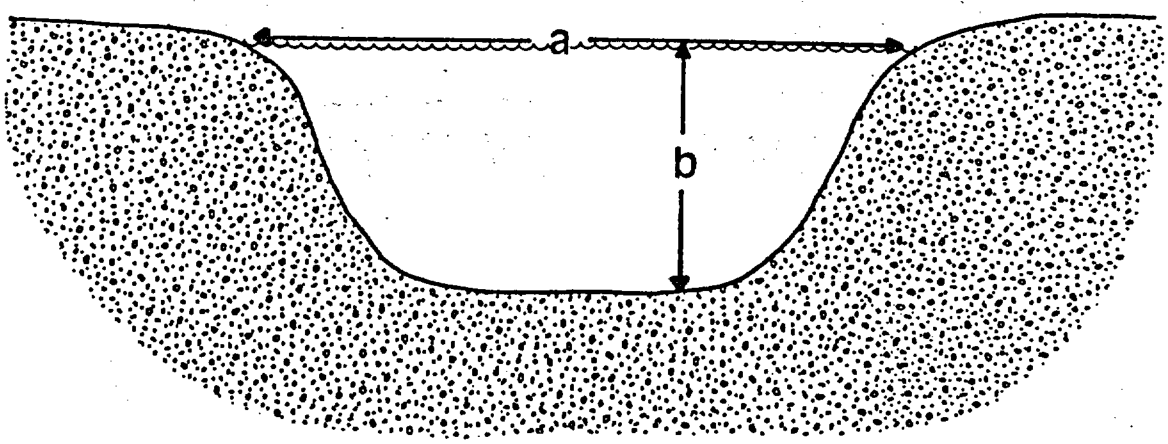

Fig. D.2. Stream Cross Section.

Then:

$$K = (K_h\ K_v)^{1/2} \tag{1}$$
$$= (10^{-2} \times 10^{-4})^{1/2}$$
$$= 10^{-3}\ \text{cm/s or } 6 \times 10^{-4}\ \text{m/min}$$
$$Q_L = (Q_S + Q_E)L \tag{2}$$
$$B = a + 2b \text{ (see Fig. D.2)} \tag{3}$$
$$Q_S = KB \tag{4}$$
$$Q_E = Ea \tag{5}$$
$$V = 36\ \text{m/min} \tag{6}$$
$$A = \frac{Q_{in}}{V} \tag{7}$$
$$A = a \times b \tag{8}$$

Assuming a ratio of $\frac{b}{a} = 0.01$ (9)

From (6) (7) (8):

$$a = \left(\frac{Q_{in}}{3.6}\right)^{1/2} \tag{10}$$

From (3) (9):

$$\therefore \quad B = 1.2a \tag{11}$$

From (2) (3) (4) (5):

$$Q_L = (1.2K + E)aL$$
$$= [1.2\ (6 \times 10^{-4}) + (4 \times 10^{-6})]aL$$
$$\therefore \quad Q_L = (7.24 \times 10^{-4})aL \tag{12}$$

By use of equations (10) and (12), Table D.1 is obtained for mine dewatering flows through the channel cross section shown in Figure D.2.

Table D.1. Results of Streamflow Calculations for Selected Stream Sections

Section[a]	Number of Mines	Section Length, meters L(m)	(D_{in})/Mine, 6 m^3/min	Total (Q_{in}), m^3/min	$a=\left(\frac{Q_{in}}{3.6}\right)^{1/2}$	Q_L = $(7.24 \times 10^{-4})aL$	$Q_{in}-Q_L$	Area Discharge, m^3/min
E	4	4,000	24	24.0	3.0	8.0	16.0	
A	1	12,000	6	6.0	1.3	11.2	6-11.2[b]	b_1=11.4
D	0	3,000	-	16.0	2.0	4.6	11.4	
B	1	8,000	6	6.0	3.0	17.4	6-17.4[b]	
C	3	3,000	18	18.0	2.2	5.0	13.0	b_2=17.5
G	2	3,000	12	12.0	1.8	4.0	8.0	
H	0	2,000	-	21.0	2.4	3.5	17.5	
I	0	3,000	-	18.0	2.2	4.8	12.7	
J	2	4,000	12	12.0	1.8	5.3	6.7	b_3=26.8
K	0	7,000	-	19.0	2.3	11.6	7.4	
L	2	3,000	12	12.0	1.8	3.9	8.1	
M	6	9,000	36	36.0	3.0	20.6	15.4	
N	0	4,000	-	23.5	2.6	7.4	16.1	
O	4	4,000	24	24.0	2.6	7.4	16.6	b_4=42.9
P	0	3,000	-	32.7	3.0	6.5	26.2	
R	2	4,000	12	12.0	1.8	5.2	6.8	
S	3	3,000	18	51.0	3.8	8.2	42.9	
T	0	2,000	-	42.9	3.5	5.0	3.9	b_5=50.2
U	3	2,000	18	55.9	3.9	5.7	50.2	
V	2	2,000	12	12.0	1.8	2.6	9.4	
W	3	5,000	18	27.4	2.8	10.1	17.3	b_6=69.8
X	3	5,000	18	35.3	3.1	11.2	24.1	
Y	1	5,000	6	30.1	2.9	10.5	19.6	
Z	0	4,000	-	69.8	4.4	12.8	57.0	b_7=57.0
AA	1	11,000	6	6.0	1.3	10.3	6-10.3[b]	b_8=0
BB	0	24,000	-	57.0	4.0	69.1	57.0-69.1[b]	b_9=0

[a]See Fig. D.1 for location of sections.

[b]Total loss by infiltration and evaporation exceeds input--no discharge from section.

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APPENDIX E. GROUNDWATER CONTAMINATION BY TAILINGS POND SEEPAGE

Contamination of groundwater by seepage from the model mill tailings pond is considered in this appendix. A geometric model is used to calculate the rate of seepage from the tailings impoundment (App. E-1); the downgradient groundwater velocity and dispersion of contaminants (App. E-2); and the concentrations of toxic contaminants at selected locations downgradient from the tailings impoundment (App. E-3).

Although there is considerable range in the hydrogeologic conditions that could be found at different uranium tailings pond sites, only typical values for such parameters as permeability, distribution coefficient, and porosity were chosen for the calculations herein. A sensitivity analysis showing the range of variation of these parameters and the resultant effects on environmental impacts is given in Chapter 6.

Groundwater impacts are largely site-specific, and there are few widely accepted models available to predict groundwater contamination. Although rigorous theoretical and computer models have recently been developed, the applicability of these models is generally unknown because of the lack of confirmatory field data. The analyses presented in this appendix involve determination of seepage rates and groundwater contamination through the use of fairly simple mathematic and geometric models. Readers are referred to a recent report relevant to this area (see R. Williams and M. Robinette, A Guide to the Prevention of Ground Water Contamination by Uranium Mill Waste Disposal Facilities, University of Idaho, September 1980), which is a revision of the basic mechanisms which control seepage and contaminant migration, as well as evaluates methods for determining suitability of sites from a groundwater protection point of view.

APPENDIX E-1. CALCULATION OF SEEPAGE DISCHARGE FROM AN UNLINED TAILINGS POND*

When a uranium mill tailings pond is operational, seepage can be calculated as the difference between the net liquid inflow from the mill and evaporation, with the latter estimated by using pan evaporation data in conjunction with the area of the tailings pond.[1] The area through which seepage will occur is not known. Seepage can be estimated, however, by a method involving establishment of a hydrologic budget for the tailings area, and the seepage and resulting pond size are dependent upon subsoil permeability.[2]

The water budget for the model mill tailings pond can be expressed as:

$$Q_{in} = Q_{out} + Q_{entr} \tag{1}$$

where Q_{in} is the rate of water discharge into the pond, Q_{out} is the rate of water discharge out of the pond, and Q_{entr} is the rate of consumption of water that is permanently entrained in the tailings material.

Q_{in} is the sum of the net inflow from the mill (Q_{mill} = 1260 m^3/day = 4.60 × 10^5 m^3/yr) and precipitation (Q_{ppt}). The average annual precipitation is 31 cm, and it is assumed that all of the precipitation that falls on the surface area within the centerline of the embankment (roughly 90 ha) contributes to the water in the pond. Thus Q_{ppt} = 2.79 × 10^5 m^3/yr. (This is a maximum because some precipitation is expected to evaporate directly from the dry dike or tailings.)

Q_{entr} can be expressed as a discharge and is determined from consideration of the tailings porosity and rate of tailings discharge. The in-place dry density of tailings is 1.6 g/cc. Assuming that the specific gravity of the solid (sand) particles is 2.65, then 1.6/2.65 = 60% of the volume of tailings consists of tailings particles (sand) and 40% is void space. Therefore, one cubic centimeter of saturated tailings contains 0.40 g of water and 1.6 g of sand, or 20% water by weight. If the rate of dry tailings production is 1800 MT/day (6.57 × 10^5 MT/yr), then the rate of water consumption by entrainment in the tailings would be 1.64 × 10^5 MT/year if the pores were completely saturated. Shortly after cessation of mill operation, gravitational water in the tailings can be expected to drain out, leaving only hygroscopic and capillary water held as thin films on the soil particles.[3] On the basis of published data for the "specific retention" of water in unconsolidated deposits of the grain size typically found in tailings (fine sand),[4] 60% (0.98 × 10^5 MT/yr) of the water in the pores can be expected to drain out, leaving 40% (Q_{entr} = 0.66 × 10^5 MT/yr, or 0.66 × 10^5 m^3/yr) entrained in the tailings. Although all of the 0.98 × 10^5 MT/year would not drain out until cessation of the mill operation, for simplicity of calculations it is assumed to contribute to seepage during operation. The overall long-term seepage volume would be the same.

Q_{out} is the sum of seepage discharge (Q_{seep}) and evaporation rate (Q_{evap}), which are interdependent variables. Both are related to the evaporation area (A_e), which includes both the water surface and the wetted sands from which evaporation occurs (Fig. E-1.1). Q_{evap} is equal to unit evaporation ($Q_{unit\ evap}$) times the area over which evaporation occurs (A_e). Q_{seep} is equal to the unit seepage ($Q_{unit\ seep}$) times the area over which seepage occurs (A_s). A_s will be somewhat larger than A_e, but is difficult to establish because of unknown tailings parameters. If the permeability of the tailings is infinite, seepage occurs from the entire pond bottom, i.e., $A_s \sim 80$ ha. The possible range of β, where $\beta = A_s/A_e$, is shown in Figure E-1.2. During the initial years of operation, β nearly equals 1. β reaches a maximum of 3.2 when the tailings impoundment is nearly full. The values of A_s and A_e shown on Figure E-1.2 were calculated from a water balance, an example of which is given below. In view of the probable range of vertical and horizontal permeability of the tailings and the range in geometric possibilities that could occur during the 15 years of operation, it is assumed that β = 2, or $A_s = 2A_e$. Equation (1) thus can be written:

$$Q_{ppt} + Q_{mill} = Q_{entr} + Q_{unit\ evap}(A_e) + Q_{unit\ seep}(A_s) \tag{2}$$

*For simplification, SI units only are used in the appendix. Calculations show two or three significant figures to enable the reader to follow more easily. Ordinarily, geologic parameters are too uncertain to justify this degree of accuracy.

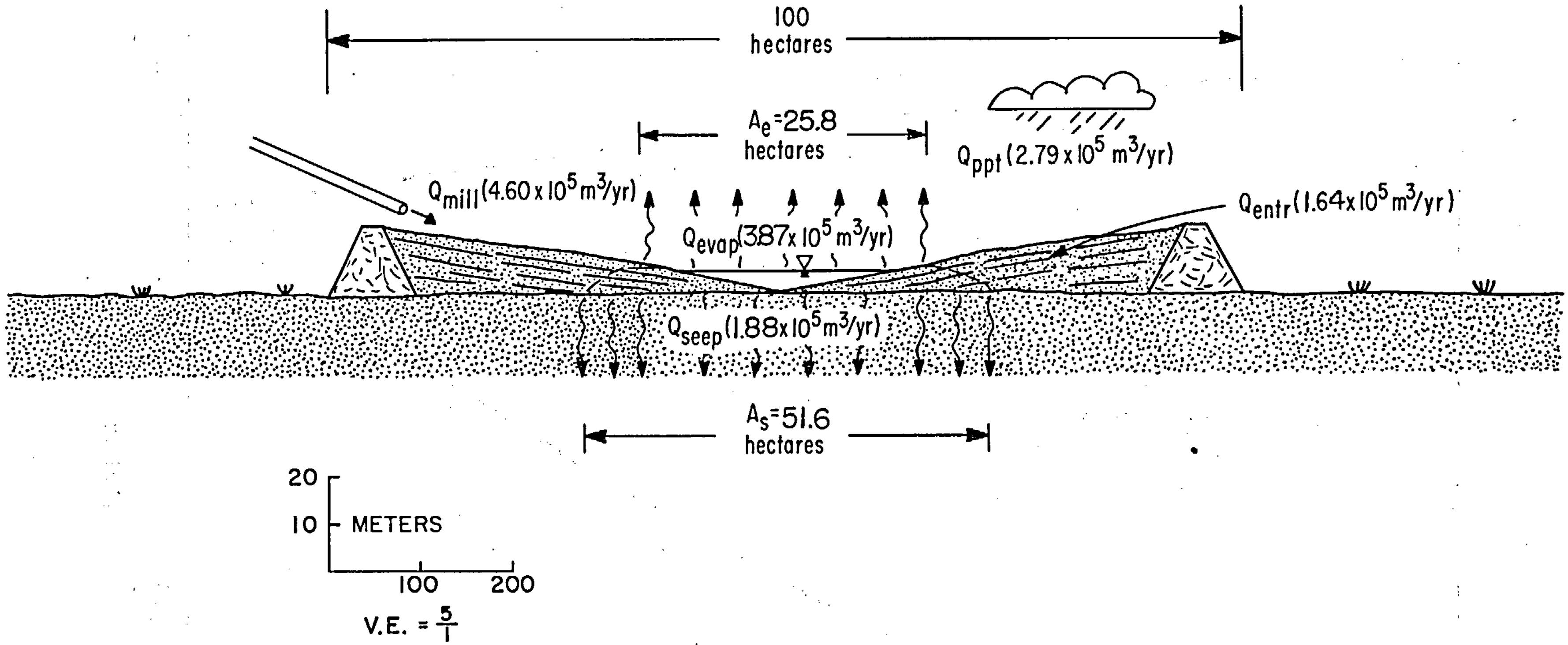

Fig. E-1.1. Water Budget for Tailings Pond Area.

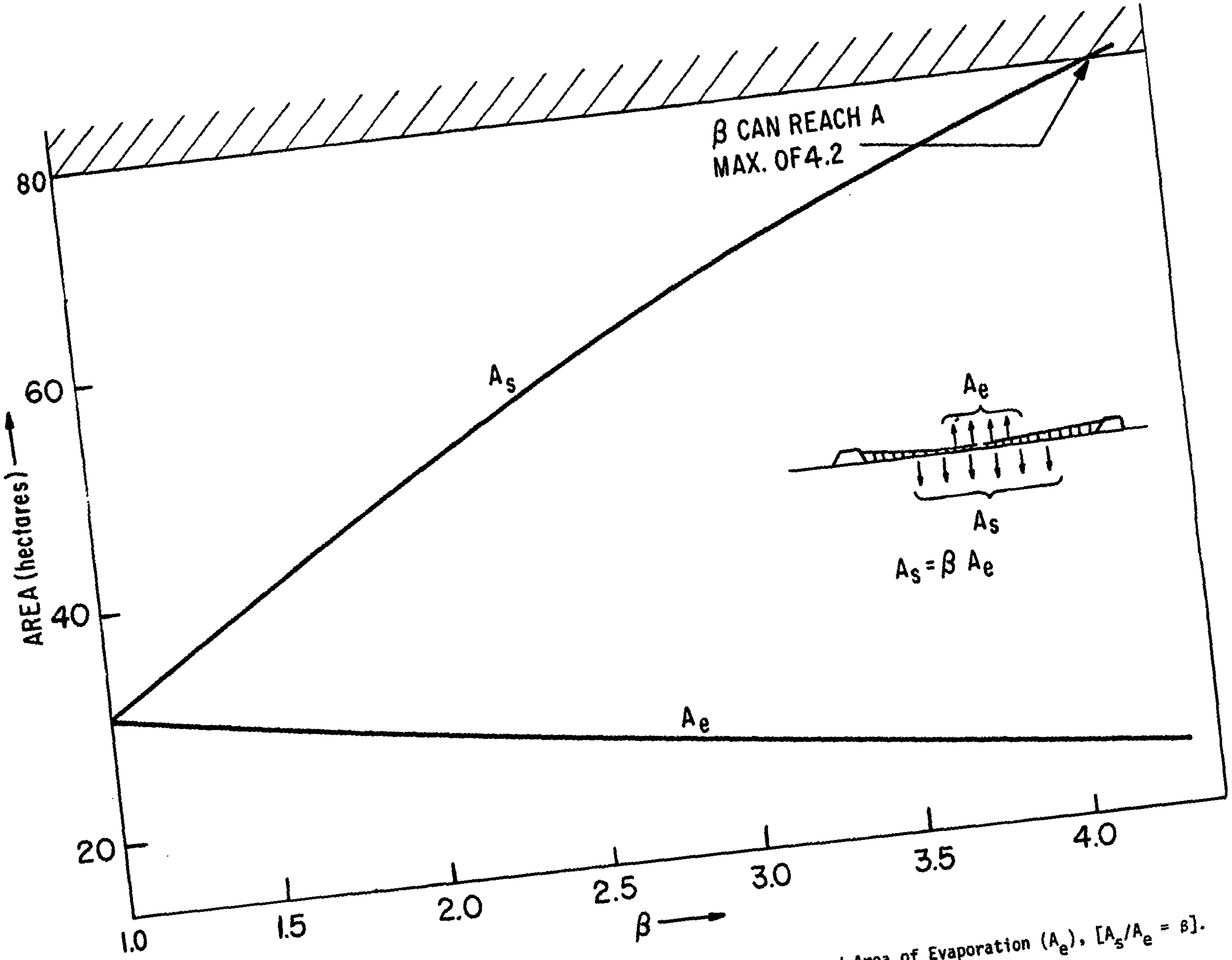

Fig. E-1.2. Potential Range of Relationship between Area of Seepage (A_s) and Area of Evaporation (A_e), [$A_s/A_e = \beta$].

Substituting known quantities and substituting for A_S:

$$2.79 \times 10^5\ m^3/yr + 4.60 \times 10^5\ m^3/yr = 0.66 \times 10^5\ m^3/yr + Q_{unit\ evap}(A_e) + Q_{unit\ seep}(2A_e)$$

$$A_e = \frac{6.73 \times 10^5\ m^3/yr}{Q_{unit\ evap} + 2 \times Q_{unit\ seep}} \qquad (3)$$

$Q_{unit\ evap}$ can be determined from published data for reservoir evaporation rates. For the model mill the average evaporation from the surface of a body of water is assumed to be 1.5 m/yr. Therefore $Q_{unit\ evap} = 1.5 \times 10^4\ m^3/yr\text{-}ha$.

$Q_{unit\ seep}$ can be calculated from Darcy's Law:

$$Q = KA\frac{H}{L} \qquad (4)$$

where

Q = Discharge through porous media.

K = Permeability. This parameter is difficult to quantify in the field and has a wide range of values for the great diversity of rocks found in nature. Permeability (more properly called hydraulic conductivity) is a constant in the zone of saturation. Based on pump tests and published data for alluvial sediments similar to those assumed to be found in the area of the model mill, the horizontal hydraulic conductivity (K_h) of the saturated subsoil is here taken to be 10^{-2} cm/sec.[4-10] Based on published reports, the vertical hydraulic conductivity (K_v) appropriate for this seepage prediction is assumed to be 0.1% of the horizontal hydraulic conductivity.[4,10-12] Because the water table is initially 25 m below the bottom of the tailings pond area, the subsoil immediately below the impoundment is not saturated. It is known that the hydraulic conductivity of unsaturated soil varies with moisture content.[13-16] For instance, when soil is 50% saturated, it may be only 6% as permeable as when saturated.[2] It is beyond the scope of this document to assess a year-by-year rate of infiltration due to an advancing saturation front; therefore, for simplicity it is assumed that the average hydraulic conductivity in the range of moisture contents likely to be encountered during the operation of a tailings pond area is about 10% of the saturated hydraulic conductivity. Consequently, for the purpose of calculating the seepage using equation (4), the vertical unsaturated hydraulic conductivity equals 10^{-6} cm/sec.

A = Cross-sectional area (1 ha).

H = Head loss. It is assumed that the saturated tailings and overlying free-water level averages 4 m deep over the life of the project; therefore, the change in head over the 25 m of unsaturated thickness of subsoil below the tailings pond area is 29 m.

L = Thickness of deposit. For these calculations, only the 25-m thickness of unsaturated subsoil immediately below the tailings pond area is considered.

Substituting into equation (4):

$$Q_{unit\ seep} = (10^{-6}\ cm/sec)\ (1\ ha)\ \left(\frac{29\ m}{25\ m}\right)$$

$$= 3.65 \times 10^3\ m^3/yr\text{-}ha$$

Substituting the values of $Q_{unit\ seep}$ and $Q_{unit\ evap}$ into equation (3):

$$A_e = \frac{6.73 \times 10^5\ m^3/yr}{1.5 \times 10^4\ m^3/yr\text{-}ha + 2(0.365 \times 10^4\ m^3/yr\text{-}ha)}$$

$$= 30.2\ ha$$

It is assumed that the area from which evaporation occurs ($\approx$ 30 ha) consists of approximately 20 ha of open water and 10 ha of wetted sand. Examination of aerial photographs indicates that these are reasonable values for active tailings impoundments. Since $Q_{unit\ evap} = 1.5 \times 10^4\ m^3/yr\text{-}ha$, the total evaporation on 30.2 ha is $4.53 \times 10^5\ m^3/yr$.

The seepage area $A_S = 2A_e = 60.4$ ha; since $Q_{unit\ seep} = 3.65 \times 10^3\ m^3/yr\text{-}ha$, the total seepage from 60.4 ha is $2.20 \times 10^5\ m^3/yr$.

In summary, the water budget for the tailings pond area (shown on Fig. E-1.1) can be written as:

$$Q_{ppt} + Q_{mill} = Q_{entr} + Q_{evap} + Q_{seep}$$

$$2.79 \times 10^5\ m^3/yr + 4.60 \times 10^5\ m^3/yr = 0.66 \times 10^5\ m^3/yr + 4.53 \times 10^5\ m^3/yr + 2.20 \times 10^5\ m^3/yr$$

Not taken into account in these calculations are such complex phenomena as the possible reduction in seepage because of the buildup of slimes and because of chemical reactions associated with seeping acidic solutions. Nevertheless, the characteristic features of existing uranium tailings ponds seems to confirm the assumptions and calculations used in this analysis.

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APPENDIX E-2. CALCULATION OF SEEPAGE WATER VELOCITIES IN THE SUBSOIL

In Appendix E-1 it was shown that liquid from the tailings pond area at the model mill would seep downward at a discharge rate of 2.2×10^5 m^3/yr. The subsoil consists of a 125-m-thick deposit of relatively permeable alluvium. Seepage water is not expected to enter the relatively impermeable Triassic siltstone bedrock below the subsoil. The seepage water travels in two subsoil environments: (a) the unsaturated subsoil directly beneath the tailings pond area, and (b) the saturated subsoil below the water table. At the start of operations, the water table (25 m below the surface) will be nearly level, sloping at about 2.5 m/km (0.0025) toward the north (Fig. E-2.1). With high seepage rates into subsoils of low permeability, the water table could rise under the tailings pond area, forming a groundwater "mound." The shape of this mound can be predicted by various mathematical techniques,[1-3] and for the model mill the staff has calculated that because of the permeability of the subsoil, the rising water-table mound will not reach the bottom of the tailings during the 15-year life of the mill and will subside after discharge of tailings to the impoundment ceases.

1. VELOCITY OF SEEPAGE WATER IN UNSATURATED ZONE

The Darcy Law velocity (V_d) in the 25 m of unsaturated subsoil equals the vertical partially saturated hydraulic conductivity ($K = 10^{-6}$ cm/sec = 0.315 m/yr; see App. E-1) times the hydraulic gradient (H/L):

$$\begin{aligned} V_d &= KH/L \\ &= 0.315 \text{ m/yr } (29 \text{ m}/25 \text{ m}) \\ &= 0.365 \text{ m/yr} \end{aligned} \qquad (1)$$

The actual velocity of the seepage water (V_s) equals V_d divided by the effective porosity (N_e). Based on typical values of specific yield of silty sandy alluvium,[4] N_e is assumed to be 10%:

$$\begin{aligned} V_s &= V_d/N_e \\ &= (0.365 \text{ m/yr})/0.10 \\ &= 3.65 \text{ m/yr} \end{aligned} \qquad (2)$$

It can be seen that seepage water first reaches the water table in 6.85 years [25 m/(3.65 m/yr)].

It is assumed that in addition to the 2.2×10^5 m^3/yr seepage to groundwater, after one year of operation a small seep develops on the outside edge of the northern side of the tailings dam (see Fig. E-2.1). The seep is caused by leakage through a thin layer of permeable gravel that allows for piping of tailings water under the dam. Based on field observations, the rate of seepage is assumed to be less than 3.2×10^3 m^3/yr (0.1 L/s).

2. VELOCITY OF SEEPAGE WATER IN SATURATED ZONE

Taken into account in the model adopted by the staff for these calculations are two groundwater flow regimes that determine the velocity and disposition of seepage water in the saturated zone: (a) radial forced velocity, and (b) aquifer velocity.[5] The radial forced velocity is determined by the flow pattern of the seepage water, typically expanding downward and outward from the place of origin. The aquifer velocity, or regional downgradient flow rate of natural groundwater, is determined by the subsoil permeability and hydraulic gradient. For the characteristics assumed for the model mill, seepage discharge into the saturated subsoil is fairly substantial (2.2×10^5 m^3/yr); the seepage therefore will displace some of the natural groundwater for a time and then will be swept downgradient.

The geometry of the bulb of seepage water that expands radially in the zone of saturation below the tailings pond is calculated in the following paragraphs. It is assumed that the bulb expands until it reaches a subsoil cross-sectional area normal to the regional groundwater gradient that is equal to a cross-sectional area carrying an equivalent natural discharge in the subsoil. When this is achieved, radial expansion ceases, and the seepage water bulb begins to be carried downgradient.

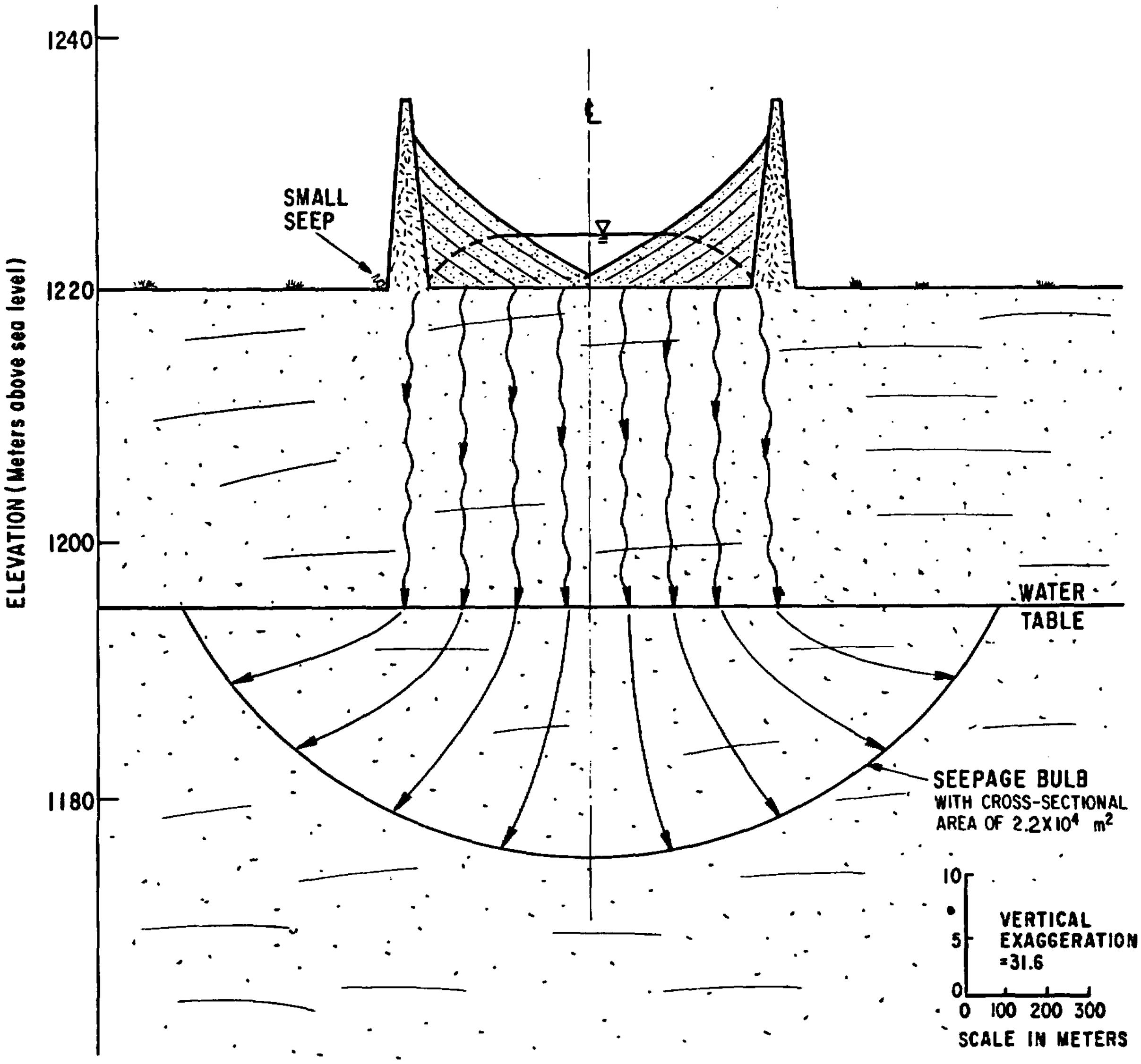

Fig. E-2.1. Transverse Section of Seepage Water.

Not all quantitative models for tailings pond seepage and dispersion in groundwater are universally applicable, but there is both theoretical and field confirmation of the model described above. Examples of groundwater contamination flowing radially and then downgradient in the manner used in this model have been found at a thorium tailings area near Chicago,[6] at the Idaho National Engineering Laboratory (formerly the National Reactor Test Station),[7] at a uranium tailings pile in Wyoming,[8] at a chromium waste dump in Michigan,[9] and at other places.[5,10]

Figure E-2.1 is a cross section of the tailings impoundment area. The pond (A_e = 30.2 ha) is assumed to be circular in outline and to be situated in the center of the tailings impoundment. The seepage area (A_s = 60.4 ha) also is assumed to be circular in outline and hence has a radius of 438 m. It is assumed that during the 15 years of mill operation the seepage water enters the subsoil through the 438-m-radius cylinder in the unsaturated zone and intercepts and displaces the natural flow of groundwater passing below the tailings pond area in the saturated zone.

The staff has determined through the following calculations, modified from a method of determining spread of contaminants from a point source of contamination in the saturated zone,[11] the rate and geometry of the seepage bulb as it enters the zone of saturation. From equation (1) in Appendix E-1, it follows that the natural groundwater discharge through the subsoil deposit equals the saturated horizontal permeability ($K_h = 10^{-2}$ cm/sec = 3150 m/yr) times the slope of the water table (H/L = 0.0025) times the subsoil cross-sectional area (A). The cross-sectional area through which a discharge of 2.2×10^5 m³/yr occurs can be calculated as follows:

$$Q = K_h \times A \times (H/L) \qquad (3)$$
$$2.2 \times 10^5 \text{ m}^3/\text{yr} = (3150 \text{ m/yr})\ (A)\ (0.0025)$$
$$A = 2.8 \times 10^4 \text{ m}^2$$

If this cross-sectional area includes the entire 100-m-thick saturated subsoil zone and if the area is rectangular in shape, the width will be 280 m. However, the actual shape of the cross-sectional area will be influenced by the seepage area (A_s = 60 ha) and the subsoil anisotropy. Figure E-2.1 is a graphical solution for the shape of the cross-sectional area.

The calculation of the shape of the seepage bulb in the saturated zone can be refined by taking into account the K_h/K_v ratio for the subsoil, which is 1000. A flow net using isotropic media constructed with vertical exaggeration = $\sqrt{K_h/K_v} = \sqrt{1000/1}$ = 31.6 will correct this anistrophy.[4,12] For this reason, Figure E-2.1 has a vertical exaggeration of 31.6. Evenly spaced, radially expanding flow lines were drawn, taking into consideration the seepage area (A_s = 60 ha), until a bulb cross section equal to 2.8×10^4 m² was reached. It is assumed that the 2.8×10^4 m² cross-sectional bulb shown in Figure E-2.1 expands radially. The volume of the bulb would thus be 3.3×10^7 m³. When the expanding seepage bulb reaches this volume it will be swept downgradient. It is assumed that density contrasts between the seepage water and the natural groundwater are small, and therefore the seepage geometry is not affected by density gradients.

The rate of seepage is 2.2×10^5 m³/yr, which would produce a water volume of 3.3×10^6 m³ in 15 years. Since the subsoil effective porosity (N_e) is 10%, the volume of aquifer saturated in 15 years will be 3.3×10^7 m³. This is coincidently exactly the same value as the seepage bulb described above. As shown on Figure E-2.1, the maximum horizontal extent of seepage water is 1000 m from the center of the tailings pond. The contaminants are confined to the upper 20 m of the zone of saturation. After spreading to the bulb shape shown on Figure E-2.1, seepage water drifts downgradient with the regional groundwater flow.

3. DOWNGRADIENT MOVEMENT AND DISPERSION OF SEEPAGE WATER

It is assumed that after 22 years the seepage water drifts downgradient with the natural groundwater. It is further assumed that prior to this time longitudinal dispersion occurs, and the seepage water is diluted accordingly. A simple mathematical model can be used to determine the rate of longitudinal dispersal. Methods of analyzing dilution and chemical changes accompanying dispersion are presented in Appendix E-3.

The horizontal hydraulic conductivity (K_h) of the subsoil is 10^{-2} cm/sec (3150 m/yr). The slope of the water table (H/L) is 0.0025; therefore, the average downgradient seepage velocity (V_s) of the slug of contaminants can be calculated by first solving for the Darcy Law Velocity [Eq. (1)]:

$$V_d = K_h\ (H/L)$$
$$= (3150 \text{ m/yr})\ (0.0025)$$
$$= 7.9 \text{ m/yr}$$

This value is then substituted in equation (2):

$$V_s = V_d/N_e$$
$$= (7.9\ m/yr)/(0.10)$$
$$= 79\ m/yr$$

If no longitudinal dispersion occurs, the seepage water bulb would move downgradient at a velocity of 79 m/yr.

Because the alluvial subsoil consists of units of varying permeability, water will move more rapidly in some units than in others, resulting in longitudinal dispersion of seepage water. It is assumed that the "longitudinal dispersivity" (a_I) equals 5 m, based on data from the literature.[5,13-15] The "longitudinal dispersion coefficient" (K_L) is equal to a_I times the velocity of groundwater (V_s):

$$K_L = V_s \times a_I \qquad (4)$$
$$= (79\ m/yr)\ (5\ m)$$
$$= 395\ m^2/yr$$

Times of arrival of seepage water at various distances are shown by "breakthrough curve" concentration plots. Because the reverse S-shaped curves are essentially cumulative normal (Gaussian) curves, the standard deviation (σ) is defined as the spread between the 50% and the 16% or 84% value. The longitudinal dispersion coefficient is related to the standard deviation and time (t) as follows:[5]

$$\sigma = (2\ K_L\ t)^{1/2} \qquad (5)$$

Tailings pond seepage water breakthrough curves for 1, 2, 3, 4, 5, 10, 20, 50, 100, 200, 500 and 1000 years for locations directly downgradient are shown in Figure E-2.2. (It should be pointed out that year 0 on Fig. E-2.2 is actually the 22nd year after the start of mill operations.)

It is assumed that no lateral or vertical dispersion occurs beyond the 2000-m-wide bulb and 20-m-thick zone described above. Limited experimental data available in the literature suggest that the transverse dispersion coefficient (K_T) is much less than the longitudinal dispersion coefficient (K_L).[16] Lateral or vertical dispersion would not change the rate of downgradient movement of contaminants, but would spread those contaminants over a wider and deeper belt, allowing for greater mixing and dilution. Therefore, if such dispersion were to occur, the concentration of contaminants would be decreased. The total contaminant release and rate of release into Middle Reservoir, however, do not depend upon lateral or vertical dispersion.

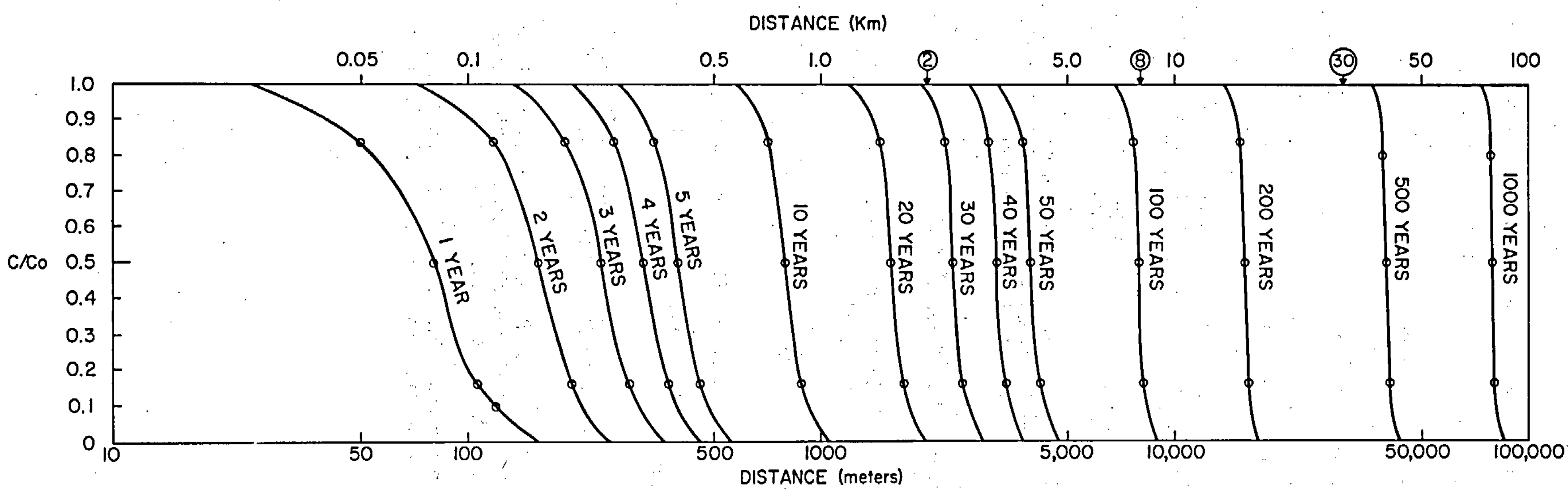

Fig. E-2.2. Breakthrough Curves. (All times shown are years after downgradient movement began, approximately 22 years after start of mill operations. All distances shown are distance downgradient from 1000 m north of the center of the tailings impoundment area, or 500 m north of the northern edge of the impoundment.)

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APPENDIX E-3. CALCULATION OF CHEMISTRY OF SEEPAGE WATER

1. GENERAL THEORY OF DISPERSION*,[1]

Dissolved ions (solutes) may be readily soluble and transported by virtue of the fact that the transporting groundwater (solvent) is free and slowly moving through the subsoil.[2] In addition to this slug-like transportation, other natural phenomena cause movement of solutes relative to the transporting solution. These phenomena are often collectively entitled "dispersion," and include: (1) (molecular) diffusion, (2) hydrodynamic (mechanical) dispersion, and (3) (chemical) sorption.

1.1 Diffusion

The diffusion process is best illustrated by considering gases, which quickly mix with each other in proportion to their molecular weight. An unequal distribution of solutes in a limited volume of water (e.g., salt water placed into a bathtub full of fresh water) will also diffuse at a molecular level. Examples of groundwater diffusion are shown in studies using dye and other tracers and saltwater/freshwater interfaces.

1.2 Hydrodynamic Dispersion

In 1905 Slichter injected a salt solution into a well and noted the time of arrival at a nearby observation well.[3] He observed that the salt did not arrive at the observation well as a slug, but that instead the salt concentration gradually increased to some maximum value. This mixing is greater than can be accounted for by molecular diffusion, and Schleidegger called it "dispersion."[4] Recent studies indicate that the mixing of miscible fluids in porous media is dependent upon the flow characteristics, which in turn are influenced by the geometry of the deposits.[5] Individual fluid particles travel at variable velocities through the irregularly shaped pore channels of the medium, resulting in a variation of concentration of the displacing fluid in the dispersion zone.[6] Ogata states that macroscopic variations, such as a sand lens, may have marked effects on dispersion, but these variations are virtually impossible to quantify.[7] The rate at which solutes may hydrodynamically (mechanically) disperse in an aquifer may be due to stratigraphic inhomogeneities or anisotropies. If, for example, an aquifer consists of linear or gently sinusoidal, highly permeable channel deposits oriented at an angle to the general dip of potentiometric surface, a greater dispersal could be expected laterally than if the channels are parallel to the dip of the potentiometric surface. Hydrodynamic dispersal can occur along faults, cavernous zones, and other geologic features, and can occur in vertical and horizontal directions.

1.3 Sorption

Chemical processes can affect the rate at which solutes are transported by the solvent. Ion exchange is a well-known phenomenon utilized in water softeners whereby dissolved high-valence solute cations, such as calcium or magnesium, replace sodium or potassium cations (which commonly occur in clay minerals). Robinson, who wrote a review of the principles of ion-exchange processes and their roles in the disposal of high-level radioactive wastes, states that clay minerals (e.g., montmorillonite and vermiculite) and zeolites have high exchange capacities, and points out that high-valence cations with high atomic weight have great replacing power.[8]

The "distribution coefficient", or "adsorption coefficient" (K_d) is a laboratory determination of the amount of solute left on a soil sample after it has been mixed and allowed to reach equilibrium with the soil:[9]

$$K_d = \bar{C}/C \qquad (1)$$

*This introduction to the principles of dispersion is presented as an aid to understanding of the subsequent assessment of the movement of contaminants in tailings seepage. A recent book by Fried provides more detailed information on this subject.[1]

where $\bar{C}$ = concentration sorbed per gram of soil

C = equilibrium concentration in external waste solution.

If $K_d = 0$, there is no sorption whatsoever; this is commonly the case with anionic solutes such as sulfate and chloride, and is the reason why these anions are good groundwater tracers.

There is no accepted theory of solute movement encompassing all of the above phenomena of dispersal that can be used to predict the time rate of change in concentration (i.e., dilution) of a solute. Existing theories of dispersive mechanisms can be divided into two general categories: (1) those which consider only solid phase sorption as a dispersive mechanism, and (2) those which consider convection, diffusion, hydrodynamic dispersion, and solid phase sorption.[10]

- Theories Using Only Solid Phase Sorption - A one-dimensional laboratory study of sorption, determined by a soil column or by shaking a solution with soil, can be extrapolated to predict the amount of sorption likely to occur in the field. The velocity of the ion transport in the field can be predicted using the formula developed by Hajek:[9]

$$v_i = \frac{v}{1 + \frac{K_d B_d}{\theta}} \qquad (2)$$

where v_i = ion velocity

v = solution velocity

K_d = distribution coefficient

B_d = bulk density

θ = volumetric moisture content

Convection, hydrodynamic dispersion, and diffusion are not accounted for in equation (2); the seeping water is assumed to move straight down in a column.

- Theories Using Convection, Diffusion, Hydrodynamic Dispersion, and Solid Phase Sorption - A special mathematical solution utilizing the error function is commonly used to describe a limited system of these phenomena. The following equation predicts the time rate of change in the concentration of a solute some distance from point of injection:[10]

$$C/C_0 = 1/2\left[1 - \text{erf}\left(\frac{x - V_x \cdot t/a}{2\sqrt{D_m \cdot t/a}}\right)\right] \qquad (3)$$

where $a = 1 + \frac{B_d \cdot K_d}{\theta}$

C = effluent concentration of solute

C_0 = influent concentration of solute

θ = pore fraction of exchanger

K_d = distribution coefficient

D_m = dispersion coefficient

V_x = solution velocity

x = distance from influent end of the column

t = elapsed time

erf (x) = error function of $x = \frac{2}{\sqrt{\pi}} \int_0^x e^{-t^2} dt.$

This function shows that the solute concentration is very weak at first, then increases rapidly before a final slow approach to the injection concentration.

In arriving at equation (3) it is assumed that: (1) the dispersion coefficient (D_m) accounts for both hydrodynamic dispersion and diffusion, (2) the porosity, permeability, and distribution coefficients of the exchange are constant, (3) equilibrium has been attained, and (4) the flow rate is constant.[10] In a natural system these assumptions are not valid, and thus the movement of solutes predicted by this theory is questionable. Pinder, for example, attempted to predict groundwater contamination in Long Island and reported values of the dispersion coefficient that were orders of magnitude larger than values obtained for flow in isotropic porous-medium models in the laboratory.[11]

Field confirmation of dispersion is at best qualitative in nature. A literature search of field studies of groundwater contamination reveals numerous instances where a particular toxic substance may have been found in a well or goundwaters.[12-15] Often these references illustrate some obvious contamination from some specific source, such as gasoline pipeline rupture, injection wells in cavernous rock, or highway salt stockpile.

There is very extensive literature on mathmatical modeling of solute movement and dispersion phenomena,[16-23] and there are studies on the prediction of movement of absorbed chemicals, including trace elements.[24-26] Most of these studies are site-specific, such as the transfer of boron and tritium through cores of sandstone from New Mexico,[27] or the sorption of molybenum by alpine and desert soils from Colorado and Arizona.[28] Borg and others have prepared through analyses of radionuclide sorption data in the literature and show that the distribution coefficient for cesium may range through six orders of magnitude.[29] Trace element mobility was recently studied in the leachate from ash generated from five coal-fired electric generating stations.[30] It was found that in general, fluorine, chomium, and selenium had low distribution coefficients; however, the range of distribution coefficients for any element was great, e.g., chromium ranged from 0 to 550. Thus, it would be difficult to predict the general mobility of chromium without detailed site-specified data. Chromium is known to have contaminated groundwater in Long Island, where up to 17 ppm of hexavalent chromium, apparently originating at a chemical plant, was found in water from municipal wells.[31] Chromium and tritium plumes about 6 km long have been observed at the Idaho National Engineering Laboratory (formerly the National Reactor Testing Station).[1] Distribution coefficients have been calculated for elements found in the tailings liquid at the Split Rock uranium mill site in Wyoming.[32]

In summary, a survey of the literature indicates that there are many specific instances of groundwater contamination, and there are many general theories and mathematical models used to explain the movement and dispersion of toxic elements or tracers in groundwater. In this attempt to predict the movement of contaminants at the model mill (for which background data on on such parameters as permeability, sorption, and dispersivity are arbitrary, although based on the best of the meager data in the literature) recourse to elaborate mathematical models seems inappropriate. Therefore, only basic mathematical assumptions and the construction of a simple geometric model as shown in Appendices E-1 and E-2 are used in this analysis of the extent of groundwater contamination.

Two of these assumptions merit brief discussion. First, the soil is assumed to be homogeneous, with respect to horizontal permeability, vertical permeability, and chemical composition. Fissures, clay caps, and lenses of high permeability could alter the results of the chemical transport analysis. Specifically, the acid front and the acid-soluble chemical constituents dissolved there would be expected to travel farther from the point of contaminant release than is projected below. The presence or absence of such subsurface features must be determined at each individual site, using a comprehensive program of data collection. Secondly, the soil was assumed to be an inorganic type, and to constitute an oxidizing environment. The presence of black shales or other materials with high organic content could produce a reducing environment in which certain elements such as arsenic, selenium, uranium, and molybdenum would be precipitated closer to the point of release than is projected below. As before, the determination of chemical soil properties requires a site-specific investigation.

2. ANALYSIS OF MODEL MILL SITE

In Table E-3.1 are shown the expected concentrations of dissolved substances contained in the tailings pond water at the model mill (Column A) and the maximum permissible concentrations (MPC) established by the U. S. Public Health Service, as modified by the U. S. Environmental Protection Agency in 1975 (Column C). It was shown in Appendix E-1 that the evaporation rate ($Q_{evap} = 4.53 \times 10^5$ m^3/yr) is greater than the precipitation rate ($Q_{ppt} = 2.79 \times 10^5$ m^3/yr). Therefore, there is a deficit of 1.74×10^5 m^3/yr of pure water, and the concentration of dissolved substances in the mill discharge ($Q_{mill} = 4.60 \times 10^5$ m^3/yr) become increased by a factor of about 1.6 [(4.60-174)/460] in the residual tailings pond liquid (see Column B). The ratios of Column B to Column C are given in Column D, and this information indicates that the water is acidic and that concentrations of iron, manganese, sulfate, selenium, radium, thorium, lead, and other trace metals are high. In addition to the substances listed in Table E-3.1, which are contaminants commonly found in uranium tailings pond water, there may be other trace metals in a specific ore which could be present in the tailings pond liquid, such as boron, barium, or chromium.

It was shown in Appendices E-1 and E-2 that 2.2×10^5 m^3/yr of tailings pond seepage water flows downgradient (to the north) through the top 20-m portion of the 100-m-thick saturated portion of the alluvial subsoil about 2000 m wide. The downgradient rate of movement and the resulting spread of concentration of dissolved ions are described in Appendix E-2. "Breakthrough curves" were plotted (Fig. E-2.2) to show the concentration (C) for a substance in terms of its original

Table E-3.1. Chemistry of Tailings Pond Liquid

	Column A Mill Effluent Liquid Waste Concentration (mg/L unless otherwise specified)	Column B Column A times 160%	Column C USPHS-USEPA Max. Perm. Concentration (mg/L unless otherwise specified)	Column D Ratio of Column B/ Column C
Al	2,000	3,200	(no limit)	--
As	0.2	0.32	0.05	6.4
Ca	500	800	200	4
Cd	0.2	0.32	0.01	32
Cl	300	480	250	1.9
Cu	50	80	1	80
F	5	8	1.4-2.4	∿ 4.2
Fe	1,000	1,600	0.3	5,333
Hg	0.07	0.11	0.005	22
Mo	100	160	(no limit)	--
Mn	500	800	0.05	16,000
Na	500	800	200	4
NH_4	500	800	(no limit)	--
Pb	7	11	0.05	220
Se	20	32	0.01	3,200
SO_4	30,000	48,000	250	192
V	0.1	0.16	0.1	1.6
Zn	80	128	5	25.6
TDS	35,000	56,000	500	112
pH (units)	2	1.9	6-9	--
U-nat (pCi/L)	3,400	5,400	550	9.8
Ra-226 (pCi/L)	250	400	5	80
Th-230 (pCi/L)	90,000	150,000	2,000	75
Pb-210 (pCi/L)	250	400	100	4.0
Po-210 (pCi/L)	250	400	700	0.6
Bi-210 (pCi/L)	250	400	400	1.0

concentration (C_0) for a wide range of distances downgradient from the center of the tailings pond area. In general the C_0 values are given in Column B in Table E-3.1, but those values must be modified by changing pH and other factors as discussed below. Continual seepage input is traditionally assumed for breakthrough curves; however, in this case seepage from the tailings pond ceases after 15 years, and thus breakthrough curves (Fig. E-2.2) of background groundwater quality would follow 15 years behind the contaminant curves shown on Figure E-3.1. C/C_0 histogram plots are shown on Figure E-3.1 for distances of 2, 8, and 30 km downgradient, and take into account the 15-year total life of the project and the return to background water quality. It was assumed in Appendix E-2 that no lateral or vertical dispersion occurs, but since some such dispersion is to be expected in a natural system, some additional dilution, beyond that assumed, will actually be achieved. For this reason, the peak C/C_0 values would not be quite as high as shown by the three histograms of Figure E-3.1. The 2-km and 8-km histograms would not change appreciably, but the 30-km histogram would have a lower C/C_0 peak.

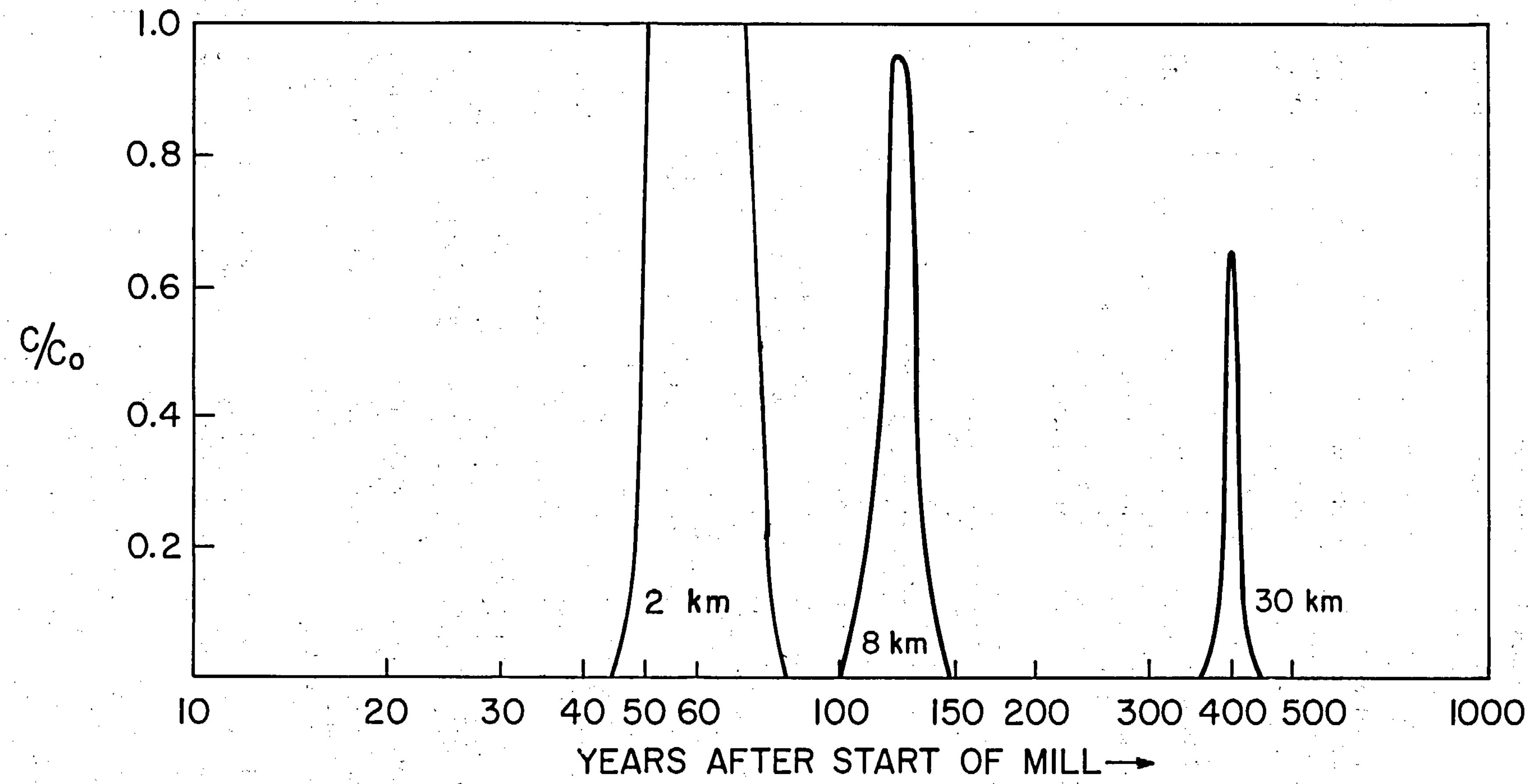

Fig. E-3.1. Contaminant Concentration in Groundwater 2, 8, and 30 Kilometers Downgradient from Edge of Impoundment.

The fates of the major contaminants are analyzed below:

• pH--The volume of subsoil necessary to react with and neutralize seeping sulfuric acid can be predicted. The general equation is:

$$H_2SO_4 + CaCO_3 \rightarrow CaSO_4 + H_2O + CO_2$$

The subsoil is an alluvial deposit ranging in consistency from clay to sand-sized particles of minerals and rock fragments of various compositions. It is assumed that 1% of the aquifer consists of calcium carbonate (limestone) fragments or other minerals capable of neutralizing acid. Seepage water with a pH of 2 has by definition a concentration of 0.01 moles per liter (0.01 equivalents/l) of hydrogen ions. Assuming the subsoil has a dry density of 2 g/cc and contains 1% $CaCO_3$, there would be 0.02 g/cc $CaCO_3$. This is equal to 2×10^{-4} moles/cc = 4.0×10^{-4} equivalents/cc = 0.4 equivalents/liter. It follows that the ratio of equivalents of hydrogen ions per liter to calcium carbonate ions per liter is 0.01/04 = 1/40. Therefore 1 m^3 of subsoil could neutralize about 40 m^3 of acid if complete mixing could be obtained. Because the effective porosity (N_e) of the subsoil is 10%, 1 m^3 of subsoil at the model site would be invaded by 0.1 m^3 of acidic seepage and could easily neutralize the water. It should be noted coal mine drainage studies have shown that precipitation crusts may form around limestone fragments, when the limestone fragments are depended upon as a mechanism for neutralizing acid waste solutions.[33] However, in this model study, this effect was assumed not to be operative whereupon one can conclude that there exists sufficient neutralizing capacity in the model subsoil to neutralize the invading solution.

• Iron--Although it is shown in Column D of table E-3.1 that the expected concentration of iron in the tailings liquid is more than three orders of magnitude greater than the MPC for drinking water, most is expected to precipitate out of solution as iron oxides in the tailings pond area and in the subsoil as neutralization occurs. Iron is not a toxic substance; the MPC of 0.3 mg/L was established as a recommended limit because of the inconvenience of iron stains in porcelain domestic fixtures. Although the contamination of groundwater by iron may not represent a serious hazard to man, the general use of breakthrough curves to predict the rate of spread of iron can be used for other contaminants as well.

As the seepage water is neutralized, the solubility product of iron decreases dramatically. In a neutral solution, the solubility of ferric ions is so low that most will be precipitated, and the concentration of ferrous ions in groundwater is probably limited by the solubility of ferrous carbonate, but still ranges between 1 and 10 mg/L if the pH is between 6.0 and 8.0.[34] If the seepage is neutralized (as discussed above for pH), then the highest concentration of total ferrous and ferric iron will be about 10 mg/L; however, this is still about 30 times the MPC for drinking water and the water would be rendered useless for domestic and most industrial uses.

If no further absorption or cation exchange occurs, the changes in concentration of the 10 mg/L iron solution as it migrates downgradient can be determined from Figure E-3.1. For example, at the well 2 km downgradient from the edge of the impoundment, contaminated water begins to arrive at about 35 years after mill operations begin, reaching a maximum C/C_o = 1 (10 mg/L Fe) from 45 to 55 years, then declining until 65 years when C/C_o = 0 (background concentration).

Because seepage water may discharge to the surface at Reservoir I, 8 km downgradient, consideration of potential effects on cattle, wildlife, and the fluvial environment becomes important. As is shown in Figure E-3.1, surface seepage begins after about 100 years, reaching a maximum C/C_o = 95% (9.5 mg/L Fe) after 125 years, and decreases to background after 150 years.

At 30 km downgradient, where groundwater ultimately discharges as it seeps along Middle Reservoir on Tributary River, the concentration of a contaminant is to a greater degree influenced by the fact that a breakthrough curve of background water quality follows 15 years behind the initial contaminant breakthrough curve. From Figure E-3.1 it can be seen that seepage water arrives at 360 years, reaching a maximum C/C_o of 65% (6.5 mg/L Fe) at 400 years, and drops back to background at 440 years.

The above analysis is believed to be conservative in that no lateral dispersion is assumed, and no credit is given to absorption, precipitation, or ion exchange of the contaminants en route. These mechanisms would result in lower concentrations of dissolved ions in the seepage water than discussed above.

• Manganese--The geochemistry of maganese is similar to that of iron. Both metals are precipitated as hydrous oxides in response to neutralization of acidic water.[35] In natural waters the concentration of manganese is typically less than one-half that of iron.[36] Above it was assumed that the iron concentration would be 10 mg/L after neutralization; therefore, it is assumed here that the concentration of manganese (800 mg/L in tailings liquid at pH = 2) will be reduced to 5 mg/L after neutralization. This is still 100 times the MPC for drinking water, which was established to minimize formation of black stains on porcelain fixtures. It should be noted also that manganese at these concentrations will gradually precipitate in any water distribution carrying it. It, along with iron, eventually will plug any distribution system if these concentrations are maintained. In addition, other domestic uses of water must be curtailed if manganese concentrations reach these levels. Most notably, it is impossible to launder fabrics in waters of this quality.

Based on the curves shown in Figure E-3.1, and assuming no further precipitation or ion exchange en route, it can be shown that manganese concentrations are:

--5 mg/L from 45-55 years at 2 km downgradient

--4.75 mg/L peak at 125 years at 8 km downgradient (Reservoir I)

--<3.25 mg/L peak at 400 years at 30 km downgradient (Middle Reservoir).

• Sulfate--as shown in Column B of Table E-3.1, the residual tailings pond water will have 48,000 mg/L sulfate, more than 190 times greater than the 250 mg/L MPC for drinking water. As the tailings water seeps into the subsoil, the sulfuric acid (H_2SO_4) will react with limestone ($CaCO_3$) or caliche in the subsoil to produce anhydrite ($CaSO_4$) and carbonic acid (H_2CO_3). The precipitation of anhydrite ($CaSO_4$) that coats the calcium carbonate particles in the porous medium and makes difficult the continuation of this reaction is discussed in reference 33. The carbonic acid will decompose to water and carbon dioxide. These reactions are reversible, and it can be shown that the maximum dissolved sulfate that can occur at equilibrium is governed by the solubility of anhydrite and wil be about 2000 mg/L. As the sulfuric acid is neutralized, calcium and (depending on subsoil mineralogy) sodium and potassium ions will be added so that the solution will have equal milliequivalents of cations and anions. (If only calcium ions were added, the concentration of calcium would be about 1040 mg/L, compared with the 200 mg/L MPC for drinking water.)

In essence, calcium and sulfate are expected to reach the water table in quantities about five to ten times greater than the recommended limits for drinking water. These contaminants will flow downgradient as discussed above for iron, and will probably be further reduced by precipitation and ion exchange en route. Although neither of these contaminants poses a serious health hazard, calcium in water makes it hard for soap to lather, and excessive sulfate has a laxative effect.

• Selenium--Although selenium is a rare element, it is found in association with many uranium deposits,[37] and a concentration of 32 mg/L selenium is assumed present in the residual tailings pond water at a pH of 2. This toxic element has caused poisoning of livestock in numerous areas of the western United States. The geochemistry of selenium is poorly understood, but it is known that selenium can form an anion (selenate) similar to sulfate that will not be subject to cation exchange. It can be assumed, therefore, that in the worst case no reduction of selenium concentration will occur due to changing pH or ion exchange. Therefore, based on Figure E-3.1, the following selenium concentrations may be expected:

--32 mg/L from 45-55 years at 2 km downgradient

--30 mg/L peak at 125 years at 8 km downgradient

--<21 mg/L peak at 400 years at 30 km downgradient.

• Radium and Thorium--As shown in Table E-3.1, the residual tailings pond water will contain 400 pCi/L radium and 150,000 pCi/L thorium. These are, respectively, 80 and 75 times greater than drinking water MPC.

The rate of movement of radium and thorium is related to the distribution coefficient (K_d), which is a laboratory measure of the ratio of the amount of ions adsorbed onto soil divided by the ions remaining in solution [see equation (1)]. It is indicated by data in the literature[32,38-41] that a conservative value for the distribution coefficient of radium in nearly neutral water is 10 mL/g. Using equation (2):

$$V_{Ra} = \frac{V}{1 + \frac{K_d \gamma}{N_e}}$$

where V = water seepage velocity = 3.65 m/year (from Appendix E-2)
γ = dry density of subsoil = 132 lb/ft^3 = 2.12 g/cc
N_e = effective porosity = 10% = 0.10.

It is shown by solving equation (2) that the radium will move at 1/215 the speed of seepage water, or 0.017 m/year, so it would move 0.26 m in 15 years, the life of the pond. The water table is at a depth of 25 m, and since radium is expected to be isolated in the unsaturated zone within 1 m below the tailings, no groundwater contamination by radium is expected. Thorium has a very high distribution coefficient and would be expected to be fixed within a few centimeters of the tailings pond bottom.[32,38-40]

• Uranium--The chemistry of uranium is quite complex; uranium ions occur in several valence states, are affected by oxidation state as well as pH, and form soluble compounds with carbonate ions. Based on both laboratory tests and field studies (Refs. 42-46), it is expected that most (i.e., 95 to 98 percent) of the uranium concentration in the tailings liquor would be adsorbed onto alluvium, directly beneath the tailings impoundment. Nonetheless, some of the remaining uranium may stay in extremely mobile form, and, as a result, uranium will move more readily than radium and thorium (Ref. 47). While it is expected that the 550 pCi/l (see Column C of Table E-3.1) standard would not be exceeded, long-term transport of uranium at levels substantially above background is possible, where there is uncontrolled seepage.

• Other Possible Contaminants--It is shown in Table E-3.1 that other ions are present in the tailings pond liquid in concentrations greater than the MPC. These include arsenic, cadmium, copper, mercury, lead, and zinc. Concentrations of aluminum and ammonia also are high. It is assumed that as the pH increases from 2 to neutrality, as discussed above, most of the trace metals will precipitate out. Further, trace metal cations are generally subject to ion exchange and will substitute for sodium, calcium, or potassium, particularly in clayey portions of the subsoil. Those cations with the higher oxidation state (such as $zinc^{+2}$, $lead^{+2}$, etc.) tend to exchange more readily than those with lower valence. However, some ions, such as arsenic, selenium, molybdenum, cyanide, and chromium, can behave as anions as well as cations, and as such should be considered especially dangerous contaminants.

The geochemistry of trace metals and their effects on human health are generally poorly understood. It is assumed that the neutralization of the seeping water will allow for the precipitation of aluminum, cadmium, copper, mercury, lead, and zinc so that seepage reaching groundwater will contain near the MPC values. Arsenic may not be affected by pH and can be expected to follow the concentration curves shown in Figure E-3.1, where C_0 = 0.32 mg/L.

Ammonia and possibly other gases, such as hydrogen sulfide, are not expected to remain in the seepage solution.

In summary, as stated in the case of each of the elements described above, the geochemistry of potential contaminants in tailings solutions is variable and complex and, therefore, difficult to make general statements about. One report containing a generalized discussion of trace element geochemistry is Reference 42, which reports on research conducted under NRC sponsorship, on geochemistry of tailings solutions.

3. LONG-TERM SEEPAGE

Following the cessation of mill operations, seepage from the tailings pond area will be substantially reduced because there will be no more tailings water discharged from the mill. Assuming no surface water, such as runoff from an ephemeral stream drainage, enters the tailings pond area, the only source of water will be from precipitation falling directly on the tailings pile. In general, precipitation leaves a basin either by evapotranspiration or by runoff. Surface water runoff will be negligible on the abandoned tailings pile, so that the amount of precipitation which does not evapotranspire can be assumed to infiltrate deep into the tailings. In northwestern New Mexico, where the mean annual precipitation is 31 cm, the mean annual runoff is about 4% of the precipitation.[48] Applying this ratio to to the 90-ha tailings area would result in a the long-term rate at which water would seep through the tailings into the subsoil. [It is $(1.12 \times 10^4\ m^3/yr)(2.2 \times 10^5\ m^3/yr)$ = 5% of the rate of seepage during the time of mill operation.]

The chemistry of the seepage water draining out of the tailings is difficult to predict. During the initial years following mill shutdown the concentrations of dissolved contaminants would be nearly the same as shown in Column B of Table E-3.1. These concentrations would gradually decrease with the passage of time. Radium, moving at 0.017 m/yr, would require about 1500 years to reach the water table at a depth of 25 m, and nearly one-half would have decayed to radon.

Contamination of groundwater with nonradioactive materials is probable, but the magnitude is small compared with the contamination that would occur during mill operation because (1) the long-term seepage rate is only 5% of the 15-year operation seepage rate, and (2) the concentration of contaminants decreases with time.

4. CONCLUSION--COMPARISON WITH OTHER AREAS

The conclusion of the analysis herein is that little or no contamination of groundwater with radioactive material will occur because of seepage from the model mill tailings pond, but that contamination from sulfate, iron, manganese, selenium, and possibly other trace elements will occur. Support of these predictions comes from examination of existing mills and from other studies. In a recent study using a computer model and laboratory distribution coefficient it was predicted that radium would be reduced to 10% of its original concentration at 3 m below the bottom of a seeping uranium tailings pond after 20 years.[39]

Field studies of sorption of radium and thorium, which would support laboratory values of the distribution coefficient of radionuclides, are meager. Among the better ones is a study of soil and groundwater contamination from a large thorium waste pile in West Chicago, Illinois.[49] The waste piles and surface ponds used for disposal of plant wastes are located on a 30-m-thick deposit of glacial till and interbedded sand and gravel and overlies flat-lying permeable Ordovician limestone. The mean annual precipitation in this area is 90 cm, and the water table is within 3 m of the surface. Water wells in the limestone showed sulfate and chloride contamination in groundwater up to about 1.5 km from the site. No radionuclide concentrations above background values were found in the water wells. Ra-226, Ra-228, Th-228, and daughters were detected in glacial drift up to 80 m from the waste ponds and up to a depth of about 10 m in shallow test holes drilled around the edge of the waste. Beyond that distance and below that depth, radionuclide concentrations seemed to drop off to background values for soils found in northern Illinois. The radionuclides seem to have been carried by groundwater in a sandy unit and held up at the top of a clayey unit within the glacial drift. Although the research did not include sufficient test holes to make a conclusive study, the preliminary findings are that dissolved anions such as sulfate have migrated through the till and limestone and have contaminated the groundwater up to 1500 m away, but the dissolved radionuclides (radium and thorium) have not traveled more than 100 m. Because the thorium plant operated from 1915 to 1965, the rate of movement of dissolved anionic contaminants was about 30 m per year, but the rate of movement of radium and thorium was less than 2 m per year.

Other field studies documenting the movement of radium and thorium below tailings ponds seem to verify the West Chicago study. One report on the hydrogeology of five uranium mills in the Grants, New Mexico, area showed that vast quantities of radionuclides were seeped or being injected into groundwater, but only one of 72 water wells tested within about 5 km of the tailings ponds showed any radioactivity above background.[50] (This one contaminated well is at the edge of the Kerr-McGee tailings pond.) Other ongoing research by Ford, Bacon and Davis, Utah, Inc., for DOE has included the drilling of test holes around the 22 inactive tailings piles in the western states. The preliminary conclusions of these studies are that thorium and radium concentrations typically drop off to background within a meter below the bottom of the tailings piles.[51] A study by the U.S. Department of Health showed that samples from two water wells within 3 km of the Tuba City uranium tailings area had shown background radioactivity, and based on this limited data there appears to be no groundwater contamination from leaching of radioactivity from the tailings piles.[52] Another study at the Mexican Hat tailings pile area showed no radium in groundwaters in the vicinity of the tailings.[53] Water wells sampled in the vicinity of the Split Rock tailings pond near Jeffrey City, Wyoming, showed no radioactive contamination beyond several meters of the tailings, although the leading edges of sulfate, manganese, and arsenic fronts had migrated about 1 km downgradient in 20 years of operation.[32]

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APPENDIX F. SOCIOECONOMIC IMPACTS

APPENDIX F-1. ANALYTICAL APPROACH FOR SOCIAL AND ECONOMIC IMPACT ANALYSIS

1. INTRODUCTION

The information included in this appendix is a brief description of the conceptual framework and assumptions used to generate the impact analysis of the model region. Briefly, this approach is based on the application of a systems model to an impact assessment which could be used to identify major kinds of changes that could occur in a local community as a result of the proposed action. In addition, a brief discussion also is provided on the kinds of impact situations potentially affecting archaeological and historic sites.

A cultural/ecological model has been selected for characterizing major regional and community-level impacts that might be attributed to uranium milling. This model (Fig. F-1.1) has been used in making the impact assessment for each community in the region.[1] In the figure, demography; settlement pattern; and the social, political, and economic systems of a community are shown to be the five major variables that can be directly or indirectly affected by uranium milling. However, demography and settlement pattern are considered to be the prime movers of sociocultural change, and these are the components of the model that are the most directly affected by the in-migration of a construction and operational work force. Sociocultural impacts include organizational and behaviorial changes as well as new service demands. The characteristics and service demands of a uranium work force are illustrated in Figure F-1.2. Changes in one part of the community produced by the in-migrant workers may produce changes in other parts and thereby alter a community's social, economic, or political makeup. As long as sufficient time is available for these responses to be made, major impacts may not be perceived by community members as disruptive.

The model structure outlined in Figures F-1.1 and F-1.2 depicts the important elements of change which can be assessed and often quantified. The model shows how interaction among the parts is perceived to occur. In the following sections, the five major community variables that can be most affected by uranium milling are more thoroughly discussed. Discussion of each variable includes consideration of the variations in the nature of the changes and general processes causing the changes.

It should be pointed out that this model is designed with flexibility so that destructive sociocultural factors for communities and neighborhoods can be incorporated. Actual use of the model in a site-specific instance requires identification of factors that may be of particular importance to different sociocultural and ethnic groups. Without sensitivity towards understanding the internal organization, goals and values of such groups, the potential for serious impacts may not be recognized. Loss of group identity, social stress, and decreased regional cultural diversity may result.

2. CHANGES IN THE SOCIAL, ECONOMIC, AND POLITICAL SYSTEMS

Impacts are usually recognized at the community level when the in-migrating population reaches 5% of local population, and a community may perceive impacts as being severe when the local population is rapidly increased by 10% or more.[2,3] However, it should also be pointed out that the type and magnitude of the impacts vary according to the specific characteristics of a particular community. Communities which tend to be the more severely affected have one or more of the following attributes: (1) small size, (2) rural location, (3) Long-term residence, (4) homogeneous sociocultural background, (5) informal organization, (6) a distinct ethnic makeup, and (7) traditionality.[1] The magnitudes of the impacts have also been qualitatively evaluated along the lines of a study prepared by Booze, Allen, and Hamilton.[4] In this document, a five point scale for socioeconomic impact evaluation was developed: highly desirable, desirable, no effect, undesirable, highly undesirable. Determination of desirability, as used in this study, is based on (1) the effect of an impact on the total integration of the groups and individuals that make up a community; and (2) the ability of this group of people to meet social needs and service demands at various levels. Information presented in Table F-1.1 was derived from literature in which field descriptions of actual impacts to western communities have been recorded.

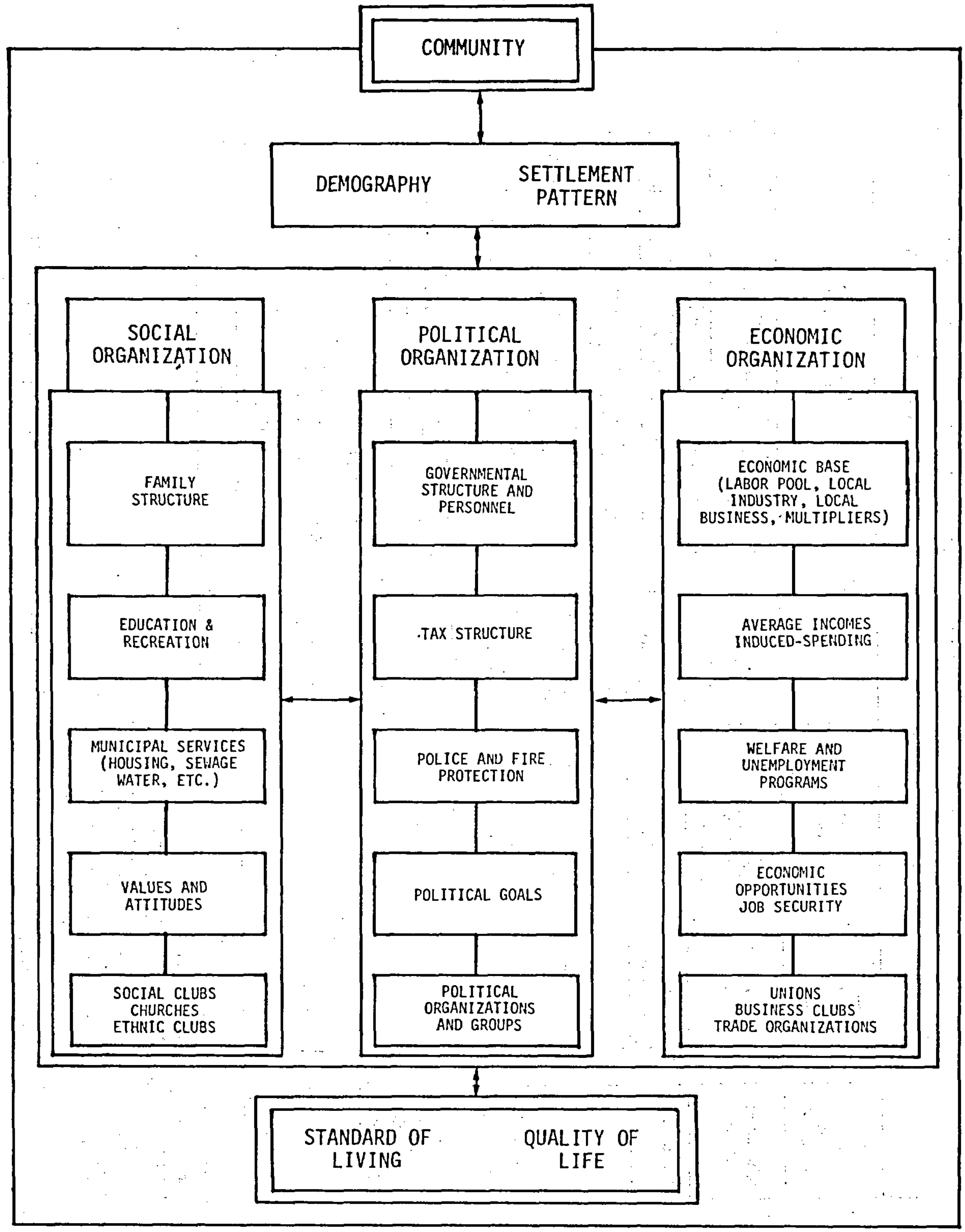

Fig. F-1.1. Structure of "The Community" Illustrating Major Dynamic Components. (From S. A. Curtis, "Application of the Cultural-Ecological Approach to Socio-Economic Impact Assessment," presented at the American Association for the Advancement of Science meeting, 29 April 1978.)

SOCIOCULTURAL IMPACTS OF URANIUM DEVELOPMENT

Workers and Service Personnel	Family of Worker and Service Personnel	Residence Patterns	Land Use
Total Number per Year	Total Number per Year	Number of Single Family/ Individual Units per Year	Change in Current Land Use
Job Turnover Rate	Family Structure	Tenancy Status	Period of Demand
Job Category	Job Category	Residence-Employment Relationships	Employment-Residence Patterns and Convenience Demands
Education	Education and Demands	Nearness to Schools	Land Use Changes
Ethnic Background/ Community of Identity	Same	Housing Type and Desired Setting	Conflict with Current Land Use Goals
Values and Goals	Same	Temporary or Permanent Commitment	Change in Land Use in One Area Alters Land Use in Nearby Areas

IN-MIGRANT POPULATION

	Impacts on Social Service Demands (average)	
Sewage, Water	190-285 gallons of water per each residential family of 3.8 persons	(1)*
	Public sewage treatment required when population exceeds 2500 persons/sq. mi.	(1)
Education	1 school teacher for every 18.2 new students	(2)
	Average cost for educating every new student--$900	(3 & 4)
Medical Services	1 M.D. for every 770 new persons	(5)
	4.5 hospital beds for every 1000 new persons	(6)
Recreation	3.5 acres of community park area for every 1000 new persons	(1)
Police, Fire Protection	1 police officer for every 1000 new persons	(7)
	Manpower for fire protection varies according to three factors: (1) staff permanency, (2) water availability, and (3) station location.	

*Numbers in parentheses refer to following sources:

1. J. DeChiara and L. Koppelman, "Urban Planning and Design Criteria," 1975.
2. B. Foster and J. Carpenter, "Statistics of Public Elementary and Secondary Day Schools, Fall 1975," 1976.
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Fig. F-1.2. Characteristics and Service Demands of a Uranium Work Force. (From S. A. Curtis, "Application of the Cultural-Ecological Approach to Socio-Economic Impact Assessment," April 1978.)

Table F-1.1. Impact Categories and Criteria of Desirability for Small Homogeneous Communities Experiencing Rapid Energy Development[a]

			EVALUATION			
			Highly Desirable	Desirable	Undesirable	Highly Undesirable
SOCIAL IMPACTS	Structure	Community Integration	Increase in the feeling of belonging to a community experienced by old residents and new residents	Sense of "community" is maintained and experience by old and new residents	New residents feel excluded from sense of community	Loss of sense of community experienced by both old and new residents
		Social Institutions	Number and types of institutions do not change too rapidly, producing social stress, and participation rates for old and new residents remain high	Institutions may change and and assume new function; participation rates remain high for old residents and moderate for new residents	Old and new residents are associated with different institutions and decline in participation rates in both groups	Institutions break down for both old and new residents
		Family Structure	Kinship patterns remain stable for old and new residents	Kinship pattern change in some subgroups	Kinship patterns break down for the majority of subgroups and families	Kinship patterns break down for all community subgroups and families
	Services	Mental Health/Social Services	Social pathologies decrease and mental health/social service demands are met	Mental health and social services meet all demands	Mental health and social service demands cannot be met due to proportional increase in population	Increase in social pathologies and mental health problems faster than the increase in the population
		Quality of Public Services (sewage, water, refuse)	New growth demands for services met by company	New demand growth 10% or less of existing population	New demand growth over 10% of existing population	New demand growth over 25% of existing population
		Housing	New permanent housing constructed	Demand matches supply	Large number of mobile homes	Extensive number of mobile homes
		Community Planning	Presence of well-developed county-community plan which controls growth, and is adequately staffed	County-community planning capability and long term goals established	Incomplete plans with time lag problems and small staff	No developed plans or planning staff
		In-Patient Hospital Care	Occupancy rate and staff size meet hospital/community goals	Less 75%-85% occupancy and staff at capacity	100% occupancy and staff stressed	Well over 100% occupancy and understaffed
		Out-Patient Care	Doctors easily accessible to local residents			Doctors not available to local community and ambulance service poor
POLITICAL IMPACTS	Structure	Political Structure	Local structure and personnel little affected	Changes in structure and personnel gradual	Change from very informal to formal organize in short time frame	Rapid change from informal to formal structure and new personnel
		Political Goals	Political goals of old and new residents similar and and goals implemented	Political goals for old and new residents defined	Political goals of new and old residents are different	Conflict between political goals of old and new residents
		Crime Rate	Crime rates decrease or remain stable for all types of crime, especially violent crimes	Decrease in serious crimes	Crime rates increase proportionally with increase in population	Crime rates and numbers of serious crimes increase faster than the increase in population
	Services	Police and Fire Protection	Protective services meet suggested standards	Protective service at capacity	Protective services understaffed	Protective services cannot meet current demand
ECONOMIC IMPACTS		Income Level	At least 50% increase in mean	At least 25% increase in mean	No increase in mean	Decrease in mean
		Employment	Current unemployment of over 8% is greatly reduced	Current unemployment of 3-8% reduced	Higher unemployment caused by in-migration	--
		Impact on Nonbase Economy	Expansion needs met at gradual pace		Wage increase needed in small local businesses to keep employees	Strong competition for employees, and large wage increases
		Retail Sales	Increased over 100%	Increased 50-100%	--	--
		Municipal Property Values	City has 75% base employment	City has 25-75% base employment	Population dispersed in agricultural areas	Facility and population located on reservation
		Tourist Industry	--	Strong reclamation controls in scenic and natural areas, and little land lost to development	Scenic areas with tourist interest disturbed	Total and rapid development of large expanses of natural areas

[a]Based on "A Procedures Manual for Assessing the Socioeconomic Impact of the Construction and Operation of Coal Utilization Facilities in the Old West," Booz, Allen and Hamilton, Inc., (undated) and on data in Appendix F-4.

3. ARCHEOLOGICAL AND HISTORIC SITES

Impacts to archeological and historical resources are affected by several Federal laws; the major ones applicable to the uranium industry and guidelines for their implementation are presented in Appendix F-6. In general, there are five basic kinds of construction and operation impact situations that may occur singularly or in combination at a specific mill site. (This assumes that prior to construction the mill property has been adequately examined for surface evidence of cultural resources as discussed in Appendix F-6. Criteria for determining the adequacy of the field study are presented in Appendix F-7). The five main impact situations are: (1) the surface reconnaissance has disclosed no evidence of cultural resources; (2) surface remains of prehistoric/historic sites have been located and eligibility for inclusion in the National Register has been determined under the guidelines specified in 36 CFR 800 (see Appendix F-6); (3) surface remains of prehistoric/historic sites have been located and it has been determined that they are not eligible for inclusion in the National Register; (4) regardless of National Register status, salvage excavation of the prehistoric/historic sites has removed all of the artifacts, or a sample portion, using current state-of-the-art techniques (it should be noted, however, that removal rather than in-situ protection contains the risk of losing scientific data that might have been recovered if the sites had been excavated at a later date using improved or new techniques); (5) a sampling error has occurred in the initial survey and prehistoric/historic materials are destroyed during construction activities.

The postoperation impacts are the result of removing from the protection of the mill license holder the care of known sites on the mill property. Subsequent to operation, sites may be vandalized by relic hunters.

The impact situations described for all phases of uranium production have been illustrated in the flow diagram presented in Figure F-1.3. In many cases, destruction or disturbance of cultural resources can be avoided or minimized through the development of adequate monitoring-preservation programs. When this is not possible, mitigation by salvage excavation must be undertaken.

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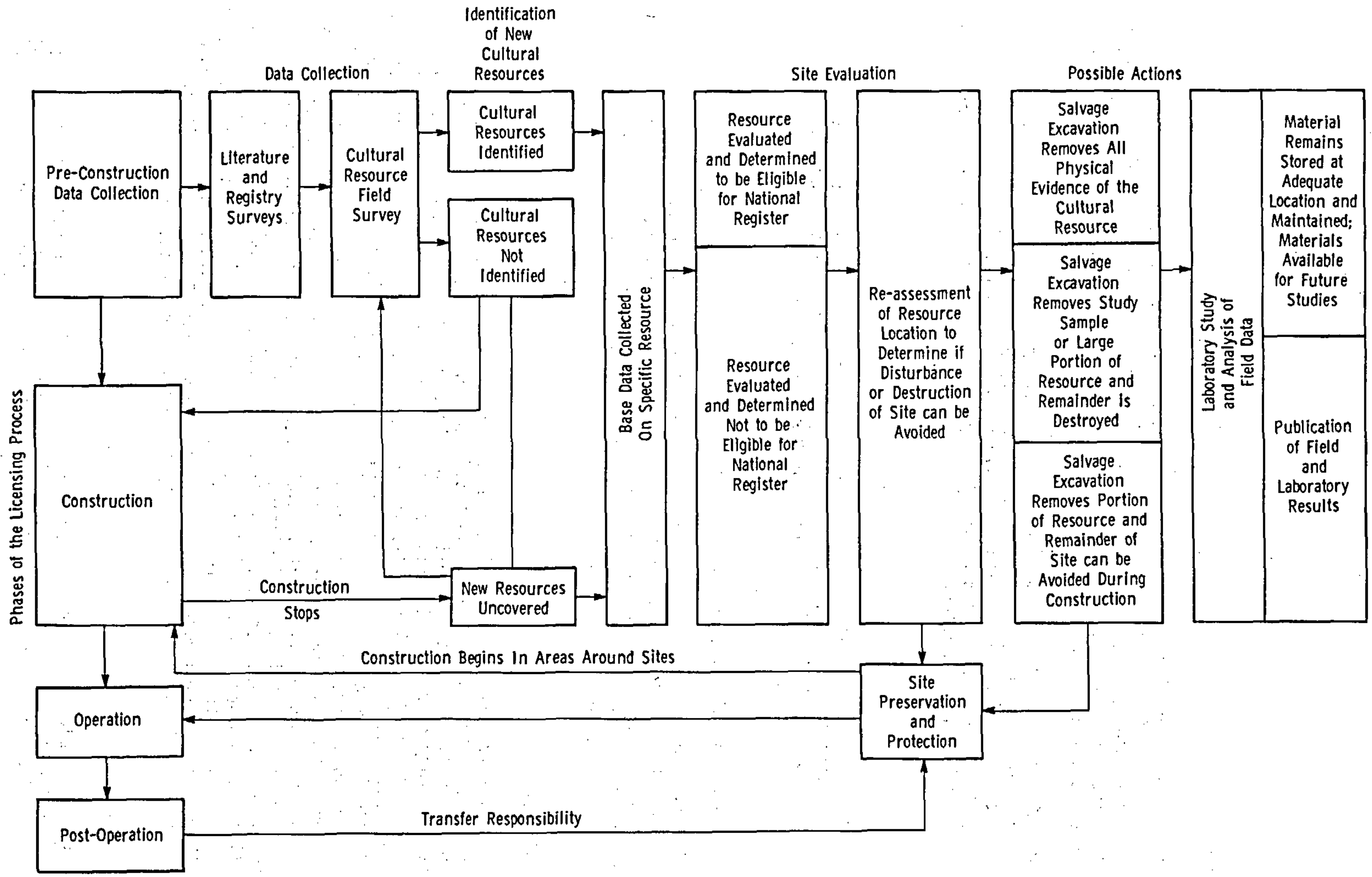

Fig. F-1.3. Impacts on Cultural Resources. (From S. A. Curtis, "Application of the Cultural-Ecological Approach to Socio-Economic Impact Assessment," presented at the American Association for the Advancement of Science Meeting, 29 April 1978.)

APPENDIX F-2. LABOR FORCE PROFILE

1. INTRODUCTION

A general profile of the construction and operational personnel associated with the uranium industry is presented in this appendix. Although the construction and operational work forces are very similar, it should be noted that the characteristics of the work force will vary from region to region. Factors affecting the geographic variations include community background, nearness to cities, duration of employment, and social goals and values.

A summary of some general characteristics is provided in Tables F-2.1 and F-2.2. Information presented in these tables, as well as in the text of this appendix, was derived from regional studies. While most studies in the social science and impact literatures reviewed was focused on the Wyoming work force and other kinds of energy developments, a basic set of common characteristics are expected in the uranium industry.

2. DEMOGRAPHY

The average age ranges of construction and operation workers are similar--25 to 34 years old and 26 to 35 years old, respectively. About 75% of the construction workers are married, with an average family size of 3.7, and 83% of the operational employees are married, with an average family size of 3.4.

3. SOCIAL AND ECONOMIC CHARACTERISTICS

In general, social and economic characteristics of construction and operation workers are thought to be similar throughout the western United States. In the following discussion, the basic socioeconomic characteristics that will be presented apply to both groups of workers unless otherwise noted. (However, some differences between construction and operational personnel are expected in specific regions.)

4. FAMILY ORGANIZATION

On the average, the family of the construction and operational worker may be generally smaller, and the children younger, than the local families of a community. This is more typical among the younger, mobile subgroups. In some construction-operational families, the wife has previously been the secondary source of financial support, but she experiences difficulties in finding employment when moving with her family into a more rural area where local women already occupy the few available job positions.[1-3] Moreover, in the construction trades, employment is usually not available for a woman.[1-4] Thus, the wife is less able to adjust because she has neither a job nor community activities typical of a more settled lifestyle. In effect, a wife moving from an urban to a rural area may experience "cultural shock."[5] She often becomes bored and discontent with the little activity that is available to her, and as a result develops a desire to leave the area.[1-3] Feelings of isolation, temporary residences and friendships, economic over-commitments, and lack of social amenities all may contribute to this problem. The children, much like their mother, are also faced with lack of school and community activities and, in some cases, with overcrowded classrooms.[1-3] Social problems have been reported among wives and children of in-migrating workers, particularly among those living in rural fringe developments associated with various types of energy exploitation projects.[6,7]

5. RESIDENCE PATTERN

In many instances, the in-migrating workers (especially construction workers) have no intentions of taking up residency in the community (see Tables F-2.1 and F-2.2). Consequently, they select temporary housing, such as apartments and mobile homes. Often the available mobile home units are in mobile home parks outside of town.[1,8] Since such families are physically separated from the local community, they tend not to integrate within the social framework of the community,

Table F-2.1. Profile of Construction Workers[a]

Parameter	Value[b] Non-Local[c]	Local
Source of workers	60%	40%
Age		
25-34	23%	14%
Education		
High school	46%	44%
Salary (construction/operational)		
$10,000-$14,999	18%	24%
$15,000-$24,999	58%	39%
Marital status		
Married w/family present	50%	82%
Married w/o family present (non-local only)	25%	
Single/widowed/divorced	25%	18%
Age of household heads		
25-34	41%	24%
35-44	16%	23%
Average family size	3.6	3.8
Percentage of workers' children of school age (5-18) (non-local only)	23%[d]	-
Residency in area		
Take-up residency	10%	76%
Stay as long as work is available	51%	10%

[a]"Construction Worker Profile, Final Report," Mountain West Research, Inc., December, 1975.

[b]Some percentages do not total 100 because only certain classifications were used to give pertinent information on workers.

[c]Denotes elsewhere in state and out of state.

[d]"Social Impact Assessment of the Proposed Laramie River Station," Dept. of Sociology, University of Wyoming, December 1975.

nor to become active in local community affairs.[1,8] However, in-migratory operational workers may develop a stronger sense of permanency and buy a home in the community.[2,8] Slightly less than one-fourth of both local and nonlocal operational workers have long-term employment (see Tables F-2.1 and F-2.2).

Another factor influencing the settlement patterns of the construction and operational workers is lifestyle interests.[2,8] Approximately half of the workers surveyed across the country preferred living in small towns or rural areas where outdoor recreation opportunities are numerous.[4] They enjoy all outdoor sports and tend to become irritated when facilities are not available.[2-4,8] Therefore, in-migrants may choose to live relatively close to the job in a rural area rather than commute from the nearest city.

6. JOB SELECTION

Three distinct groups of workers were identified in one recent study of construction-operational workers in various industries.[9] The first, termed the "professionals," follow the trade because of work satisfaction. Next are the "travelers," who are highly skilled but also wish to travel. Finally, there are the "searchers," who are the least skilled and not dedicated to the trade. The company and community are primarily interested in attracting the "professionals" and "travelers" as operational workers.[9] In a regional and subregional impact assessment it is important to consider the differences among these groups and their interaction with the local community.

Table F-2.2. Profile of Operational Workers[a]

Parameter	Value	
Age		
26-35	34%	
Education		
High school	73%	
Marital Status		
Married	82%	
Single/widowed/divorced	19%	
Average family size	3.4	
Percentage of workers' children of school age (5-18)	38%	
Type of dwelling unit		
Permanent, single-family home	63%	
Mobile home	31%	
Residency in area		
Expect to leave the area when work is unavailable	36%	
	In-State (but different location)	Out-of-State
Previous residence[b] and length of time employed (months)		
0-12	43%	52%
More than 60	10%	10%

[a]The data used is primarily from the Wyoming area; however, the staff believes that other areas can be expected to be generally similar. Except as noted, the information has been derived principally from "The Residents of Sweetwater County, Wyoming: A Needs Assessment Survey," by Bickert, Browne, Coddington, & Associates, Inc., October 1974.

[b]Adapted from "Profile of a Rural Area Work Force: Wyoming Uranium Industry," Agricultural Experiment Station, January 1974.

7. WORKER TENURE

The annual turnover rate at a job ranges between 50% and 120%.[8] This rate includes construction workers who help build the mill and leave after completion, and construction and operational workers who work on the mill and then transfer to the mining operation.[1,8] There appears to be a direct relationship between age, educational level, and turnover rate.[8] The higher the educational level and younger the age of the worker, the higher the probability of job turnover.[8] Conversely, older workers with lower educational levels generally stay on the job longer.[8] In addition, residency status also is related to job tenure patterns. Regardless of age and educational status, the out-of-state workers tend to remain employed for a shorter time than in-state workers.[8]

8. SALARY

Earnings for the workers are determined by skill category, and regardless of particular tenure patterns and job locations, workers at the skilled and semiskilled levels tend to pursue the same type of occupations.[8] The highest earners are electric shovel and heavy equipment operators, truck drivers, maintenance men, and instrument men.[8] The lowest paid are the unskilled laborers, who frequently come from an agricultural background.[8] The average yearly salary for all workers is about $17,000.[1] The average construction salary is usually higher than the average for the local inhabitants (see Ref. 1 and Table F-2.1).

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APPENDIX F-3. BACKGROUND INFORMATION FOR PROJECTED PERSONNEL DISTRIBUTION PATTERNS

The summaries of demographic effects for the one-mill and twelve-mill cases, as given in Table 6.8 (Sec. 6.2.7) and Table 6.29 (Sec. 6.3.7), were derived by rounding off values shown in this appendix in Tables F-3.1 and F-3.2. The assumptions used in generating each set of data for the two tables are as follows:*

1. Characterization of the construction work force for the model mill was based on the following sets of factors and assumptions:

   (a) An in-migrant/local ratio of mill workers of 60/40 (Tables F-3.3 and F-3.4).

   (b) Construction work force of 120 (Table F-3.4).

   (c) A multiplier of 2.3 for family members per construction worker (Table F-3.3).

   (d) A base-to-service multiplier of 1/0.6 (Table F-3.3).

   (e) Distribution of the local and in-migrant work force families and service workers was designed to reflect the results of a general survey of the literature and presentation of patterns identified in communities that have experienced energy development.

2. Characterization of the operational work force for the model mill was based on the following sets of factors and assumptions:

   (a) An in-migrant/local ratio of mill workers of 65/35 (Table F-3.3).

   (b) An operational work force of 160 (Table F-3.4).

   (c) A multiplier of 2.3 for family members per operational worker (Table F-3.3).

   (d) A base to service multiplier of 1/1.2 (Table F-3.3).

   (e) Distribution of the local and in-migrant workforce families and service personnel was designed to (1) reflect patterns identified in a general survey of the literature describing communities that have experienced energy development, and (2) parallel the distributional trends shown in the projected locations of the operational work force and associated persons.

3. Characterization of the construction work force for the multiple mills was based on the following sets of factors and assumptions:

   (a) The in-migrant/local ratio of 65/35, the multiplier of 2.3 for family members, and the base/service ratio of 1/0.6 remained the same for the multiple mill situation (Table F-3.4).

   (b) The size of the construction force was determined by multiplying the work force assumed for the single model mill (120) by the number of crews (4) assumed present at any one time at the multiple-mill site (Table F-3.4).

   (c) The distribution of workers, families, and service personnel was derived by holding constant the percentages used to assign the workers to towns in the single mill case and then applying these same percentages to the total work force for the multiple-mill situation.

*The number before each set of assumptions is keyed to the corresponding number above the appropriate column of Table F-3.1 or Table F-3.2.

Table F-3.1. Regional Demographic Effects of Construction and Operation of a Single Model Mill (keyed to explanatory text)

				1[a] Construction Phase				2[a] Operation Phase			
				Workers and Families				Workers and Families			
Towns	Distance from Mill, kilometers	Base-Year Population	Natural Increase Without Development (2.5% Increase over 5 Years)	Non-Local	Local	120 Workers x 2.3 Family Members	Secondary Workers and Families (0.6 multiplier)	Non-Local	Local	160 Workers x 2.3 Family Members	Secondary Workers and Families (1.2 multiplier)
Green	38	500	513	25	8	75	47	34	12	106	127
Brown	29	500	513	4	8	28	18	5	12	39	47
East	48	13,000	13,325	40	20	138	83	54	27	186	224
Purple	64	500	513	1	5	14	8	1	6	16	19
Blue	38	500	513	2	2	9	5	2	1	7	8
West	80	22,000	22,500	0	5	12	7	0	6	14	17
Red	70	1,500	1,538	0	0	0	0	0	0	0	0
White	60	500	513	0	0	0	0	0	0	0	0
Orange	63	500	513	0	0	0	0	0	0	0	0
Total		39,500	40,491	72	48	276	168	96	64	368	442

[a]Numbers are keyed to appropriate explanatory material in accompanying text.

Table F-3.2. Regional Demographic Effects of Construction (4 mills) and Operation (12 mills) of a Multiple-Mill Site (keyed to explanatory text)

				3[a]				4[a]				5[a]	6[a]
				Construction Phase (4 mills)				Operational Phase (12 mills)					
				Workers and Families				Workers and Families					
Towns	Distance from Mill, kilometers	Base-Year Population	Natural Increase Without Development (2.5% Increase over 5 Years)	Non-Local	Local	480 Workers x 2.3 Family Members	Secondary Workers and Families (0.6 multiplier)	Non-Local	Local	1920 Workers x 2.3 Family Members	Secondary Workers and Families (1.2 multiplier)	Associated Increases in Development[b]	Permanent Population Associated with Development[b]
Green	38	500	513	108	28	313	188	442	126	1306	1567	2873	
Brown	29	500	513	17	28	104	62	65	126	439	527	966	
East	48	13,000	13,325	173	70	559	335	702	284	2268	2722	4990	
Purple	64	500	513	5	18	53	32	13	63	175	210	385	
Blue	38	500	513	9	6	34	20	26	10	83	99	182	
West	80	22,000	22,500	0	18	41	25	0	63	145	174	319	
Red	70	1,500	1,538	0	0	0	0	0	0	0	0	0	
White	60	500	513	0	0	0	0	0	0	0	0	0	
Orange	63	500	513	0	0	0	0	0	0	0	0	0	
Total		39,500	40,491	312	168	1104	662	1248	672	4416	5299	9715	19,430

[a]Numbers are keyed to appropriate explanatory material in accompanying text.

[b]Miners, equipment sales, and repair personnel, etc., assumed to be equal to mill operation personnel.

[c]Including mill workers and families, service personnel and families, and people associated indirectly with development--including mining, machine and equipment sales, repair, etc.

Table F-3.3. Major Assumptions for Work Force Characterization

	In-Migrant Workers, %	Employment Multiplier	Population/Worker
Single-Mill Case			
Construction		0.6[a]	
Primary	60		2.28
Secondary	20		2.28
Operation		1.2[b]	
Primary	60		2.28
Secondary	20		2.28
12-Mill Case			
Construction		0.6[a]	
Primary	65		2.28
Secondary	25		2.28
Operation		1.2[b]	
Primary	65		2.28
Secondary	25		2.28

[a]The ratio of 0.6 was selected as a middle range estimate that falls between the HUD range of 0.3 to 0.9 (see "Rapid Growth from Energy Projects," HUD 1976).

[b]Because construction is temporary, construction base to service ratios are lower than that after operation begins (ibid); therefore the construction ratio was doubled. HUD's estimate for the numbers of secondary workers ranges from 1.1 to 2.3 for each employee of the energy project (ibid.). Consequently, the ratio selected for this model study is conservative.

Table F-3.4. Job Opportunities Generated

Type of Employment	Construction	Operation
Single-Mill Case		
Primary	120	160
Local	48	64
In-migrant	72	96
Secondary	72	192
Local	58	154
In-migrant	14	38
Total	192	352
Local	106	218
In-migrant	86	134
12-Mill Case		
Primary	480	1920
Local	312	672
In-migrant	168	1248
Secondary	288	2304
Local	216	1728
In-migrant	72	576
Total	768	4224
Local	528	2400
In-migrant	240	1824

4. Characterization of the operational work force for the multiple mills was based on the following sets of factors and assumptions:

   (a) The in-migrant/local ratio of 65/35, the multiplier of 2.3 for family members, and the base/service ratio of 1/1.2 remained the same for the multiple mill situation (Tables F-3.3 and F-3.4).

   (b) The size of the work force was determined by multiplying the work force assigned to the model mill (160) by the number of mills (12) at the multiple-mill site (Table F-3.4).

   (c) The distribution of the workers, families, and service personnel was derived by holding constant the percentages used to assign the workers to towns in the single mill case and then applying these same percentages to the total work force for the multiple-mill situation.

5. The additional people included in this column are those expected to be attracted to the region as a result of the mill operations. This would include miners, persons employed in heavy-equipment sales and repair, and persons in induced service jobs associated with these base workers, and their families. The influx of these people may actually begin during construction and continue throughout the operational phase. It should be noted that the numbers represented are expected to at least parallel the numbers of mill workers and induced service workers.

6. This number is the approximate total number of people expected to reside in the region as a direct and indirect result of the operation of 12 mills. This includes the mill workers and families, service workers and families, and indirect employment of associated miners, heavy equipment repairmen, service workers, and families.

APPENDIX F-4. SERVICE DEMAND INCREASES

The information presented in this appendix demonstrates the social and political service demands and costs associated with construction and operation of a single model mill and of a multiple-mill site. The expected population changes and the corresponding increases in the different service categories for each community and county are presented in Tables F-4.1 through F-4.4. A dash (-) has been used when the population increase does not warrant any additional services or service personnel. The ratios used for calculating the increases were derived from Table F-3.3 of Appendix F-3.

The expected costs of new county and municipal service demands are outlined in Tables F-4.5 through F-4.8. Counties and towns are listed in the tables only when expected costs have been identified. All cost estimates have been based on 1977 dollars. Following these tables on cost projections are a series of explanatory notes and a list of sources of information used in developing the projections. These footnotes and references are keyed to the number beside each service subheading in the tables.

Table F-4.1. Incremental Demands on Social Services during Construction of Model Mill

County and City	Current Population	Predicted Population: Project-Related[a]	Predicted Population: Total	New Public Utility Systems Needed[b]: Sewage	New Public Utility Systems Needed[b]: Water	Education: New Students	Education: Add'l Teachers Required[c]	Education: Add'l Annual Operation and Maintenance Costs[d]	Medical Services: Add'l Doctors Needed[e]	Medical Services: Add'l Hospital Beds Needed[f]	Add'l Park Acreage Needed[g]	Protective Services[h]: Add'l Police Officers Needed	Protective Services[h]: Add'l Sheriff's Deputies Needed
County S_1													
Green	500	95	595	-	-	30	-	$27,000					
Brown	500	15	515	-	-	5	-	4,500					
East	13,000	145	13,145	-	-	45	-	40,500					
County total		255		-	-	75	1	$72,000	No Additional Facilities or Personnel Needed		No New Parks Needed	No Additional Officers Needed	
County S_2													
Purple	500	15	515	-	-	5	-	$ 4,500					
Blue	500	15	515	-	-	5	-	4,500					
West	22,000	-	22,000	-	-	-	-	-					
Red	1,500	-	1,500	-	-	-	-	-					
White	500	-	500	-	-	-	-	-					
Orange	500	-	500	-	-	-	-	-					
County total		30		-	-	10	-	$ 9,000					
Regional total	39,500	285	39,785	-	-	85	1	$81,000					

[a]Includes nonlocal construction workers and their families and nonlocal secondary workers and their families.

[b]"X" means new system needed. Sewage treatment required when population density exceeds 2500 persons per square mile, otherwise septic systems used; public water systems justified when population density exceeds 1000 persons per square mile, otherwise private wells used.

[c]Assumptions: (1) Teacher:student ratio of 1:18.2; (2) existing excess capacity for 50 additional students.

[d]Includes town elementary schools (1-6) and county secondary schools (7-12). Cost estimates based on $900 per pupil per year.

[e]Based on doctor:patient ratio of 1:770.

[f]Based on hospital bed:patient ratio of 4.5:1000.

[g]Based on 3.5 acres per 1000 people.

[h]Need for police officers and sheriff's deputies based on one officer per 1000 people. Needs for additional fire protection are outlined in Tables F-4.7 and F-4.8 and discussed in the explanatory notes for Tables F-4.5 through F-4.8, Note 4.

Table F-4.2. Incremental Demands on Social Services during Operation of Model Mill

County and City	Current Population	Predicted Population: Project-Related[a]	Predicted Population: Total	New Public Utility Systems Needed[b]: Sewage	New Public Utility Systems Needed[b]: Water	Education: New Students	Education: Add'l Teachers Required[c]	Education: Add'l Annual Operation and Maintenance Costs[d]	Medical Services: Add'l Doctors Needed[e]	Medical Services: Add'l Hospital Beds Needed[f]	Add'l Park Acreage Needed[g]	Protective Services[h]: Add'l Police Officers Needed	Protective Services[h]: Add'l Sheriff's Deputies Needed
County S_1												NO ADDITIONAL OFFICERS NEEDED	
Green	500	170	670	-	-	50	-	$45,000	-	-	-		
Brown	500	25	525	-	-	10	-	9,000	-	-	-		
East	13,000	275	13,275	-	-	85	-	76,500	-	-	-		
County total		470		-	-	145	5	$130,000	0.5[i]	2	1		
County S_2													
Purple	500	25	525	-	-	10	-	9,000	-	-	-		
Blue	500	25	525	-	-	10	-	9,000	-	-	-		
West	22,000	-	22,000	-	-	-	-	-	-	-	-		
Red	1,500	-	1,500	-	-	-	-	-	-	-	-		
White	500	-	500	-	-	-	-	-	-	-	-		
Orange	500	-	500	-	-	-	-	-	-	-	-		
County total		50		-	-	20	-	$ 18,000	-	-	-		
Regional total	39,500	520	40,020	-	-	165	5	$148,000	0.5[i]	2	1		

[a]Includes nonlocal construction workers and their families and nonlocal secondary workers and their families.

[b]"X" means new system needed. Sewage treatment required when population density exceeds 2500 persons per square mile, otherwise septic systems used; public water systems justified when population density exceeds 1000 persons per square mile, otherwise private wells used.

[c]Assumptions: (1) Teacher:student ratio of 1:18.2; (2) existing excess capacity for 50 additional students.

[d]Includes town elementary schools (1-6) and county secondary schools (7-12). Cost estimates based on $900 per pupil per year.

[e]Based on doctor:patient ratio of 1:770.

[f]Based on hospital bed:patient ratio of 4.5:1000.

[g]Based on 3.5 acres per 1000 people.

[h]Need for police officers and sheriff's deputies based on one officer per 1000 people. Needs for additional fire protection are outlined in Tables F-4.7 and F-4.8 and discussed in the explanatory notes for Tables F-4.5 through F-4.8, Note 4.

[i]0.5 indicates a person needed for at least half-time work; persons working for less than half-time not taken into account.

Table F-4.3. Incremental Demands on Social Services during Construction of Multiple Mills

County and City	Current Population	Predicted Population: Project-Related[a]	Predicted Population: Total	New Public Utility Systems Needed: Sewage	New Public Utility Systems Needed: Water	Education: New Students	Education: Add'l Teachers Required[c]	Education: Add'l Annual Operation and Maintenance Costs[d]	Medical Services: Add'l Doctors Needed[e]	Medical Services: Add'l Hospital Beds Needed[f]	Add'l Park Acreage Needed[g]	Protective Services[h]: Add'l Police Officers Needed	Protective Services[h]: Add'l Sheriff's Deputies Needed
County S_1													
Green	500	400	900	-	-	120	-	$108,000	-	-	1	0.5	-
Brown	500	60	560	-	-	20	-	18,000	-	-	0.5	-	-
East	13,000	635	13,635	X[b]	-	190	-	171,000	-	-	2	-	-
County total		1095		1	1	330	20	$297,000	1	5	3.5	0.5	1
County S_2													
Purple	500	20	520	-	-	5	-	4,500	-	-	-	-	-
Blue	500	30	530	-	-	10	-	9,000	-	-	-	-	-
West	22,000	-	22,000	-	-	-	-	-	-	-	-	-	-
Red	1,500	-	1,500	-	-	-	-	-	-	-	-	-	-
White	500	-	500	-	-	-	-	-	-	-	-	-	-
Orange	500	-	500	-	-	-	-	-	-	-	-	-	-
County total		50		-	-	15	-	$13,500	-	-	-	-	-
Regional total	39,500	1145	40,645	1	1	345	20	$310,500	1	5	3.5	0.5	1

[a]Includes nonlocal construction workers and their families and nonlocal secondary workers and their families.

[b]"X" means new system needed. Sewage treatment required when population density exceeds 2500 persons per square mile, otherwise septic systems used; public water systems justified when population density exceeds 1000 persons per square mile, otherwise private wells used.

[c]Assumptions: (1) Teacher:student ratio of 1:18.2; (2) existing excess capacity for 50 additional students.

[d]Includes town elementary schools (1-6) and county secondary schools (7-12). Cost estimates based on $900 per pupil per year.

[e]Based on doctor:patient ratio of 1:770.

[f]Based on hospital bed:patient ratio of 4.5:1000.

[g]Based on 3.5 acres per 1000 people.

[h]Need for police officers and sheriff's deputies based on one officer per 1000 people. Needs for additional fire protection are outlined in Tables F-4.7 and F-4.8 and discussed in the explanatory notes for Tables F-4.5 through F-4.8, Note 4.

Table F-4.4. Incremental Demands on Social Services during Operation of Multiple Mills

County and City	Current Population	Predicted Population		New Public Utility Systems Needed		Education			Medical Services		Add'l Park Acreage Needed[g]	Protective Services[h]	
		Project-Related[a]	Total	Sewage	Water	New Students	Add'l Teachers Required[c]	Add'l Annual Operation and Maintenance Costs[d]	Add'l Doctors Needed[e]	Add'l Hospital Beds Needed[f]		Add'l Police Officers Needed	Add'l Sheriff's Deputies Needed
County S_1													
Green	500	2225	2,725	X[b]	X[b]	670	-	$603,000	-	-	8	2	-
Brown	500	330	830	-	-	100	-	90,000	-	-	1	-	-
East	13,000	3540	16,540	X[b]	-	1060	-	954,000	-	-	12	-	-
County total		6095		2	1	1830	100	$1,647,000	8	25	21	2	3.5[i]
County S_2													
Purple	500	75	575	-	-	25	-	22,500	-	-	-	-	-
Blue	500	130	630	-	-	40	-	36,000	-	-	-	-	-
West	22,000	-	22,000	-	-	-	-	-	-	-	-	-	-
Red	1,500	-	1,500	-	-	-	-	-	-	-	-	-	-
White	500	-	500	-	-	-	-	-	-	-	-	-	-
Orange	500	-	500	-	-	-	-	-	-	-	-	-	-
County total		205		-	-	65	1	$58,500	-	-	-	-	-
Regional total	39,500	6300	45,800	2	1	1895	101	$1,705,500	8	25	21	2	3.5[i]

[a]Includes nonlocal construction workers and their families and nonlocal secondary workers and their families.

[b]"X" means new system needed. Sewage treatment required when population density exceeds 2500 persons per square mile, otherwise septic systems used; public water systems justified when population density exceeds 1000 persons per square mile, otherwise private wells used.

[c]Assumptions: (1) Teacher:student ratio of 1:18.2; (2) existing excess capacity for 50 additional students.

[d]Includes town elementary schools (1-6) and county secondary schools (7-12). Cost estimates based on $900 per pupil per year.

[e]Based on doctor:patient ratio of 1:770.

[f]Based on hospital bed:patient ratio of 4.5:1000.

[g]Based on 3.5 acres per 1000 people.

[h]Need for police officers and sheriff's deputies based on one officer per 1000 people. Needs for additional fire protection are outlined in Tables F-4.7 and F-4.8 and discussed in the explanatory notes for Tables F-4.5 through F-4.8, Note 4.

[i].5 indicates a person needed for at least half-time work; persons working less than half-time not taken into account.

Table F-4.5. Cost Analysis of Additional Public Facilities and Services Needed during Construction Phase of Single Model Mill[a]

County/City	Education (2)[b]	Total Cost (actual cost over 15 years)
County S_1	Schools (elem. & H.S.) Structure - 3,000 to 3,750 sq. ft. Structure cost - $106,000 to $201,000 Teacher & maintenance cost - $1,380,000	$1,486,000 to $1,581,000

[a]All costs have been derived using 1977 dollars, which were developed at 7% a year, simple interest, and then rounded to the nearest thousand. All operating, maintenance and personnel costs shown are for 15 years. Shows only county(s) and/or town(s) and facilities affected.

[b]Number is keyed to explanatory text in this appendix.

Table F-4.6. Cost Analysis of Additional Public Facilities and Services Needed during Operation Phase of Single Model Mill[a]

County/City	Recreation (1)[b]	Education (2)[b]	Hospital (7)[b]	Total (actual cost over 15 years)
County S_1		Schools - (Elem. & H.S.) Structure - 11,400-14,250 sq. ft. Structure cost - $405,000-492,000 Teacher & maintenance cost - $2,520,000	2 beds - $972,000	$3,897,000 to $3,984,000
East	Community park (additional 1.0 acre) Development - $10,000 Operating & maintenance cost - $39,000			$49,000

[a]All costs have been derived using 1977 dollars, which were developed at 7% a year, simple interest, and then rounded to the nearest thousand. All operating, maintenance and personnel costs shown are for 15 years. Shows only county(s) and/or town(s) and facilities affected.

[b]Numbers are keyed to explanatory text in this appendix.

Table F-4.7. Cost Analysis of Additional Public Facilities and Services Needed during Construction Phase of Multiple Mills[a]

County/City	Recreation (1)[b]	Education (2)[b]	Police Protection (3)[b]	Fire Protection (4)[b]	Water (6)[b]	Hospital (7)[b]	Total Cost (actual cost over 15 years)
County S_1		Schools - (Elem. & H.S.) Structure - 39,600-49,500 sq. ft. Structure cost - $1,405,800-1,707,750 Teacher & maintanance cost - $1,188,000	Personnel (1) - $56,000			5 beds - $648,000	$3,297,800-3,599,750
Green	Community park (additional 1 acre) Development - $10,000 Operating & maintenance cost - $10,400		Personnel (0.5)[c] - $28,000	Station - $375,000 Equipment - $218,000 Personnel (3), operating & maintenance expense - $164,000	Public water system - $1,210,000		$2,015,400
Brown	Community park (additional 0.5 acre) Development - $5,000 Operating & maintenance cost - $10,400						$15,400
East	Community park (additional 2 acres) Development - $20,000 Operating & maintenance cost - $10,400		Personnel (0.5)[c] - $28,000	Personnel (0.5)[c] - $25,000			$83,400

[a]All values are rounded to the nearest thousand. All operating, maintenance and personnel costs are for 4 years. Shows only county(s) and/or town(s) and facilities affected.

[b]Numbers are keyed to explanatory text in this appendix.

[c]0.5 indicates person needed for half-time work.

Table F-4.8. Cost Analysis of Additional Public Facilities and Services during Operation Phase of Multiple Mills[a]

County/ City	Recreation (1)[b]	Education (2)[b]	Police Protection (3)[b]	Fire Protection (4)[b]	Sewage (5)[b]	Water (6)[b]	Hospital (7)[b]	Total (actual cost over 15 years)
County S_1		Schools - (Elem. & H.S.) Structure - 213,600-267,000 sq. ft. Structure cost - $7,587,000-9,211,000 Maintenance cost - $31,620,000	Personnel (sheriff-6) - $1,260,000				25 beds - $12,195,000	$52,662,000-54,286,000
Green	Community park (additional 8 acres) Development - $82,000 Personnel (1) - $150,000 Operating & maintenance cost - $39,000		Personnel (2) - $420,000	Station - $375,000 Equipment - $218,000 Personnel, operating & maintenance cost - $825,000	Sewage system - Plant - $545,000 Collection - $2,057,000 Trunk - $85,000	Public water system - $1,210,000		$6,006,000
Brown	Community park (additional 1 acre) Development - $10,000 Operating & maintenance cost - $39,000							$49,000
East	Community park (additional 12 acres) Development - $123,000 Personnel (1) - $150,000 Operating & maintenance cost - $39,000		Personnel (3.5)[c] - $743,500[d]	Personnel (4) - $753,000				$18,805,500
County S_2		Schools - (Elem. & H.S.) Structure - 1,800-2,250 sq. ft. Structure cost - $64,000-78,000 Teacher & maintenance cost - $1,118,000						$1,182,000-1,196,000

[a]All values are rounded to the nearest thousand except as indicated. All operating, maintenance and personnel costs are for 15 years. Shows only county(s) and/or town(s) and facilities affected.

[b]Numbers are keyed to explanatory text in this appendix.

[c]0.5 indicates person needed for half-time work.

[d]Value not rounded due to hiring of part-time personnel.

EXPLANATORY NOTES FOR TABLES F-4.5 THROUGH F-4.8*

1. Recreation**

   (a) Approximate cost of facilities and development - $10,000 per acre (includes profit, overhead, engineering and design of facilities, and site improvement).

   (b) Assumes one employee per approximately 10-15 acres. Community park acreage determined using 3.5 acres per 1000 inhabitants.

   (c) Operation and maintenance cost assuming salary 80% of total expenditure -

$10,000	annual salary per employee
2,600	operation and maintenance cost
$12,600	approximated total expenditure (per employee)

2. Education

   The range of the figures show the initial cost if all in-migrant pupils were to attend elementary school (low figure) to all attending secondary school (high figure). These figures thus would be inclusive of a division between pupils (e.g. 50% to high school, 50% to elementary). It is the staff's opinion that these figures show a reasonable range of education expenditures the county will be confronted with in the future.

   (a) Structure - allows approximately 150 square foot per high school pupil
   allows approximately 120 square foot per elementary pupil.

   (b) Structure cost (includes profit, overhead and fees) assumptions:
   high school - $34.50 per square foot
   elementary school - $35.50 per square foot

   (c) Operating and maintenance - assumes $900.00 average expenditure per student.

3. Police Protection

   (a) Officers' salaries - approximately $14,000 each per year.

   (b) Police needs determined assuming one officer per 1000 inhabitants.

4. Fire Protection

   (a) Station - new structure full size - approximately 9250 square feet ($39.35 per square foot).

   (b) Equipment - approximate cost as follows:
   Staff cars - $7,700
   1250 gpm pumper - $64,000 each
   Ladder or snorkel truck - $154,000 to $160,000.

   (c) Personnel, operating, and maintenance expense - salary per officer approximately $12,500 per year; salaries assumed to be 90% of total operating and maintenance expenses.

*All cost estimates have been derived using 1977 dollars and developed at a 7% per year simple interest, then rounded to the nearest $5.

**Numbers of topics are keyed to the numbers beside the same topics in Tables F-4.5 through F-4.8.

5/6. Sewage and Water System

Sewage and water system developed using a population of 5000 in 1430 housing units encompassing 250 acres. Assumes public sewage system is normally justified when population density is above 2500 persons per square mile. Assumes public water system is normally justified when population density is above 1000 persons per square mile.

7. Hospitals

Assumes approximately $19,000 for personnel and approximately $13,400 for other expenses. Hospital need determined using 4.5 beds per 1000 inhabitants.

BIBLIOGRAPHY

1. Recreation

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APPENDIX F-5. ESTHETICS AND RECREATIONAL RESOURCES

1. NATIONAL POLICY AFFECTING ESTHETIC AND RECREATIONAL RESOURCES

Passage of several Federal laws, such as the Wilderness Act of 1964, the National Wild and Scenic Rivers Act of 1968, the National Trails System Act of 1968, and the National Environmental Policy Act of 1969, has clearly indicated that the policy of the Federal Government is to foster the preservation and protection of certain segments of the natural landscape so that their values shall be retained for the benefit and enjoyment of present and future generations.[1] Siting and operation considerations relative to uranium mills must include evaluation of potential impacts on natural features covered in these acts.

Since the passage of the National Wild and Scenic Rivers Act, 19 rivers or segments of rivers have received Federal protection,[2] and President Carter has requested that 27 rivers be designated as "study rivers" to be examined for inclusion in the Wild and Scenic Rivers System (Fig. F-5.1.).

Congress passed the National Trails System Act in 1968. The Act defined two major categories of trails; National Scenic Trails and National Recreation Trails. National Scenic Trails are extended, continuous trails selected and developed because of their superior scenic, historical, natural, or cultural qualities. National Recreational Trails vary in length and generally are located close to urban areas. States having several thousand kilometers of trails include Colorado, Idaho, Montana, Utah, Washington, and Wyoming (see Fig. F-5.2).[3]

The Wilderness Act of 1964 set protective restrictions on sensitive landscape zones. Park managers in several areas have already had to take steps to limit use, including the rationing of backcountry visits in Rocky Mountain and Sequoia National Parks, river floats on the Grand Canyon of the Colorado and hiking on the Mt. Whitney Trail.[4]

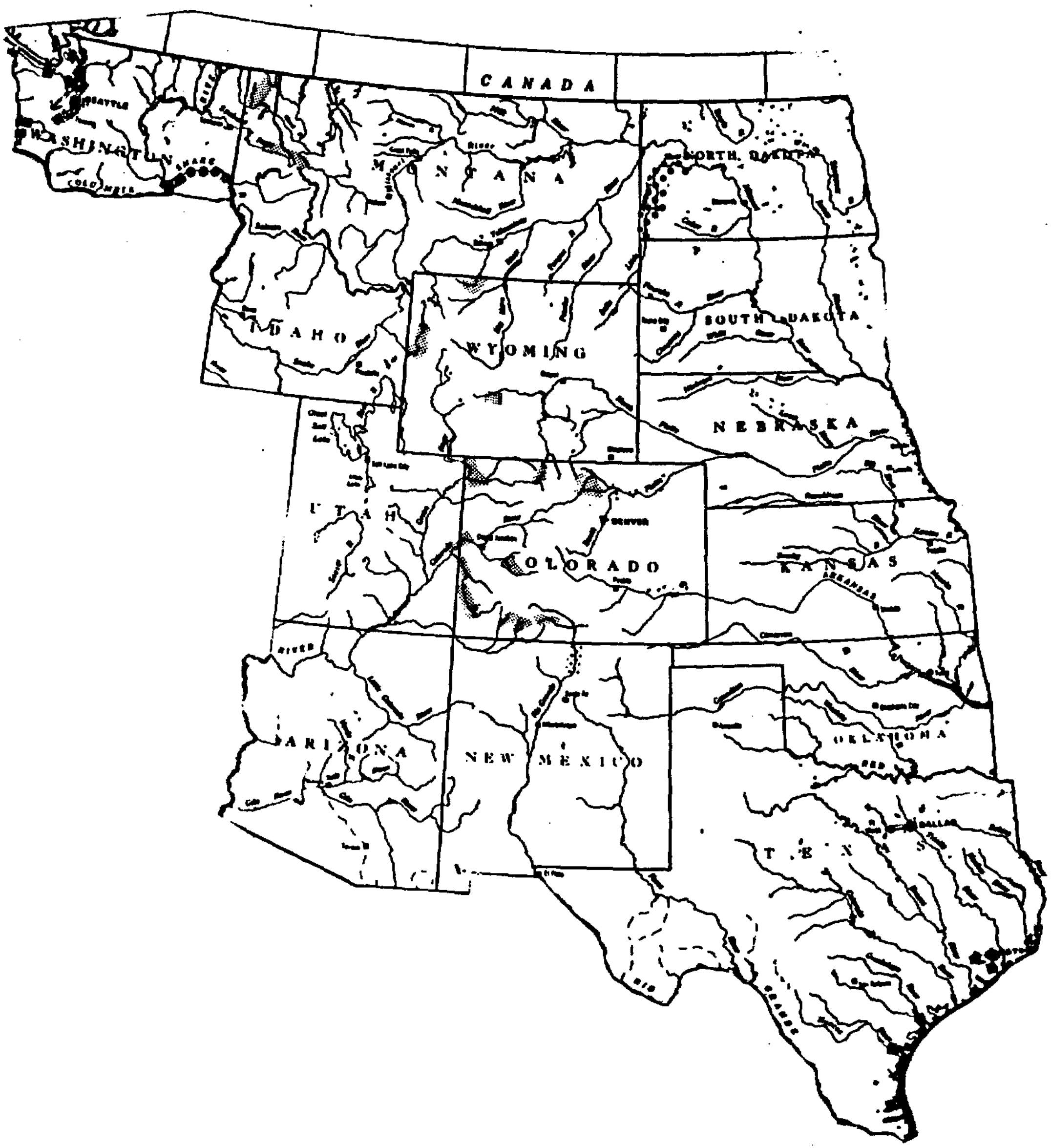
The Forest Service has completed the inventory phase of its current Roadless Area Review (RARE II), with 1920 areas covering 26.6 million ha (65.7 million acres) having been identified as roadless and undeveloped within the National Forest System. Of these areas, 1615 [(covering 25.7 million ha (63.4 million acres)] are in the West. The announced goal of RARE II is to round out the national-forest wilderness system as rapidly as possible so that multiple-use management can proceed on those areas not designated as wilderness.

Although these various programs demonstrate an awareness at the Federal level of the need to set aside portions of the nation's natural areas for esthetic, recreational, and nature-preservation purposes, the actual impact of the programs on mineral exploitation is not yet clearly established. At Lake Mead National Recreation Area, for example, the NPS recently leased over 400 ha (1000 acres) to Exxon for uranium prospecting. Though technically legal since National Recreation Areas are subject to mineral leasing, the leases cover part of an area currently being considered for categorization as wilderness and for inclusion into the Grand Canyon National Park. The NPS originally decided that the lease did not constitute a major Federal action, and therefore was exempt from the requirement that an environmental impact statement be prepared; however, the Secretary of Interior reversed that decision, ruling instead that an impact statement was necessary.[5]

One case that directly involves the esthetic resources of the nation's landscape involves Death Valley National Monument in California. There are approximately 2000 mining claims which cover 15,000 ha (36,000 acres) in the park. Most of these claims are in full view of one of Death Valley's most scenic spots--Zabriskie Point.

2. ESTHETIC CONSIDERATIONS RELATIVE TO THE MODEL MILL

The term "esthetics" implies many factors that relate to the environmental impact of a structure. Aside from the visual impact, there are other stimuli (e.g., smell and hearing) which affect and alter an observer's perception of the particular environment. Since this section deals specifically with the esthetics of the mill and tailings pond, discussion will be limited to a visual/sensory perception of selected views of the site. Landform, vegetation, and settlement,



LEGEND

The National Wild and Scenic Rivers System
Components of state scenic rivers systems
Other rivers under study for the national system

Fig. F-5.1. National Wild and Scenic Rivers. (Taken from "Wild and Scenic Rivers of the United States," The National Geographic Society, Washington, D.C., 1977.)

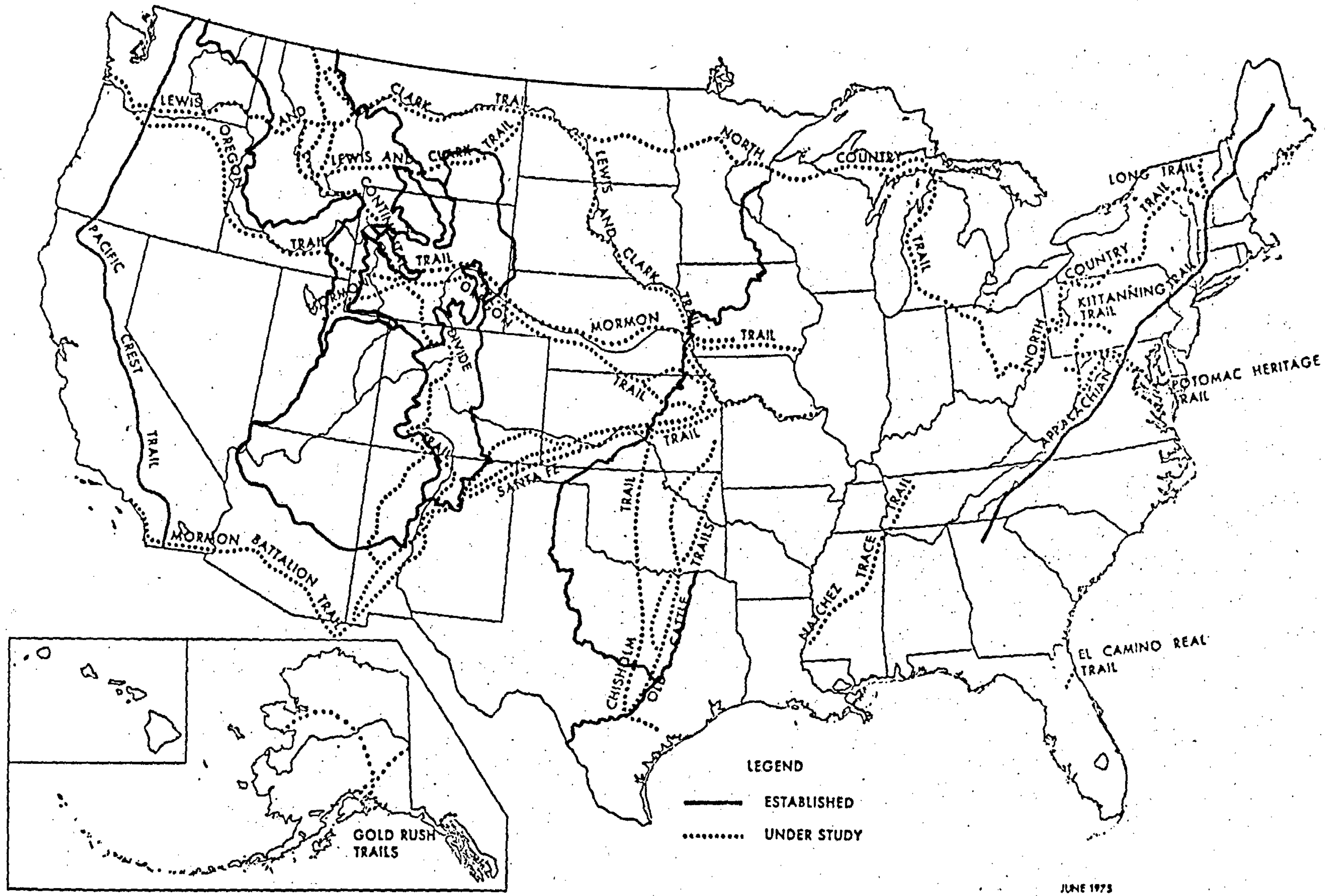


Fig. F-5.2. National Scenic Trails System.

as well as ephemeral elements (lighting, seasons, atmospheric conditions), are key factors which contribute to the visual perception of the environment. Although difficult to measure, the impacts of construction activities on these elements need to be considered in the design process.

The area of surrounding land from which construction of the mill is visible is termed the "viewshed" (see Fig. F-5.3). The viewshed of the model mill has a 8-km (5-mile) radius, and viewpoint selection will depend on the following: (1) viewing population within the area, (2) viewpoint distance from the facility, (3) vertical observer position, (4) direction of view relative to the mill's setting, and (5) visual conditions.[6]

Most of the construction activity associated with the mill and tailings ponds would occur in the central part of the model site, the Open Plains. The Open Plains are characterized by flat, barren topographical features which do little to enhance or screen the mill site.

In designing the mill, the viewshed of the site should be mapped and viewpoint selection made according to the above factors (1-5). It is the responsibility of the designer and construction team to produce structures which exhibit sensitivity to the natural state of the mill site through the use of compatible colors, lines, forms, and textures; e.g., nonreflective building materials (earthtones) instead of highly reflective (metallic) ones; free forms instead of rigid lines; and rough intricate textures instead of smooth, flat textures in building design.

In the open space surrounding the mill site, road construction affects the character of the landscape by introducing strong lines that can be observed for many kilometers. Graded areas are highly visible and may cause permanent damage to the landscape. From the viewshed interpretation, the mill can be observed from any given viewpoint within the viewshed due to the flatness of the topography. The intensity of visual impact depends solely on the observer distance/position relative to the mill (Fig. F-5.4).

In contrast to a viewshed with more rugged, forested terrain, in the model mill site compatible structural design, rather than the surrounding topography, must be relied upon to provide a cosmetic cover-up for construction and operation activities.

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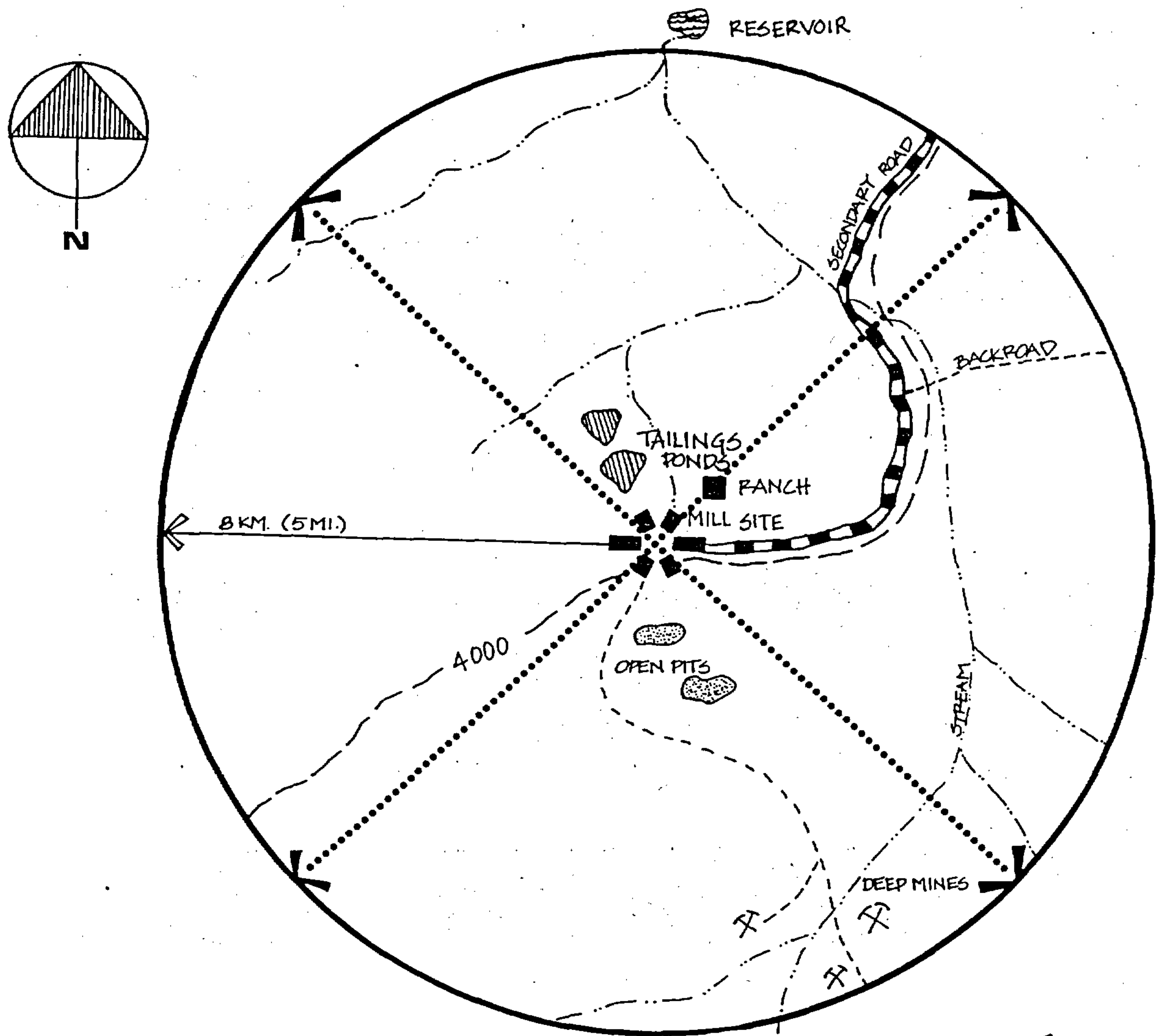

VIEWSHED CONSTRUCTION

"MANMADE ELEMENTS ARE OF LOW UNITY WITH NATURAL ELEMENTS"

Fig. F-5.3. Viewshed for Model Mill Construction.

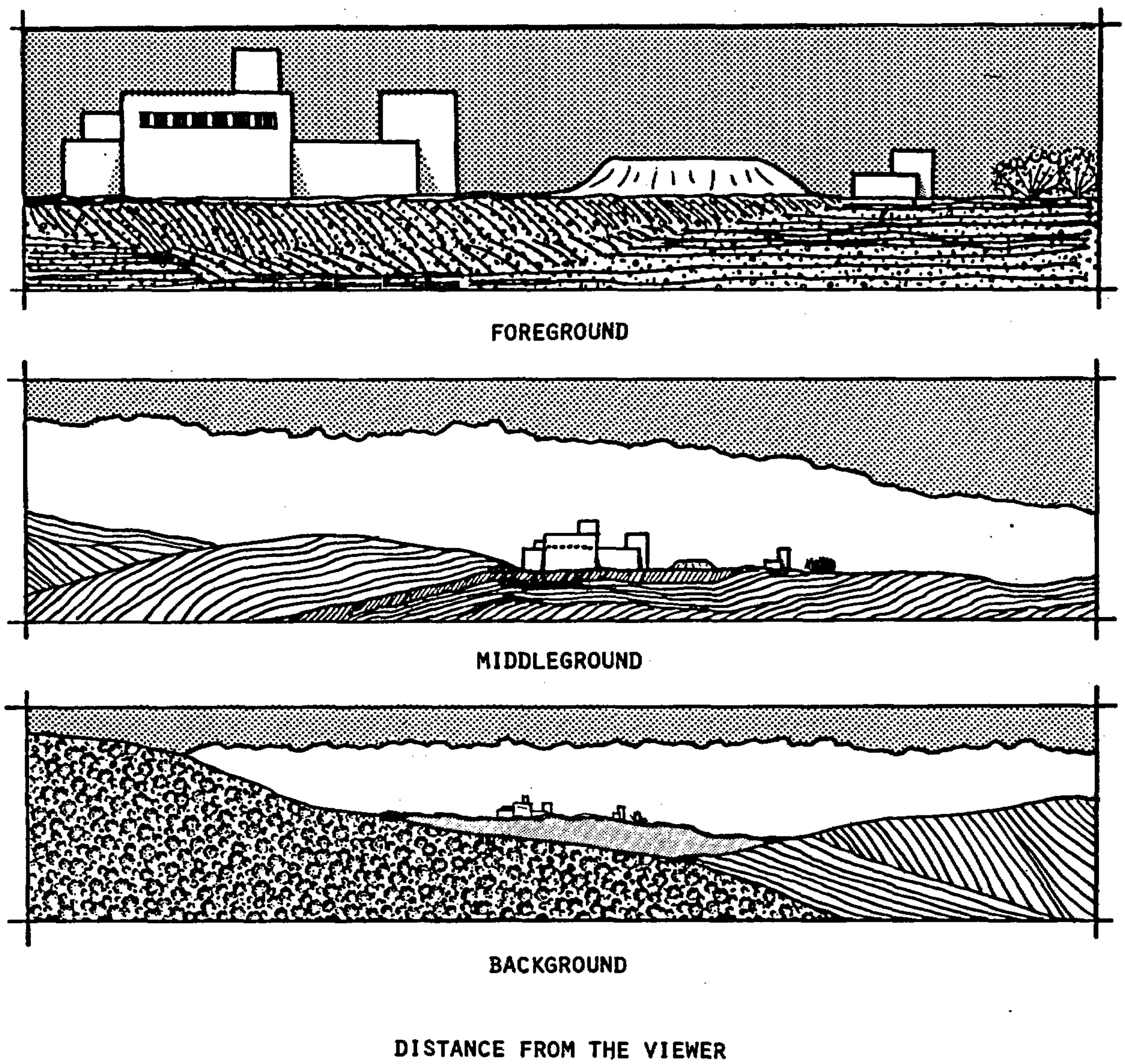

Fig. F-5.4. Relationship between Intensity of Visual Impact and Distance/Position of the Viewer.

APPENDIX F-6. SYNOPSIS OF FEDERAL LAWS AND POLICY STATEMENTS CONCERNING CULTURAL RESOURCES

• The Antiquity Act of 1906 (Public Law 59-209, 34 STAT. 225; 16 U.S.C. 431-433).

Set forth in this act is the basic principle that the Federal Government, acting for all the people, should work toward the protection, preservation, and public availability of the nation's historic and prehistoric cultural resources. With accompanying guidelines, the act provides for Federal control of all cultural resources on federally owned or controlled land and establishes a permit system for investigating them. The act makes it a Federal offense to appropriate, excavate, injure, or destroy any historic ruin or monument located on lands owned or controlled by the United States without permission from the Secretary of the Department having jurisdiction thereof. Further guidance on this matter is contained in ER 405-1-875, 7 May 1973.

• The Historic Sites Act of 1935 (Public Law 74-292, 49 STAT. 666; 16 U.S.C. 461-467).

It is declared in this act to be national policy to preserve for the public historic (including prehistoric) sites, buildings, and objects of national significance. The National Park Service is directed to "make necessary investigations and researches in the United States relating to particular sites ... or objects to obtain true and accurate historical and archeological facts and information concerning the same."

• The Reservoir Salvage Act of 1960 (Public Law 86-523, 74 STAT. 220; 16 U.S.C. 469-469c).

It is required in this act that before any agency of the United States shall undertake the construction of a dam or issue a license for construction of a dam (greater than 5000 acre feet or 40 surface acres of capacity), it shall provide written notice to the Secretary of the Interior. (The provisions of the act apply regardless of the size of the reservoir if the constructing agency finds or is presented with evidence that cultural resources are affected.) The act permits the expenditure of up to 1% of the amount authorized to be appropriated for an individual civil works project for survey, recovery, analysis, and reporting of important scientific, historical, and archeological data which are being or may be irreparably lost or destroyed as a result of civil works undertakings on federally owned lands or on non-Federal lands provided by local interests for certain types of projects.

Before undertaking construction, written notice must be provided the Secretary of the Interior setting forth the site of the proposed project, including the area to be flooded or otherwise changed.

If advised that Federal construction activity may result in the loss of important cultural data, the Secretary of the Interior will subsequently provide notice of such potential loss. The appropriate agency may undertake directly, or by contract with qualified investigators or by transfer of funds to the Secretary of the Interior, the recovery, protection and preservation, analysis, and publication of reports of such data, including surveys or other investigations as in the determination of the agency are needed. The amount expended for such activities may not exceed 1% of the amount authorized to be appropriated for the project, and all expenditures made for such activities are to be treated as nonreimbursable project costs.

The Secretary of the Interior must report annually to Congress on Federal expenditures and accomplishments under this authority.

• The Historic Preservation Act of 1966 (Public Law 89-665, 80 STAT. 915; 16 U.S.C. 470).

This act sets forth the basic concern of the nation for the preservation of its heritage. It provides for an expanded National Register of districts, sites, buildings, structures, and objects significant in American history, architecture, archeology, and culture and makes provision for matching funds to conduct statewide surveys for locating sites to be placed on the National Register.

Under this law, if a site is on the National Register, this fact must be taken into consideration when any project utilizing Federal funds or under Federal permit might adversely affect it. [However, the location of listed sites is published in the National Register and thereby becomes common knowledge; therefore many states do not nominate sites unless they are otherwise protected from casual destruction by the public. Furthermore, the sheer number of archeological sites and the fact that no survey can locate all significant sites (e.g., because of thick ground cover or because sites are buried) means that in no case can the National Register be viewed as the sole source for information about the presence of potentially significant sites to be taken into consideration before or during land alteration or for the purpose of an adequate environmental impact statement.]

Section 106 of this act requires that the President's Advisory Council on Historic Preservation (ACHP) be afforded an opportunity to comment on any undertaking which adversely affects properties listed on the National Register.

Executive Order 11593 (discussed below) applies the same consultation and protection provisions to properties which the Secretary of the Interior determines are eligible for inclusion in the Register. Implementing procedures for consultation with and securing the advice of the ACHP are contained in 36 CFR 800, 25 January 1974.

Agencies are directed to exercise caution to ensure that federally owned cultural properties on lands under their jurisdiction are not inadvertently sold, demolished, or substantially altered until the Secretary of the Interior has the opportunity to review the eligibility of the property for the National Register, and if an eligible property is to be sold, demolished, or altered, the ACHP has an opportunity to comment and steps are taken to make records of the property for deposit in the Library of Congress.

- <u>The National Environmental Policy Act of 1969</u> (Public Law 91-190, 31 STAT. 852; 42 U.S.C. 4321-4347).

This act declares that it is the policy of the Federal Government to use all practical means, consistent with other essential considerations of national policy, to--among other things--improve and coordinate Federal plans, functions, programs, and resources to the end that the nation may preserve important historic, cultural, and natural aspects of our heritage. It directs that, to the fullest extent possible, the policies, regulations, and public laws of the United States shall be interpreted and administered in accordance with the act and that all agencies shall utilize a systematic interdisciplinary approach that will insure the integrated use of the natural and social sciences and the environmental design arts in planning and decision-making which may have an impact on man's environment. It further requires that on all federally sponsored or licensed projects which significantly affect the environment, the responsible official submit an environmental impact statement which assesses the impact of the proposed action and any unavoidable adverse environmental effects (which consistently has been interpreted to include those on archeological and historical resources), and sets forth the alternatives to the project, the long- and short-term results, and any irreversible and irretrievable commitment of resources.

The act charges the government to administer its other policies, regulations, and laws to the fullest extent possible in accordance with these policies. Agencies are directed to develop methods and procedures for "giving unquantified environmental amenities and values appropriate consideration in the decision-making process along with economic and technical considerations."

The act also established the Council on Environmental Quality in the Executive Branch to advise and assist the President in carrying out the provisions of the act and in reviewing environmental impact statements.

- <u>Department of Housing and Urban Development Legislation</u>

Under certain conditions HUD is authorized to make grants for surveys for archeological sites and structures of historical and architectural value, and to fund (on a matching basis) technical assistance and studies, and to fund the acquisition, removal, or preservations of significant structures (40 U.S.C. 461, 42 U.S.C. 1460, 42 U.S.C. 1500, 42 U.S.C. 3303).

- <u>Department of Transportation Legislation</u>

The department's basic legislation charges it with responsibility for making a special effort to preserve historic sites (49 U.S.C. 1651). Construction shall not adversely affect any such site with national, state, or local significance unless there is no feasible and prudent alternative and all possible efforts have been made to minimize the adverse effects (23 U.S.C. 138). Matching funds for archeological research carried out by or under contract with a state highway department on a highway right-of-way will be provided for by the department on the same basis as other construction costs.

• Executive Order 11593

In this Executive Order it is stated: "The Federal Government shall provide leadership in preserving, restoring and maintaining the historic and cultural environment of the Nation. Agencies ... shall (1) administer the cultural properties under their control in a spirit of stewardship and trusteeship for future generations, (2) initiate measures necessary to direct their policies, plans and programs in such a way that federally owned sites, structures, and objects of historical, architectural or archeological significance are preserved, restored and maintained for the inspiration and benefit of the people, and (3) in consultation with the Advisory Council on Historic Preservation (16 U.S.C. 470i), institute procedures to assure that Federal plans and programs contribute to the preservation and enhancement of nonfederally owned sites, structures and objects of historical, architectural or archeological significance."

It is further stipulated in the Executive Order that Federal agencies are to inventory archeological and historical resources under their control or affected by their programs, are to exercise due caution with respect to those resources, give them appropriate and adequate consideration during planning, and do whatever is possible with regard to protecting and, when necessary, recovering those resources.

The Secretary of the Interior is to provide technical and advisory assistance to other agencies in their accomplishment of these goals and is to review agency procedures.

• Archeological and Historic Preservation Act of 1974 (Public Law 93-291, 88 STAT. 174)

This act amends the Reservoir Salvage Act of 1960 (PL 68-523; 74 STAT. 220) so as to expand its application for preserving scientific, prehistoric, historic, and archeological data to include all Federal or federally assisted or licensed construction projects rather than being limited to Federal dam and reservoir sites. The act places coordinating responsibility with the Secretary of the Interior so that a relatively uniform Federal program should be assured. It also provides authorization to all Federal agencies whereby they can seek future appropriations, obligate available monies, or reprogram existing appropriations for the recovery, protection, and preservation of significant scientific, prehistoric, historic, or archeological data. Finally, the act permits agencies to either undertake the requisite recovery, protection, and preservation themselves in coordination with the Secretary of the Interior or, alternatively, to transfer a maximum of 1% of the total amount authorized to be appropriated for each project (not applicable to projects of less than $50,000) to the Secretary of the Interior for this purpose.

• State Laws and Regulations

Most (but not all) states have legislation relative to cultural resources. In general, these laws regulate disturbance of cultural resources on state land, and in some instances and to different degrees, on private land. The increasing corpus of state environmental legislation also usually pertains to cultural resources. In some states effective programs for the investigation, protection, and recovery of cultural resources have been established. These laws vary considerably from state to state.

APPENDIX F-7. CULTURAL RESOURCE FIELD RECONNAISSANCE GUIDELINES

An adequate field reconnaissance for cultural resources in or near a mill site must include: (1) a survey of national, state, and local registries and histories which record or discuss important resources, (2) a well-designed field methodology for locating new sites, and (3) preliminary sampling strategy for determining the content and structure of individual sites. Guidelines for assessing each of these three aspects of the field reconnaissance are presented below. Guidelines such as these will help to ensure that the proper types of methods will be used to locate and then evaluate sites to determine eligibility for inclusion in the National Register and develop a proper mitigation program.

Literature Survey

(1) Thorough search for known sites recorded in various registries;

(2) General search of local histories to identify historic points of interest that may be in the impact area but have not been included in any registry;

(3) Specific search of the local historic literature to provide background data for evaluation of historic structures that remain in the impact area but have not been included in any registry.

Field Reconnaissance for Locating New Sites

(1) Design of a field reconnaissance method which includes total coverage of all ground surfaces in the impact area or a sample of the ground surfaces;

(2) The field reconnaissance must include inspection of those areas covered by various kinds of vegetation and areas with different types of topography;

(3) Design of a sampling procedure for testing probable locations of buried sites may be needed in some cases.

Site Structure and Content

(1) A surface sample of materials should be collected from each site identified and the type; number, and distribution of the materials determined;

(2) Sites should be selectively tested for subsurface features, evidence of a settlement system, and cultural stratification;

(3) Site structure, function, and age should be determined.

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The Final Generic Environmental Impact Statement (GEIS) on Uranium Milling focuses primarily upon the matter of mill tailings disposal. It evaluates both the costs and benefits of alternative tailings disposal modes and draws conclusions about criteria which should be incorporated into regulations. Both institutional and technical controls are evaluated. Health impacts considered were both short and long term. Restatement and resolution of all public comments received on the draft (GEIS) are presented. There are three volumes: Volume I is the main text and Volumes II and III are supporting appendices.

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