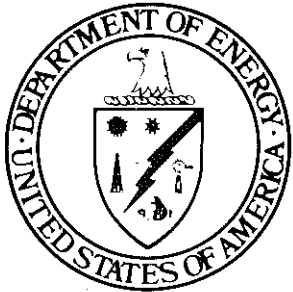


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DOE/EIS-0073

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Final Environmental Impact Statement
Volume 2 of 2



Solvent Refined Coal—I
Demonstration Project

Newman
Daviess County
Kentucky

U.S. Department of Energy

July 1981

Cover Sheet
Final Environmental Impact Statement
Solvent Refined Coal-I Demonstration Project
Newman, Kentucky
DOE/EIS-0073

- (a) Lead Agency: U.S. Department of Energy (DOE)
Cooperating Agencies: U.S. Environmental Protection Agency (EPA), U.S. Army Corps of Engineers (COE)
- (b) Proposed Action:* A cost-shared agreement between the U.S. Department of Energy (DOE) and International Coal Refining Company (ICRC), a general partnership consisting of Air Products Coal Refinery, Inc., and Wheelabrator Coal Refinery, Inc., leading to the construction and operation of a 6000 tons per stream day (tpsd) solvent refined coal demonstration project (SRC-I) with the potential for ultimate development by ICRC of a 30,000-tpsd commercial facility at Newman, Daviess County, Kentucky.
- (c) For Further Information Contact: (1) John L. Morris, SRC-I Program Manager, Office of Coal Processing under the Assistant Secretary for Fossil Energy, Mail Station E-333, Washington, D.C. 20545, Ph: (301) 353-4670; (2) Robert J. Stern, Director, NEPA Affairs Division, Office of the Assistant Secretary for Environmental Protection, Safety, and Emergency Preparedness, Room 4G-064, Forrestal Building, 1000 Independence Avenue, SW, Washington, D.C. 20585, Ph: (202) 252-4600; or (3) Stephen H. Greenleigh, Esq., Acting Deputy General Counsel for Programs, Room 6D-033, Forrestal Building, 1000 Independence Avenue, SW, Washington, D.C. 20585, Ph: (202) 252-6947.
- For Copies of the EIS Contact: James A. Reafsnyder (615/576-1055)
Research and Development Manager
SRC-I Project Office, U.S. Department of Energy
P.O. Box E
Oak Ridge, Tennessee 37830
- (d) Designation: Final EIS (FEIS)
- (e) Abstract: The Statement assesses the potential environmental impacts associated with the construction and operation of a 6000-tpsd-capacity coal liquefaction facility at Newman, Kentucky which will demonstrate the technical operability, economic viability, and environmental acceptability of an SRC-I process. Impacts assessed include the following: effects of the project on occupational and public health resulting from the production and use of SRC products; potential impacts on terrestrial and aquatic ecology, including State and Federally declared threatened or endangered species; potential and expected impacts on

*As part of the restructuring of the Federal Synthetic Fuels Program, the DOE proposed to rescind FY 1981 funding for the SRC-I project and to terminate its involvement in the project after prior year funds are exhausted. The Congress, however, decided not to rescind the FY 1981 funding. As stated in Senate Report 97-67, \$22.5 million is made available for the SRC-I demonstration to continue detailed design activity and other related work during FY 1981, and \$135 million is deferred until FY 1982. The Administration is currently developing plans to meet the Congressional directive.

land use; withdrawal and alteration of "prime" agricultural land; projected effects on floodplain and wetland areas; potential impacts on surface water and groundwater; potential impacts on ambient air quality; potential change of the cultural landscape; potential impacts on sites of archaeological significance; and changes to existing economic and social characteristics of the site area. Additionally, the statement presents an assessment of potential long-range and cumulative impacts of a future commercial expansion of the proposed facility at the proposed site to an approximately 30,000-tpsd capacity. The effects of continued operation of the demonstration plant at demonstration plant capacity, mothballing, conversion to another government use, and decommissioning are also considered. A construction and operational monitoring plan to assess the effectiveness of the planned mitigatory measures for the duration of the demonstration phase is also presented. In assessing the potential environmental impacts of the proposed action, several programmatic and project alternatives are considered and evaluated. The range of alternatives assessed includes proceeding with the proposed action, modifying the action and subsequently continuing the project, delaying the action, and terminating the contract with no further action. The alternatives section includes evaluation of alternative plant designs. Impacts of constructing and operating the proposed facility at two alternative sites are evaluated.

- (f) A Record of Decision will be issued no earlier than 30 days after the FEIS Notice of Availability is published in the *Federal Register*. A Floodplain-Wetlands Statement of Findings will also be issued.

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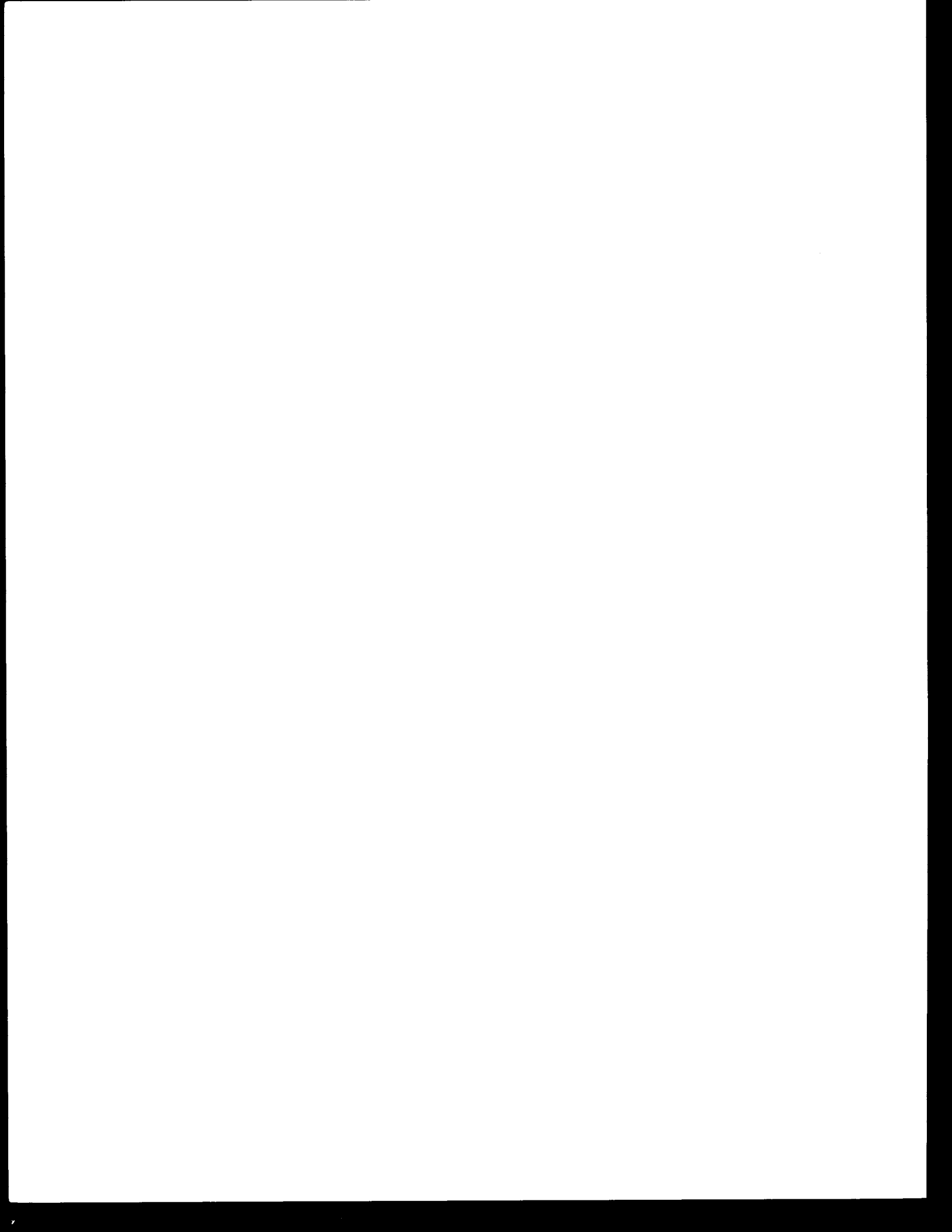
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Appendix B

SELECTION OF THE PROPOSED AND ALTERNATE SITES

B.1 INTRODUCTION

In 1976, Rust Engineering Company under the sponsorship of the Kentucky Center for Energy Research (KCER) initiated an alternate site analysis for selection of a site for a 2000-ton/d SRC-I plant. The Rust study evaluated sites from a list of potential Kentucky sites supplied by the KCER. The siting criteria used in the Rust study were primarily physical, engineering, and economic factors that were judged to be important for construction and operation of the SRC-I plant. Newman, Kentucky, was rated as the preferred site and Equality and Lewisport were rated as prime alternative sites. At that time, the Executive Orders 11988 and 11990 concerning floodplain/wetland encroachment had not been issued, and the U.S. Department of Energy (DOE) was not a participant in the project.

After Rust Engineering completed its site selection activity for the SRC-I project, several important events transpired. The DOE became a participant in the project, the proposed plant capacity was increased to 6000 tons per stream day (tpsd) with the goal of commercial expansion to 30,000 tpsd in the future, Executive Orders pertaining to floodplain/wetland encroachment were issued (May 24, 1977), and the National Environmental Policy Act (NEPA) process was altered by new CEQ regulations (November 29, 1978). The Department of Energy's Request for Proposal (RFP) to solicit an industrial partner for the SRC-I Demonstration Project required the industrial respondents to submit a site-specific proposal. Newman, Kentucky, having been chosen in the 1976 Rust site selection study, was proposed as the site for the SRC-I project. DOE, taking NEPA responsibility for the issuance of the SRC-I Environmental Impact Statement (EIS), enlisted Oak Ridge National Laboratory (ORNL) to prepare the EIS for their review. Although a site had already been proposed for the project (as specified in DOE's RFP and contract with its industrial partner), it was recognized that an evaluation of reasonable alternatives to the proposed action, including alternative sites, was necessary. Oak Ridge National Laboratory evaluated a large number of potential sites. The evaluation included the original KCER sites but also included sites identified for other synfuel demonstration projects in order to give regional diversity to the study. The proposed Newman site had been previously evaluated and primary baseline data had been collected from an extensive monitoring program conducted at the site by Dames and Moore.

A major difference between the alternate site analyses performed by Rust Engineering and ORNL is that the ORNL analysis placed primary emphasis on environmental criteria and identified the two environmentally least sensitive sites as alternatives to the Newman site. The Rust site selection study places primary emphasis on engineering criteria. Section B.2 of this appendix describes the actual site selection process conducted by Rust in 1976, which includes the Newman site. Section B.3 describes the ORNL analysis, which evaluates sites other than Newman for selection of two alternative sites for evaluation against Newman in Sects. 2.3.2, 4.3, and 4.4.

B.2 THE RUST SITE SELECTION STUDY

This section of Appendix B discusses the siting study that resulted in the choice by the industrial partner of the Newman site as the proposed site for the SRC-I facility. This study also resulted in the selection of a primary (Equality) and a secondary (Lewisport) alternative to the Newman site.

A site selection study was performed in 1976 by the Rust Engineering Company in conjunction with the KCER. The purpose of the study, completed in October 1976, was to investigate potential sites for a 2000-ton/d SRC-I facility in Kentucky. The following is a summary of the four phases of the site selection study.

B.2.1 First phase

The first-phase criteria used in the site selection study were:

1. area of 300 to 400 ha (800 to 1000 acres),
2. navigable river adjacent to site for potential barge facility,
3. water supply of at least 100 liters/s (1600 gpm) initially and 1000 liters/s (16,000 gpm) ultimately,
4. railroad contiguous to site or nearby,
5. at least half of site above 100-year flood elevation,
6. suitable topographic features,
7. suitable plot shape, and
8. possible ash disposal alternatives.

Criterion 2 above resulted in restriction of potential sites to the Ohio, Mississippi, Tennessee, and Green Rivers. Criterion 4 imposed a further geographic restriction. Investigation of the remaining potential areas resulted in identification of 24 areas that merited further study. Included in this preliminary list are three sites previously investigated by the Kentucky Department of Commerce: Baskett, Paradise, and Lewisport. At the time of site selection (1976), the proposed boundaries of the Newman site were such that it fulfilled criterion 5.

B.2.2 Second phase

The second phase of the site selection procedure consisted of detailed evaluation of the 24 areas. At this stage, many areas were eliminated from further consideration for the following reasons:

1. Land was under multiple ownership.
2. Topography was rough.
3. Road access was poor. (This criterion did not consider potential traffic problems.)
4. Percentage of land area in floodplain was large.
5. Site had been strip-mined.
6. Property had been recently sold or was being planned for development.
7. Acreage was insufficient.
8. Site had been deep-mined.

The list of potential sites was thereby reduced to the following ten:

<u>Site name</u>	<u>County</u>
Siloam	
Buena Vista	Lewis
Carrollton	Carroll
Holt Bottom	
Lewisport	Hancock
Newman	Daviess
Equality	Ohio
Paradise	Muhlenburg
DeKoven	Union
Columbus Far South	Hickman

B.2.3 Third phase

Third-phase investigation of the 10 remaining sites resulted in elimination of five, for the following reasons:

1. The Siloam site was declared "not for sale" by its owners.
2. The relatively remote Holt Bottom site was sold approximately three years before the siting study was conducted and also was declared "not for sale."
3. The Paradise site has been deep- and strip-mined; therefore, it would be prohibitively expensive to develop.
4. The DeKoven site has been deep-mined, and the topography is fairly severe.
5. The Columbus Far South site has potential barge facility maintenance problems due to sand bars, and is in seismic Zone 3, according to Algermissen.¹

B.2.4 Fourth phase

Finally, the five remaining sites were rated according to several criteria and a weighted-average point total was calculated. The criteria and their relative importance in the calculation of total point scores are listed below.*

<u>Criteria</u>	<u>Importance</u>
• Acquisition difficulty (generally, the more ownership parcels in the site area, the more difficult acquisition will be)	2
• Usable area (floodplain is considered usable because it can be diked for ponds)	1
• Flood-free percentage (percentage of site area above 100-year floodplain)	2
• Site preparation (amount of clearing and grading required)	4
• Proximity to coal supply (source presumed to be Madisonville, Kentucky)	8
• Water supply (amount of capital required to guarantee supply during periods of low flow)	1
• Highway accessibility (size of adjacent highway)	2
• Railroad accessibility (size of adjacent railroad)	4
• Waterway accessibility (transport capacity of adjacent waterway)	3
• Labor availability (size of labor force in adjacent counties)	6

* Rated on a scale from 1 (least important) to 8 (most important).

The Newman site was rated as the most desirable site for the SRC-I facility on the basis of ease of acquisition, site preparation, highway access, rail access, and labor availability, as well as on an overall basis. The Equality site, which ranked second in overall suitability, was rated as most desirable in the categories of proximity to coal supply, rail access, and labor availability. On the basis of the overall rankings, the Newman site was chosen as the preferred site, and the Equality and Lewisport site were selected as the primary and secondary alternates, respectively.

At this stage of the site selection study, a literature search was conducted to determine, on a preliminary basis, whether any archaeological or historical resources or rare or endangered species had been recorded on the preferred or the alternate sites. No sites of archaeological or historical significance had been recorded on the Newman or Equality sites (R. B. Clay, Kentucky State Archaeologist, personal communication, 1976; and E. W. Melton, Kentucky Heritage Commission, personal communication, 1976), but the Lewisport site contained a recorded burial field (R. B. Clay, Kentucky State Archaeologist, personal communication, 1976) and was near a building which had potential for designation as historically significant (E. W. Melton, Kentucky Heritage Commission, personal communication, 1976). Rare or endangered species potentially could be found on all three sites (J. Durell, Kentucky Department of Fish and Wildlife Resources, personal communication, 1976). None of the three sites appeared to present any severe development constraints at this stage, but further investigation was deemed necessary.

B.3 THE ORNL SITE SELECTION STUDY

This appendix describes the method used to select two alternative sites in addition to the proposed Newman site. Additional sites were identified for the purpose of comparing the environmental impacts anticipated at the Newman site to impacts at other sites that could be considered. This method identified two alternative sites for analysis: Ravenswood, in Jackson County, West Virginia, and Equality, in Ohio County, Kentucky. The selection of these sites was based on a survey of sensitive environmental issues. The results of the analysis of environmental impacts at the two alternative sites are discussed in Sects. 4.3 and 4.4 and are summarized and compared to the proposed site in Sect. 4.2.5 of this DEIS.

The two sites selected for detailed environmental analysis were chosen by comparative evaluation from a set of 25 candidate sites (Table B.1). All candidate sites have been identified as possible alternative sites for coal conversion demonstration facilities.²⁻⁶ However, it should be noted that not all identified potential sites have been considered. The 25 candidate sites were selected from a larger set of sites, based on two requirements. The first requirement was that a candidate site be identified and considered, at least in part, from an environmental perspective in a site selection document. The second requirement was that the site be well defined rather than identified as a much larger area (such as a county) within which a proposed facility could be located.

Any of these 25 sites may be initially considered suitable for an SRC demonstration facility; however, additional constraints must be imposed regarding plant size, design, and location. Consequently, 15 candidate sites were eliminated from further consideration because of failure to satisfy the following constraints identified for SRC-I:

1. a minimum of 323.8 to 404.8 ha (800 to 1000 acres) of available land,
2. a navigable river close or contiguous, and
3. a water supply yielding 1600 gpm initially with potential for 16,000 gpm.

Table B.1 lists the 25 sites and indicates which of these sites were eliminated for failure to satisfy these constraints. A site failing to satisfy any one of these constraints often was not evaluated for the other screening criteria since these factors determined minimal acceptability of the sites.

The remaining sites (Table B.2) were evaluated on the basis of seven important environmental issues. For each issue, each site was rated plus (+) or minus (-) or zero (0) to indicate, respectively, a potential for beneficial, adverse, or little or no impact relative to that issue (Table B.3 is an example comparison for two of the sites). The ratings were determined through

Table B.1. Initial site screening—sites not satisfying physical constraints^a

Alternative sites	Physical constraints ^a		
	1	2	3
1. Pigeon, Shelby County, Tenn.			
2. Rivergate, Shelby County, Tenn.	X		
3. Mud Island, Shelby County, Tenn.	X		
4. North, Shelby County, Tenn.	X		
5. Lewisport, Hancock County, Ky.			
6. Equality, Ohio County, Ky.			
7. Moro Island, Randolph County, Ill.	X		
8. Banner, Fulton County, Ill.			
9. Dykersburg, Williamson County, Ill.			X
10. New Athens, St. Clair County, Ill.			
11. Mt. Vernon, Posey County, Ind.			
12. Carrs, Lewis County, Ky.		X	
13. Belmont, Belmont County, Ohio		X	
14. Dilles Bottom, Belmont County, Ohio	X		
15. Haverhill, Scioto County, Ohio			
16. Clinton, Armstrong County, Pa.		X	
17. Crucible, Greene County, Pa.		X	
18. Ravenswood, Jackson County, W.Va.			
19. North Point Pleasant, Mason County, W.Va.			
20. Ben's Run, Monongalia County, W.Va.			
21. Site A, Noble County, Ohio		X	
22. Site D, Noble County, Ohio		X	
23. Site E, Noble County, Ohio		X	
24. Site F, Noble County, Ohio		X	
25. Site G, Noble County, Ohio		X	

^aPhysical constraints are (1) 323.8 to 404.8 ha (800 to 1000 acres) of available land, (2) a navigable river close or contiguous, and (3) a water supply yielding 1600 gpm initially with potential for 16,000 gpm.

Table B.2. SRC-I sites remaining after initial screening

Site No.	Site name
1	Pigeon, Shelby County, Tenn.
5	Lewisport, Hancock County, Ky.
6	Equality, Ohio County, Ky.
8	Banner, Fulton County, Ill.
10	New Athens, St. Clair County, Ill.
11	Mt. Vernon, Posey County, Ind.
15	Haverhill, Scioto County, Ohio
18	Ravenswood, Jackson County, W.Va.
19	North Point Pleasant, Mason County, W.Va.
20	Ben's Run, Monongalia County, W.Va.

contact with State and local agencies and knowledgeable persons, and through use of maps, siting reports, and other publications.

Each potential site was compared to every other site in Table B.4 on the basis of the ratings from the seven environmental issues' ratings. For each pair of sites, the site with the more positive rating for the majority of the variables was selected as the more preferable (least environmentally sensitive) site.

Table B.3. Comparison of two sites on seven important environmental variables

Variable	Site 2 Pigeon	Site 11 ^a Mt. Vernon
Surface water quality		
Significant impact potential exists at the site	0 ^b	0
Endangered species		
Breeding area or significant habitat, known or suspected	0	0
Wetlands		
Significant wetlands at or near the site	—	0
Geologic hazard		
Potential for slope failure and/or seismic risk	—	—
Prime agricultural soils		
Large portions of site having soils classified as Prime Agricultural Soils	0	0
Groundwater use		
Potential impacts to use of groundwater, quality or quantity	—	—
Air quality		
Non-attainment area for ozone, sulfur dioxide, or suspended particulates	—	0

^aSite 11, at Mt. Vernon, is selected over site 2, Pigeon, since it is rated more positively (lower impact potential) for three issues, wetlands, groundwater use, and air quality, and equivalent for the remainder.

^bKey to potential impacts: + Beneficial
0 Little or no impact
— Adverse

Table B.4. Rating of the ten remaining potential sites on seven environmental variables

Site name	Site No.	Variables ^a						
		1	2	3	4	5	6	7
Pigeon, Tenn.	1	0	0	—	—	0	—	—
Lewisport, Ky.	5	0	0	0	0	0	0	0
Equality, Ky.	6	0	0	0	0	0	0	0
Banner, Ill.	8	—	0	—	0	0	0	0
New Athens, Ill.	10	0	0	0	0	—	0	—
Mt. Vernon, Ind.	11	0	0	0	—	0	0	0
Haverhill, Ohio	15	0	0	0	0	0	0	—
Ravenswood, W.Va.	18	0	0	0	0	0	0	0
North Point Pleasant, W.Va.	19	0	0	0	0	0	0	0
Ben's Run, W.Va.	20	0	0	0	0	0	0	0

^aKey to variables:

1. Surface water — impact based on size and productivity of water body.
2. Endangered species — significant habitat or breeding area.
3. Wetland
4. Geologic hazards
5. Prime agricultural soils
6. Groundwater use
7. Air quality — nonattainment of ozone, SO₂, or suspended particulates.

Table B.5 is the matrix that results from the comparison, in pairs, of all sites. Each entry in the matrix is the number of the more preferable site from the comparison of the row-numbered site to the column-numbered site. Since there are a total of ten sites, there are nine comparisons of any one site to other sites. The more frequently a site was rated superior to another site, the more preferable the site. Table B.6 shows the number of times a given site was rated "superior" in the pair-wise comparison shown in Table B.5.

Table B.5. Comparison matrix for potential SRC-I sites

Site No.	20	19	18	15	10	8	6	5
1	10	19	18	15	10	8	6	5
5	^a	^a	^a	5	5	5	^b	
6	^a	^a	^a	6	6	6		
8	20	19	18	15	^b			
10	20	19	18	15				
11	20	19	18					
17	20	19	18	^a				
20	20	19	18					
21	^a	^a						
22	^a							

^aSites are equal.

Table B.6. Site rating following the pair-wise comparison for potential SRC-I sites

Site name	Site No.	Is superior to: (number of sites)	Is equal to: (number of sites)
Pigeon	1	0	0
Lewisport ^a	5	4	4
Equality ^a	6	4	4
Banner	8	1	0
New Athens	10		
Mt. Vernon	11	2	1
Haverhill	15	2	1
Ravenswood ^a	18	4	4
North Point Pleasant ^a	19	4	4
Ben's Run ^a	20	4	4

^aThese sites are rated best on the basis of this comparison.

For the issues considered, there are five sites that were rated equivalently as having the fewest sensitive environmental issues: Lewisport, Kentucky; Equality, Kentucky; Ravenswood, West Virginia; North Point Pleasant, West Virginia; and Ben's Run, West Virginia. These sites were further evaluated on the basis of 15 additional environmental issues which included physical, biological, and socioeconomic effects of the demonstration plant (Table B.7). Each set of sites was evaluated by the method used to produce the matrix in Tables B.4, B.5, and B.6. From this evaluation (Table B.8), Ravenswood was determined the most preferable alternative site. Although Lewisport and North Point Pleasant were rated lower, the Equality and Ben's Run sites were rated equivalently on both the first and second comparison matrices. Although the method could not distinguish between these two sites, it was necessary to select one additional alternative site. It had been previously decided that at least two alternative sites were necessary. Because of the constraints of time and the unavailability of resources, it was not possible to visit each of the remaining sites; therefore, the second alternative site at Equality was selected on the basis of location and previous consideration by the industrial partner. The first alternative site, Ravenswood, is located in West Virginia, on the Ohio

Table B.7. Second evaluation ratings for potential SRC-I sites

Environmental issues	Site No.				
	5	6	18	19	20
Socioeconomics					
Infrastructure	- ^a	-	0	0	-
Historic/arch sites	-	0	0	0	0
Transportation	-	0	-	-	-
Employment	0	0	0	0	+
Finance	+	+	+	+	+
Ecology					
Surface water	-	-	0	-	0
Vegetation	0	-	0	-	0
Aquatic habitat	-	0	0	0	0
Terrestrial habitat	-	-	-	-	-
Land use	-	0	-	-	-
Physical environment					
Lithology	0	0	0	0	0
Soils	-	-	0	-	-
Groundwater	0	-	-	-	-
Structure	-	0	-	0	-
Topography	+	-	-	-	-

^aKey to potential impacts: + Beneficial
 0 Little or no impact
 - Adverse

Table B.8. Second comparison matrix for SRC-I sites

Site name	Site No.	Is superior to (number of sites)	Is equal to (number of sites)
Lewisport	5	0	0
Equality ^a	6	2	1
Ravenswood	18	4	0
North Point Pleasant	19	1	0
Ben's Run	20	2	1

Site No.	20	19	18	6
5	20	19	18	6
6	b	6	18	
20	18	18		
21	20			
22				

^aEquality (selected over Ben's Run due to location in Kentucky and previous consideration in siting study for SRC-I).

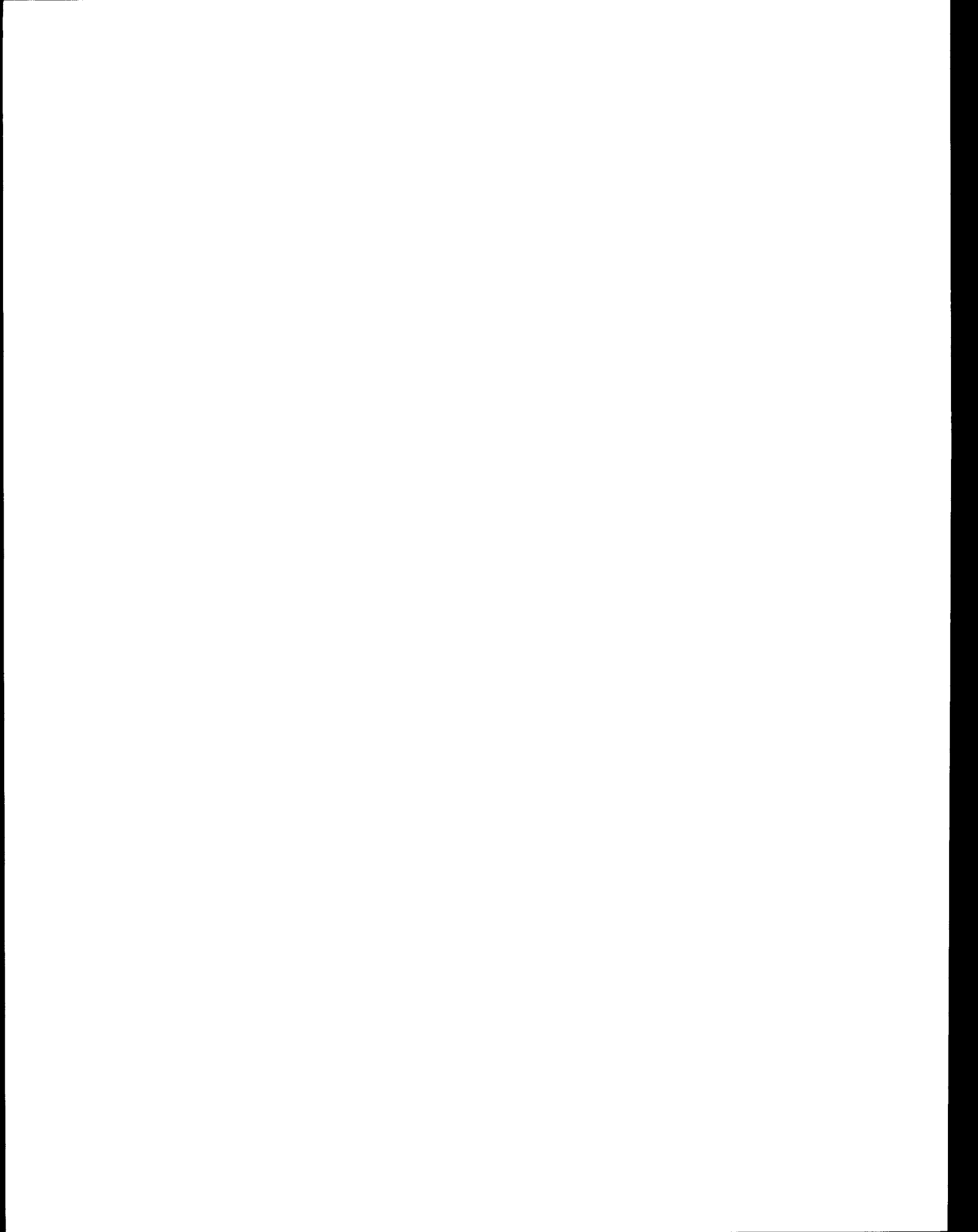
^bSites are equal.

River. The Equality site is located on the Green River in Kentucky. Also, Equality was previously considered as a prime alternative site for SRC-I in a siting study by Rust Engineering and the Kentucky Center for Energy Research (reported in Appendix P of the SRC-I Environmental Report, ref. 2).

Impacts on the proposed Newman site and at the alternative Ravenswood and Equality sites are evaluated in Sect. 4 and compared in Sect. 2.3.2.1.

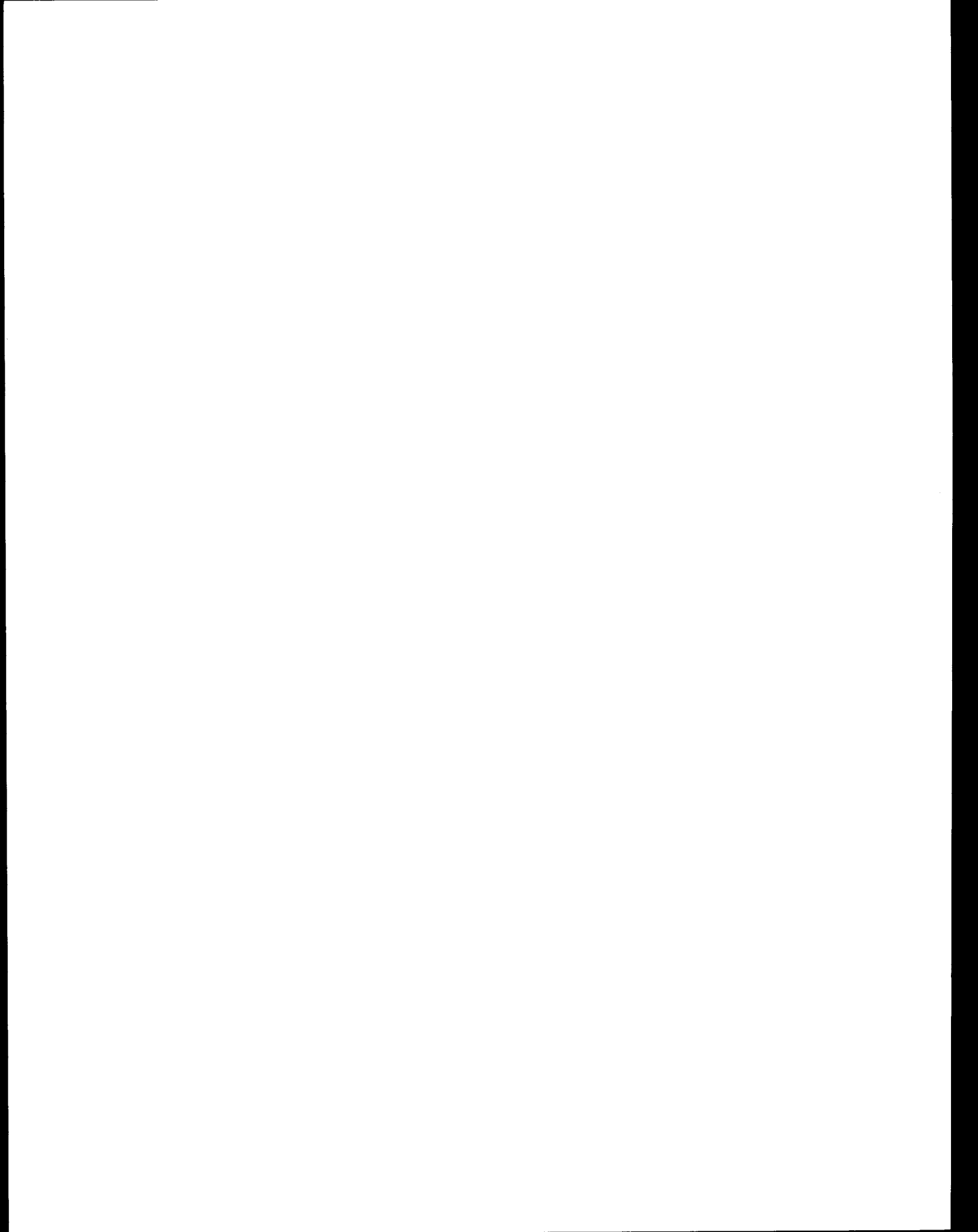
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Appendix C

PLANT DESIGN AND CHARACTERIZATION OF EFFLUENTS



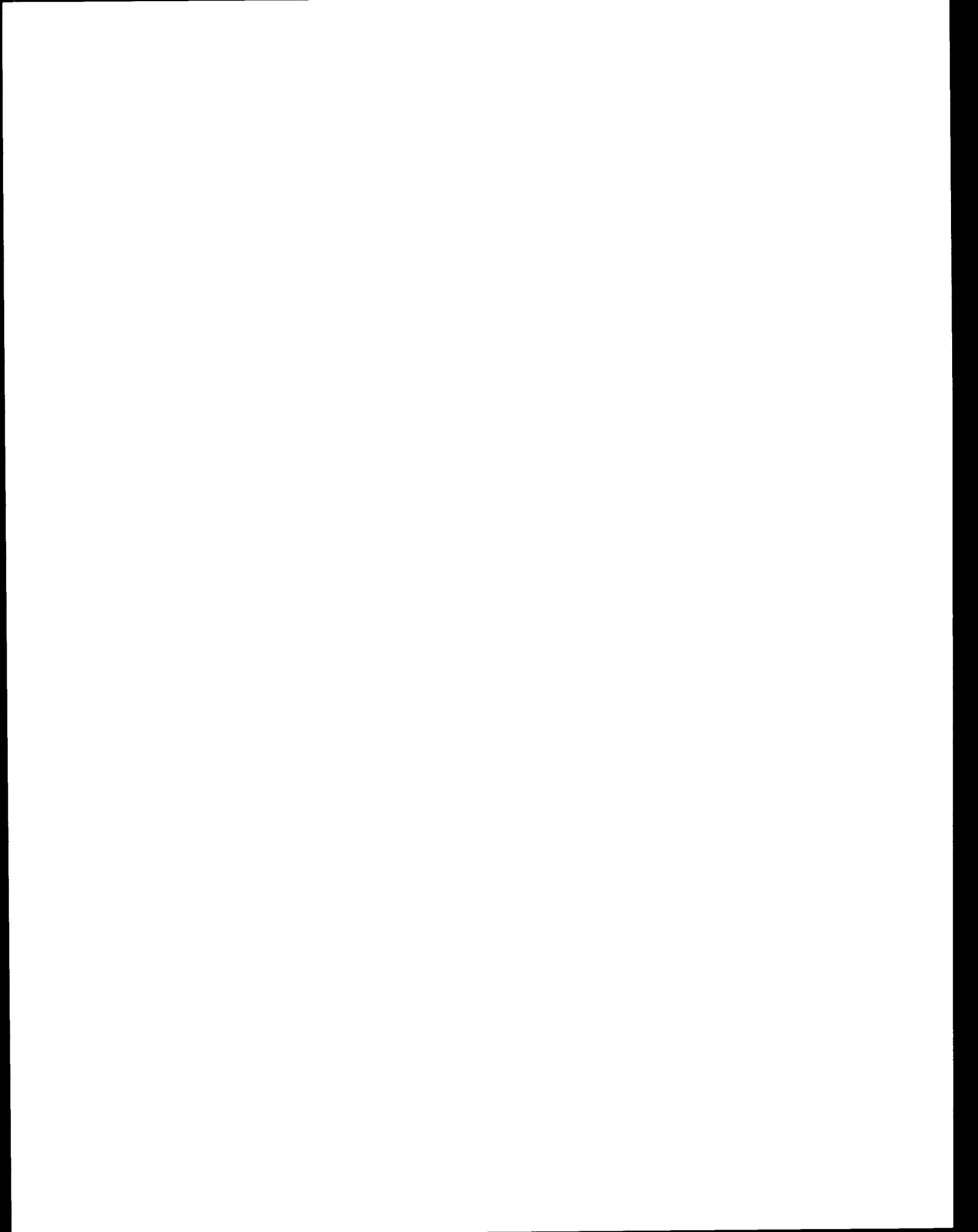
Appendix C

PLANT DESIGN AND CHARACTERIZATION OF EFFLUENTS

This appendix discusses various aspects of the proposed and alternative plant designs, the estimated emission rates of various pollutants, and summarizes resource requirements during the construction and operating phases.

The following changes from the Phase Zero conceptual design are being evaluated and have been incorporated in the data presented:

1. The site acreage is now extended to 1484 acres rather than 1050 acres.
2. Coal feed to the facility has been changed from 6606 to 6000 tons per stream day.
3. The coal is now pulverized to 200 mesh rather than 20 mesh.
4. A barge dock includes capability for construction equipment delivery and possibly coal delivery.
5. The flare system includes a controlled combustor system.
6. The zero wastewater discharge system is the baseline, with an option to discharge treated wastewater when river quality permits and water recycle is not possible.
7. Air coolers and wet indirect cooling systems have been incorporated for heat exchangers on heavy hydrocarbon oil streams containing material whose boiling point is 500°F minimum.
8. There are some changes in the plot plan to reflect the latest process changes.
9. The deashing technology is currently the Kerr-McGee Critical Solvent Deashing process.
10. The GKT gasification technology is now used rather than the Texaco gasification technology.
11. The oxygen plant now produces oxygen at low pressure rather than at high pressure for feed into the gasifier.
12. The expanded bed hydrocracker design basis is to convert one-third of the SRC with 85% conversion to material boiling at 850°F maximum.
13. The liquid hydrogen storage system has been eliminated.
14. Reduced coal-feed rate and deashing equipment result in reduced throughputs of the expanded bed hydrocracker and coker/calcliner.
15. All of the plant's fired heaters will utilize desulfurized by-product fuel gas.



Appendix C

PLANT DESIGN AND CHARACTERIZATION OF EFFLUENTS

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C.1 PROPOSED PLANT DESIGN

This section describes the basic SRC-I process and the major features of the demonstration plant as currently proposed. The currently proposed design is described in the Phase Zero deliverables with the modifications noted on page C-3. The proposed design is under evaluation by both the U.S. Department of Energy (DOE) and the industrial participant and may be further modified. Alternative plant designs are discussed in Sect. C.3.

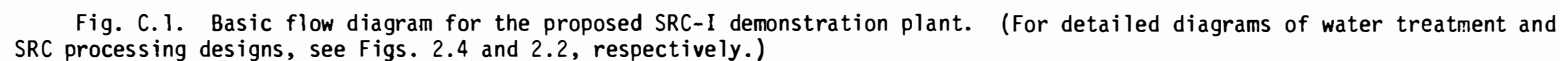
C.1.1 Overall process description

The demonstration plant facilities have been designed to produce a primary product of low-sulfur, low-ash solid solvent-refined coal from Western Kentucky No. 9 or equivalent coal. By-products will include anode coke, naphtha, fuel oil, and elemental sulfur. A process schematic of the preliminary design is presented in Figs. C.1 and C.2. A plant layout is shown in Fig. C.3, and by-products from normal operations are reported in Table C.1.

The design specifies that washed Kentucky No. 9 or equivalent coal (1-1/4 in. by 0 in.) (Table C.8) will be delivered to the demonstration plant by train. A barge unloading facility is also included for delivery of equipment during construction which can be modified to be used to supplement rail delivery in the event that coal suppliers are not located in proximity to a rail line. (Appendix Y is devoted specifically to the environmental effects of the barge facility.) From the weighing and unloading area, the coal will be transported underground to the storage area, which will consist of six active piles and two reserve piles. Coal will be reclaimed from the active piles by a tunnel reclaiming system and transported by covered conveyors to pulverizing-drying equipment for final size reduction to 200 mesh and drying. The fine coal will then be transferred through surge bins to a slurry tank for mixing. Baghouses will be employed to control the dust generated by coal-preparation activities.

The demonstration facility will utilize a noncatalytic direct-hydrogenation SRC-I process to convert 6000 tpsd of high-sulfur and high-ash coal to a solid product with a sulfur content of less than 1% and an ash content of 0.2% or less. The process encompasses the following steps:

- The coal will be slurried in the process solvent and pumped to reaction pressure (roughly 2000 psig). Hydrogen recycle gas will be mixed with the slurry and the mixture will be heated to reaction temperature in a fired heater. At the exit of the fired heater, additional hot hydrogen recycle gas will be added to the slurry, and this mixture will flow to a dissolver for further hydrogenation and desulfurization.
- The stream leaving the dissolver will be reduced in pressure from 200 psig to 25 psig to recover hydrogen, process solvent, and liquid products, and to remove water. The flash vapors from each stage will be partially condensed and the water decanted from the hydrocarbon liquids. The vapors will be combined and sent to the acid-gas removal and hydrogen purification sections for further processing before recycle to the SRC area. The hydrocarbon liquids will be fractionated to yield liquid products and process solvent. The decanted water will be sent to the ammonia-sulfide stripper for further processing and then will be sent to wastewater treatment.
- The low-pressure slurry containing process solvent, SRC product, unconverted coal, and mineral residue from the final separation stage will go directly to a vacuum column in the SRC product recovery area, where the process solvent and lighter components will be removed. The remaining SRC slurry will be sent to the Kerr-McGee Critical Solvent Deashing Unit, where it will be mixed with the deashing solvent and separated into the basic SRC product and ash concentrate.
- One-third of the molten SRC product will be solidified into a solid SRC product. Another one-third will proceed to the coker-calciner area (see Fig. C.2). There, molten SRC product will be fed to a fractionator tower where it will be mixed with an appropriate amount of recycled coking solvent. The mixture will be heated in a preheater and fed into the bottom of a delayed-coking drum, where coke is formed. Vapor from the drum will pass back into the fractionator-tower bottom where the liquid products will be fractionated into medium and light oil. Overhead vapors from the tower will be compressed and sent to acid-gas removal. The green coke will then be calcined and converted into anode-grade coke in a calciner. The flue gas from the calciner will be incinerated and treated to remove SO₂ and particulates. A sour-water stream will be produced in the coker-calciner unit and sent to the ammonia-sulfide water stripper unit and then to wastewater treatment.



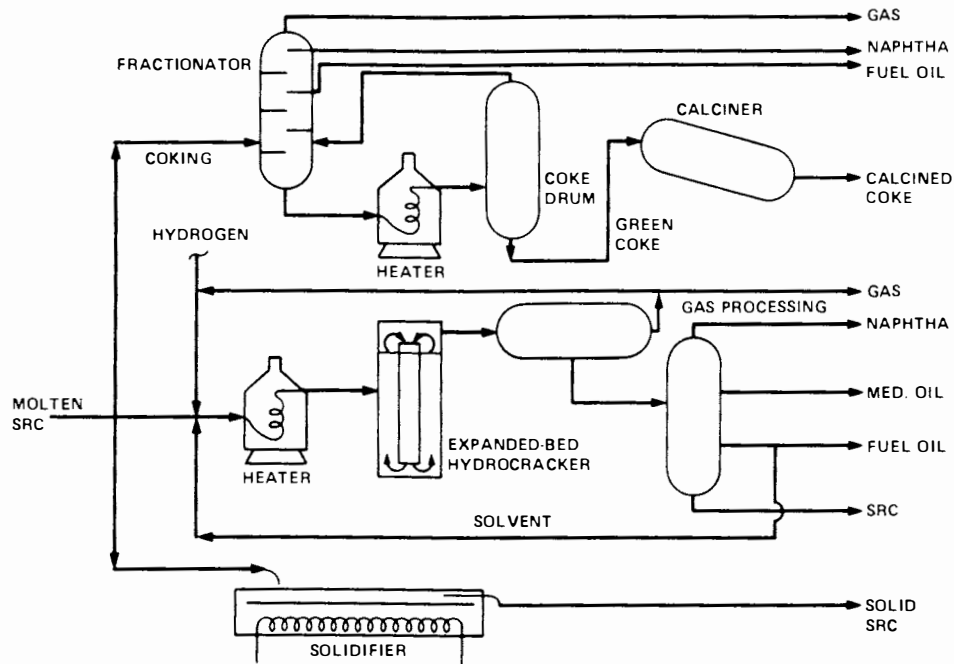


Fig. C.2. Basic flow diagram for proposed SRC processing.

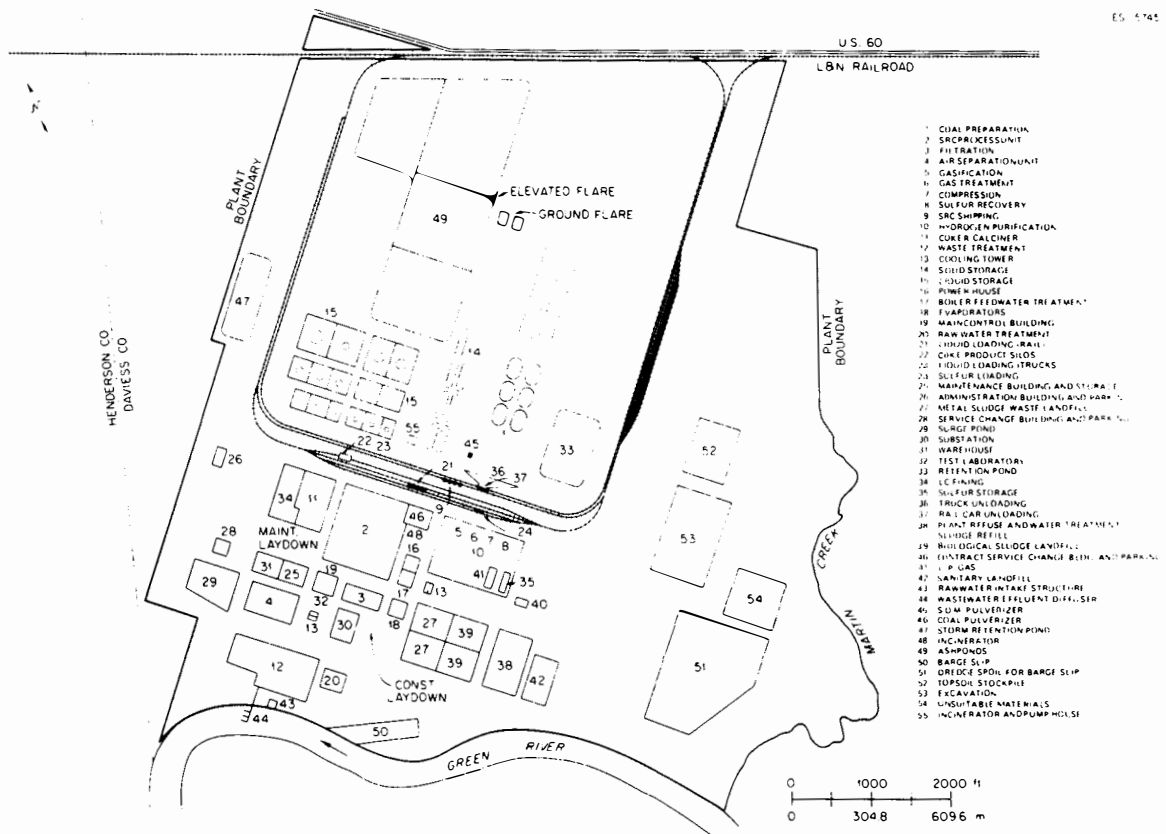


Fig. C.3. Plant layout for the proposed SRC-I demonstration plant.

Table C.1. Products from SRC-I demonstration plant^a

	Amount (tons/d)
Solid SRC	1050
Anode coke	588
Naphtha	585
Fuel oil	907
Elemental sulfur	188

^aThe product slate presented for the demonstration plant is based on the Phase Zero conceptual design with modifications as noted in the introduction to this appendix. The proposed design is currently under review by DOE and the industrial participant and may be further modified, resulting in changes to the product slate.

- The remaining one-third of the molten SRC product, as presently proposed, will be fed into an expanded-bed hydrocracker for conversion to liquid distillates (see Fig. C.2). In the hydrocracking process, SRC product will be combined with hydrogen and catalytically hydrogenated and hydrocracked in an expanded bed of catalyst. Effluents of the hydrocracker will be cooled and flashed in a series of separators where light and heavy condensates are drawn off. All liquids will then be sent into a fractionator for separation into light, medium, and heavy oil cuts (Table C.2). Net products will include light (naphtha), medium, and heavy oils and a vacuum-residue stream. Off-gases will be sent to acid-gas removal for purification. Sour water from the hydrocracker area will again be sent to the ammonia-sulfide water stripper unit and then to wastewater treatment.

Table C.2. Sources of naphtha and fuel oils

	Measured in tons per day			
	SRC	Hydrocracking	Coker	Total
Naphtha	438	110	37	585
Middle distillate (400-650° F)	359	290	75	724
Heavy distillate (650-850° F)	83	100		183
Total				1492

- The ash concentrate recovered from the Kerr-McGee deashing area, containing mineral matter, unconverted coal, and some residual SRC product, will be sent to the gasification area. In the GKT gasifier, the carbonaceous material in the ash concentrate will be partially oxidized with steam and oxygen to produce a synthesis gas, primarily carbon monoxide and hydrogen. The synthesis gas will be reacted with steam to produce the hydrogen required by the process. In the gasification process, the mineral matter of the ash concentrate will be converted to a slag and a solid fly dust which will be the primary solid wastes generated by the process. Most of the sulfur in the residue will be converted to hydrogen sulfide, which will be removed from the product gas in a Selexol unit in the gas-treating area. The hydrogen, after acid-gas removal and compression, will be sent to the coal slurry area at the front of the plant. A concentrated hydrogen sulfide stream from the Selexol unit will be sent to a Claus plant for recovery of elemental sulfur.

C.1.2 Supporting facilities

In addition to the basic SRC process, the plant will include a number of supporting facilities similar to those used by the petroleum refinery and petrochemical industry. These facilities

will provide required materials and utilities such as hydrogen, steam, electricity, process water, air, oxygen, and nitrogen; treat products to market specifications; recover by-products; and treat waste streams to remove pollutants and produce effluents suitable for emission or discharge, and to provide for the safe disposal of solid wastes. The major facilities which are of environmental importance are described briefly in the following sections.

C.1.2.1 Coal storage, preparation, and handling

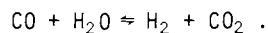
The coal-storage area will consist of eight piles: two 30-d reserve piles and six 5-d active piles. All coal used in the process will be directed to the six 5-day piles for short-term storage. Coal from these piles will be sampled, blended, and directed to process areas for use. The reserve piles will act as an emergency coal supply. Dust from loading into piles, mechanical agitation and wind action, and rainwater runoff laden with dissolved and suspended solids will constitute the principal effluents from receiving, conveying, storing, and reclaiming activities (see Appendix P for analysis of coal-pile leachates). To control fugitive dust, a water dust-suppression system will be utilized at the active storage piles, and polymer coating will be used at the reserve piles. The area surrounding the active and long-term reserve storage piles will be graded to direct uncontaminated surface runoff away from the piles, and the area under the coal pile will be contoured, lined with compacted clay or other suitable materials, and provided with a drainage-collection system designed to minimize the infiltration of leachates. Permeability testing with onsite clay indicates that the permeability of compacted on-site clay is in the order of 10^{-7} cm/s. Consequently, subject to other testing for compatability, this material will be heavily used.

Synthetic liners such as high-density polyethylene, reinforced hypalon, butyl rubber, neoprene, and others will be evaluated and tested. The EPA document "Lining of Waste Impoundment and Disposal Facilities" will be used as a guide.¹ Collected leachates will be pumped at a controlled rate from the area-retention basin to the wastewater-treatment facility. At present, onsite soils are being examined to determine their permeability characteristics. Should onsite soils prove to be unsuitable, a clay or synthetic liner will be provided at the coal pile.

At rail car unloading points and the transfer to the storage pile, water sprays will be used as required for dust suppression. Conveyors transferring coal to storage piles will be covered. Underground reclaim from the storage piles will be totally enclosed and ventilated through a baghouse. After reclaim, prior to pulverization, transfer points and conveyors will be totally enclosed to the extent possible. Any ventilation of these enclosures will be exhausted through a baghouse to the atmosphere. Provision will be made to install water spray at transfer points should monitoring during operation indicate this is necessary. After pulverization, all conveyors, transfer points, and coal processing equipment will be totally enclosed and ventilated through baghouses.

C.1.2.2 Gasification

From a process standpoint, the most important supporting operation is the gasifier. The SRC process consumes hydrogen in quantities too large to be economically procured off site. The required hydrogen may be most economically produced by a GKT gasifier. (Section C.3 discusses alternatives to the proposed gasification system.) The gasifier reacts (burns) a carbon source with steam and a limited quantity of oxygen to produce hydrogen and carbon monoxide, which is then reacted with steam in a shift-conversion reaction to produce hydrogen and carbon dioxide in accordance with the following reaction:



In a generic sense, a variety of carbon sources including coal and oil could be utilized as gasifier feed. However, in the SRC process, the ash-concentrate produced by the Kerr-McGee Critical Solvent Deashing Unit contains significant amounts of carbon and is used as the carbon source. Gasification of this material with supplemental coal offers the dual advantages of recovering the carbon content of the ash-concentrate for generation of makeup hydrogen and converting the ash concentrate into a slag and fly dust suitable for disposal. Alternatives for disposition of the ash concentrate and production of hydrogen are discussed in Sect. C.3. To facilitate production of high-purity hydrogen for process use, oxygen will be supplied to the gasifier by cryogenic separation of air. During normal operations, there will be no emissions to the atmosphere from the gasification process. The gasification and shift-conversion processes are net consumers of water; however, a wastewater stream will be produced which is

directed to the water-treatment facility. The slag and fly dust produced by the gasifier will be the major solid wastes produced by the plant. Disposal of the slag and fly dust are discussed later in this section, and in Sect. 4.2.2.2.

C.1.2.3 Acid-gas removal, sulfur recovery, and tail-gas treating

In the dissolver, hydrogen will react with both organic and inorganic sulfur to produce hydrogen sulfide. Other reduced sulfur compounds (COS , CS_2) are formed according to equilibrium such as $\text{CO}_2 + \text{H}_2\text{S} \rightleftharpoons \text{COS} + \text{H}_2\text{O}$. Most of the sulfur will be contained as hydrogen sulfide in the vapor stream; however, a significant amount of sulfur will remain with the products, including the mineral residue, and will be partially liberated during subsequent processing steps. A sulfur balance for the plant is presented in Fig. C.4. The presence of hydrogen sulfide is considered undesirable from a process standpoint, and gaseous streams containing excessive quantities will be directed to acid-gas (hydrogen sulfide) removal systems at various locations within the plant. In the SRC-I facility, the primary sources of acid gases will be the SRC process area, the gasification area, the coker-calciner area, and the expanded-bed hydrocracker areas. Two streams from the SRC process area will be treated for acid-gas removal: a high-pressure hydrogen-rich stream and a low-pressure off-gas. From the gasification area, gas leaving the shift-conversion unit will be treated to remove acid gases.* In the coker-calciner area, a low-pressure off-gas from the delayed coker will be compressed and treated for acid-gas removal. The flue gas from the calciner will be incinerated and scrubbed to remove SO_2 and particulates to an acceptable level. The flue-gas desulfurization sludge will be stored in a secure landfill. The disposal mechanism depends on the choice of FGD technology. The alternatives are discussed in Sect. C.3. The expanded-bed hydrocracker low-pressure off-gas will also be treated for acid-gas removal. Sour water streams from various areas will be combined and then stripped in the ammonia-sulfide water stripping unit. Vapors from the unit will be sent to the Claus unit for sulfur and ammonia removal, and the bottoms will be sent to wastewater treatment. Acid-gas removal systems will use several commercial processes in which the hydrogen sulfide is absorbed into a scrubbing solution and then removed from the solution by physical processing, producing a concentrated hydrogen-sulfide stream and a clean gas stream for further processing or use. The concentrated hydrogen-sulfide streams will be collected from the various acid-gas treating facilities and routed to the sulfur-recovery unit.

The systems specified for acid-gas removal at several locations in the plant include a Selexol unit and a diethanolamine (DEA) unit. The sulfur-recovery area will consist of two Claus units, one being a 100% spare, and a Beavon sulfur-removal unit (BSRU). A three-stage, straight-through, ammonia-burning Claus unit will recover the bulk of the sulfur contained in the acid gases to produce elemental sulfur, which will be recovered for sale as a by-product.

The BSRU removes residual sulfur compounds contained in the Claus tail-gas. Also, independently of Claus tail-gas processing, residual sulfur is removed from a raw fuel gas stream in the Stretford portion of the BSRU. The Stretford section contains two absorbers: one for sulfur removal from the Claus tail-gas and one for sulfur removal from the raw fuel gas. The raw fuel gas is treated for bulk acid-gas ($\text{CO}_2 + \text{H}_2\text{S}$) removal in the low-pressure section of the DEA unit and then sent to the BSRU for final sulfur removal.

The treated Claus tail-gas will then be vented to the atmosphere; it will contain approximately 4 ppmv hydrogen sulfide and less than 100 ppmv of combined hydrogen sulfide and carbonyl sulfide. Depending on decisions made during final detail design, this tail-gas may be vented from the same stack that vents the CO_2 that is removed from the shifted gas stream. The hydrogen sulfide in the fuel gas stream will be reduced down to approximately 5 ppmv. The clean fuel gas will be made available for in-plant fuel use. The environmental impacts are evaluated in Sect. 4.2.3. Alternative sulfur-control technologies are described in Sect. C.3.

C.1.2.4 Process cooling

Control of process operations requires the removal of significant quantities of heat from process streams. Wherever economically feasible, heat will be recovered through transfer to other process streams, heat-transfer fluids, or generation of steam to increase the overall

*The effluent from acid gas removal of the shifted gas stream contains about 6 ppm H_2S and 140 ppm COS , which will be vented to the atmosphere along with the other stream constituents: CO_2 (80 vol %) and N_2 (20 vol %).



NUMBERS IN PARENTHESES ARE lb/day

Fig. C.4. Sulfur balance.

thermal efficiency of the plant. The relatively small size of the demonstration plant limits the degree of heat recovery that can economically be employed. At a commercial scale, additional heat recovery would be economically feasible, and the overall thermal efficiency of a commercial plant is expected to be about 70%. Assuming only heat recovery that is economically feasible at demonstration-plant scale and utilization of cost-effective direct air cooling on heavy hydrocarbon streams, the demonstration plant will reject approximately 1.7×10^9 Btu per hour of waste heat. The currently-proposed design will utilize a recirculating cooling-water system with mechanical draft wet cooling towers for most process needs. To preclude the possibility of the release of complex hydrocarbons through the cooling system as a result of leakage in heat exchangers, aerial coolers and indirect cooling will be used for streams containing 5% or more by weight of coal- or SRC-derived material having boiling points greater than 260°C (500°F); such streams will derive from the dissolver, hydrogen recovery, liquid fractionation, separator, coking, hydrocracking, and recycle-gas systems (the systems handling intermediate product hydrocarbons of greatest concern from a health and environmental standpoint). Phenolics and volatile organic compounds released from the cooling tower will be controlled by the wastewater treatment plant, which treats wastewater to a quality acceptable for use as cooling tower makeup water (see Sect. C.3.1.5). Section C.3.3 discusses alternative waste-heat rejection systems. Section 4.2.3.1 and Appendix S present the environmental-impact analysis for the cooling system.

C.1.2.5 Product storage and shipping

Two separate product-storage areas are planned: the solids-storage area and the liquid-storage area (Fig. C.3). The solids-storage area will provide for conveying, storage, and loading of solid products including SRC, calcined anode coke, ash, char, and sulfur. Solid SRC will be stored in open piles subject to dust suppression and leachate collection as in the coal pile; it will be transported by rail. (Appendix P provides an analysis of SRC solid-product leachates.) Anode coke will be stored in silos equipped with a baghouse, handled by closed conveyor systems, and transported in hopper cars. Elemental sulfur will be stored in the molten state in a closed tank.

The liquid-storage area will include tanks, pumps, and controls to store and distribute process solvents, light oils, medium oils, process chemicals, and Dowtherm A heat-transfer fluid. All product liquid-storage tanks will be equipped with fixed roofs and vapor-recovery systems, or floating roofs with purging of vapor space between the seals, to control hydrocarbon emissions.

The tanks will be diked to prevent release of liquid product materials into the environment in an event of tank failure or operator error. The diked area will have adequate capacity to contain the contents of the tank plus precipitation from the 10-year, 24-h storm and water used in the event of a fire. Large spills of oil from the tank farm will be recovered, lesser spills will be discharged to the process sewer, and removal will occur in an oil/water separator. Slop oil from the separator will be incinerated. To avoid ground-water contamination with the liquids in the event of tank rupture or spills, the diked area will be lined with appropriate impermeable materials. Drainage from within the diked area and runoff from the product-loading areas will be pumped to the wastewater-treatment system. The bases of the tanks will be below the 100-year floodplain, but the dikes will be above the 500-year floodplain.

Permeability testing with onsite clay indicates that the permeability of compacted onsite clay is on the order of 10^{-7} cm. Consequently, subject to other testing for compactability, this material will be heavily used. The process area will also include curbed concrete pads for areas likely to be contaminated. Additional evaluation is being made in the disposal areas regarding the use of synthetic liners and/or clay liners.

Synthetic liners such as high-density polyethylene, reinforced Hypalon, butyl rubber, neoprene, and others will be evaluated and tested. The EPA document "Lining of Waste Impoundment and Disposal Facilities" will be used as a guide.¹

Dikes are expected to be constructed with compacted clay. Synthetic liners, where applicable, will be extended from the bottom (within the diked areas), over the inside face of the dike, and will be fastened at the top.

C.1.2.6 Other support facilities

Railroad. The demonstration facilities will require the construction of rail trackage to accommodate the movement of feedstocks and products. Coal will be transported by rail and

possibly by barge from the Western Kentucky coal fields, approximately 50 miles from the site. Products and by-products will be shipped by rail and truck (see Sect. 4.1.3.2).

A total of 4 miles of railroad trackage will be laid along the western edge of the site and in a loop around the central storage and shipping area (Fig. C.3). The existing Sauer Lane will be blocked off at the west end because of the railroad spur. Flanagan Road, an existing gravel road, will be relocated along the western edge of the site, and will connect with Sauer Lane. A new plant-entrance road will be built along the rail spur, linking U.S. Highway 60 with the eastern segment of Sauer Lane.

Stockpiles. To the east, near Martin Creek, will be three stockpiles for topsoil, excavated material, and unsuitable spoil material (Fig. C.3).

Barge. It is necessary that some construction materials and equipment be delivered by barge. A permanent dock or barge facility on the Green River is also being evaluated for delivery of feed coal. (Figure C.3 and Appendix Y provide diagrams of the barge-unloading facility.) Construction of barge facilities will require a permit from the Corps of Engineers.

Electricity. The demonstration plant will be supplied power via two 161-kV transmission lines, furnished by Big Rivers Electric Corporation. Estimated power demand is approximately 101,000 kW. A turbine generator on site will generate supplemental power from excess process steam, which will serve to reduce the purchased power demand. Initial start-up requirements of fuel gas and fuel oil will be furnished from an external source.

Water intake. The major water flows into the plant are makeup from the Green River and rainfall, which is impounded for use. With zero discharge of wastewater, about 2520 gpm (3.63 Mgd or 13,735 m³/d) of water will be withdrawn from the Green River. Two alternative water intake structures are being considered: conventional and submerged. The conventional water intake structure (Fig. C.5) will be built on the shore, at bluff height, to withstand a 100-year flood. The structure will be equipped with one or more sets of vertical traveling screens having intake velocities as low as practical to minimize aquatic life impingement [0.15 m/s (0.49 ft/s) at mean low water conditions]. A 25- by 80-ft channel will be dredged for the river-water intake. The channel bottom will be at 338 ft mean sea level (MSL); the top of the structure will be at 390 ft MSL. Approximately 2000 yd³ of dredge material will be deposited in a disposal stockpile next to the intake facility. Maintenance dredging of the channel will probably be required.

The submerged water intake structure (Fig. C.6) will be constructed by sinking a concrete caisson about 60 ft into the river bank. A 42-in.-diam pipe will be jacked from inside the caisson toward the river. The pipe will be at least 12 ft below normal pool level, to preclude interference with river traffic. Also, the pipe will be laid to obtain sufficient clearance above the river's bed, thereby preventing silt from being sucked into the wedgewire screens installed on the end. The river bed is disturbed only during installation of the pipe and driving of the pipe support piling.

Water discharge. The treated effluent from the excess beyond the 10-year, 24-h storm (or 1.3 Mgd when the wastewater discharge option is used) will be discharged into the Green River downstream of the intake. An underwater pipe will carry the effluent to the middle of the river, where a 50-ft diffuser will discharge it at a jet velocity of between 4.7 and 5.1 fps directed downstream. The discharge pipe will be anchored with concrete blocks. Some riprap may also be required. (Figure C.7 provides a sketch of the water-discharge structure.)

The diffuser is designed to extend about halfway across the Green River and will be constructed with a 20-in.-diam pipe with perforated 2-in. orifices, 1-in. apart. Design capacity for the diffuser has not been finalized. Data are as follows:

Plant size (tpd)	Operating mode	Assumed flow rate		Pipe diam. (in.)	Orifice diam. (in.)	No. of orifices	Jet velocity (fps)	Temp. (°F)	
		Mgd	Cfs					Summer	Winter
6,000	Normal	1.56	2.41	20	2	40	4.7	105	55
6,000	Maximum	2 x 1.56	4.82	20	2	80	5.1	105	35
30,000	Normal	5 x 1.56	12.07	20	2	100	10.8	105	55

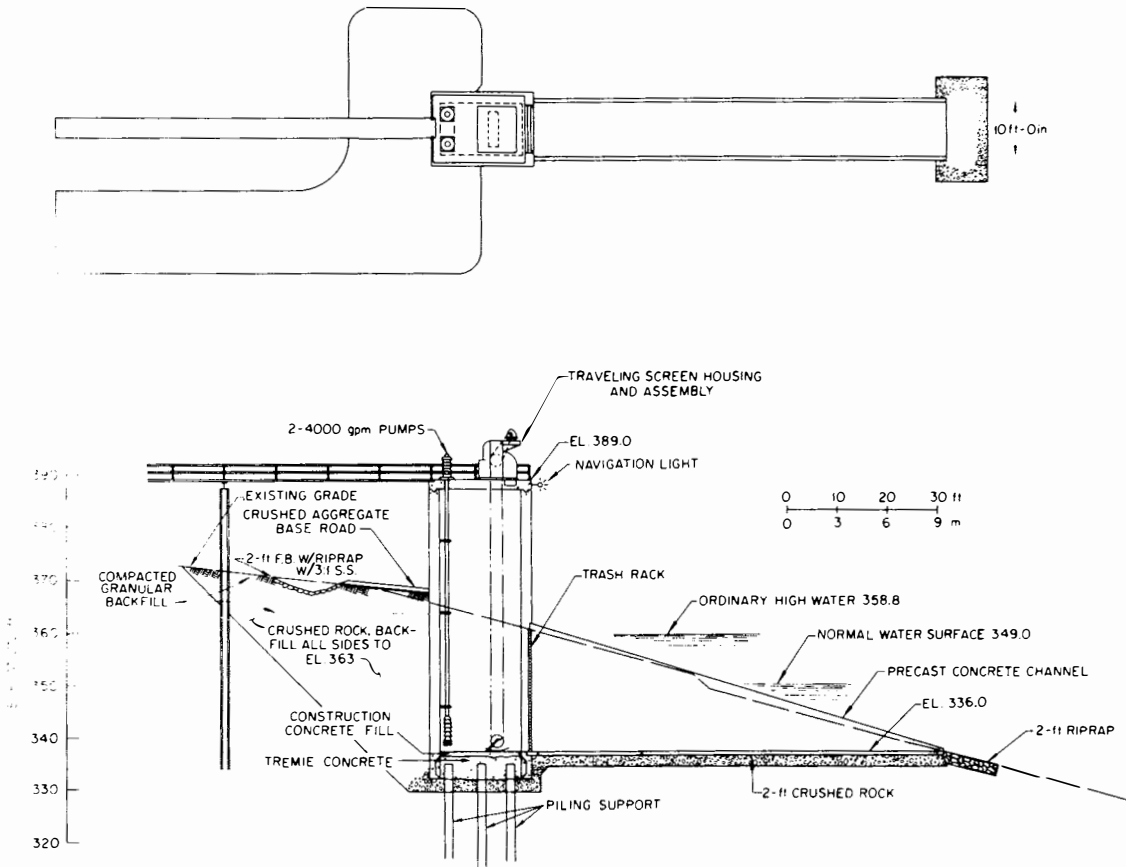


Fig. C.5. Conventional raw water intake device.

Potable water. Potable water will be withdrawn from wells (location not specified) and treated. Average demand will be about 9 gpm. However, the wells will be developed to provide 100 gpm to allow for rapid fill of the potable-water storage tank (25,000 gal) during peak demand periods and to supply untreated water for construction purposes.

C.1.3 Resource requirements

C.1.3.1 Construction phase

It is estimated that the following quantities of major resources will be required during the construction phase of the facility:

Concrete (excluding architectural buildings)	71,000 yd ³
Reinforcing steel	3,700 tons
Structural steel (excluding architectural buildings)	3,900 tons
Asphalt	1.1 x 10 ⁶ ft ²
Railroad trackage	63,000 ft
Bare pipe	3,400 tons
Glass	28,000 ft ²
Wood	1.75 x 10 ⁶ board ft

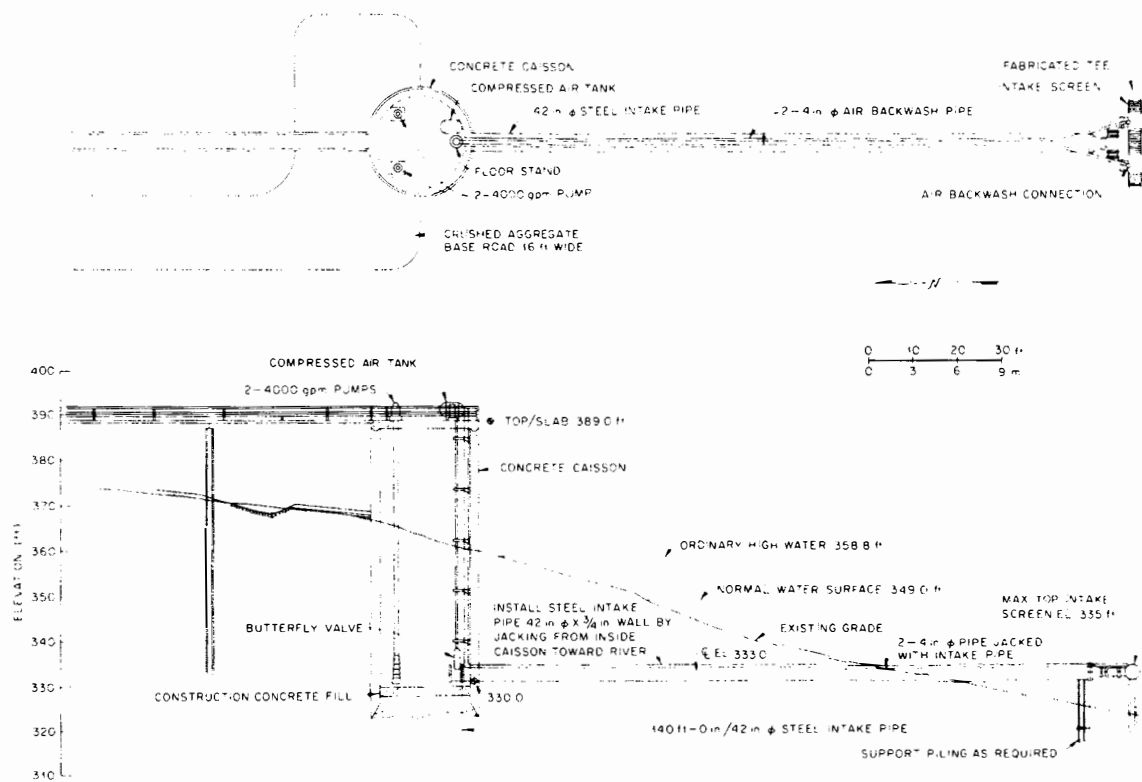


Fig. C.6. Submerged raw water intake device.

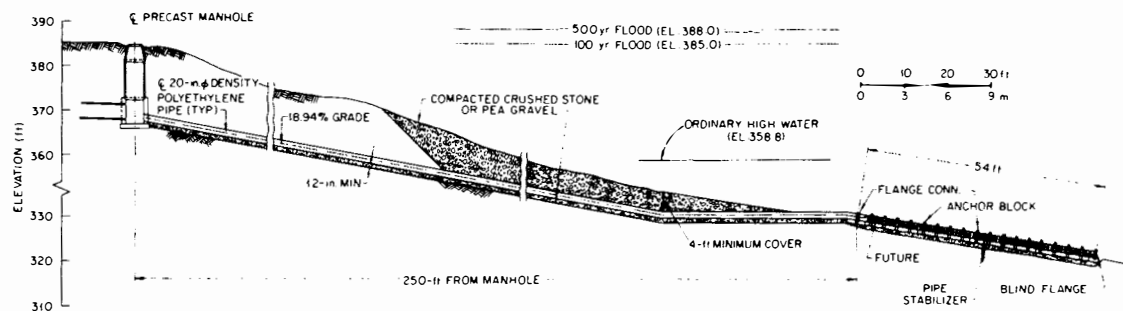


Fig. C.7. Proposed wastewater effluent river diffuser.

C.1.3.2 Operations phase

The demonstration plant is designed to process 6000 tons of coal per stream day. It is estimated that the following quantities of resources will be consumed annually:

Coal	2 x 10 ⁶ tons
Water	8.6 x 10 ⁸ gal
Electricity	75 x 10 ⁴ MWh
Lime	1,500 tons
Phosphoric acid	80 tons
Sulfuric acid	3,650 gal (int.) (max.)
Diethanolamine	30 tons
Selexol solvent	20 tons
Chlorine	70 tons
Wetting agent	40,000 gal
Critical solvent (for deashing)	370 tons
FeSO ₄ (20% solution)	1,500 tons
Soda ash	2,700 tons
Sodium vanadate	400 tons
Alum	460 tons
Rock salt	530 tons
Hydrogen peroxide	3,650 gal
Monoethanolamine (MEA)	20 tons

Additionally, catalysts will be used, but the types and amounts are proprietary.

It is presently planned that electric power will be purchased from a nearby public utility.

C.2 PROPOSED ENVIRONMENTAL CONTROLS

C.2.1 Wastewater treatment

C.2.1.1 Major wastewater streams and contaminants

The expected types of wastewater generated in the demonstration plant are given below:

- process sour water
- cooling tower blowdown
- coal pile runoff
- SRC pile runoff
- process area runoff
- runoff from liquid storage and shipping areas
- weak process wastes
- oily wastes
- sanitary wastes
- metal-sludge landfill leachate
- slag disposal leachate
- spent scrubber liquor from the coker/calcliner scrubber
- wastewater from the gasifier

A laboratory program is currently underway to characterize the wastewater streams expected at the demonstration plant (see Sect. 2.3.2.2).

About one-half of the total wastewater flow will be process sour water, the most heavily contaminated stream. Process sour water sources are from the SRC area, the coker, the expanded-bed hydrocracker, Beavon sulfur removal, and the diethanolamine (DEA) acid-gas removal process.

Process sour water from the SRC area originates from water in the coal and from water added to the process to prevent ammonium salt formation and deposition in the process lines. Current estimates of major contaminant concentrations in the sour water are 3.4 wt % hydrogen sulfide, 0.2 wt % phenolics, 1.1 wt % hydrogen chloride, 209 ppmw mercaptans, 88 ppmw thiocyanate, 2.2 wt % ammonia, and 22 ppmw hydrogen cyanide.

Process sour water from the coker will come from the overhead flash streams in the coking process. Most of the wastewater is generated during decoking. Major contaminant concentrations are currently estimated to be 0.15 wt % hydrogen sulfide, 0.12 wt % ammonia, 0.12 wt % phenolics, 380 ppmw thiocyanate, and 65 ppmw hydrogen cyanide.

The expanded-bed hydrocracker sour water will also come from an overhead flash stream in the hydrocracker process. Part of the sour water is generated by reaction of hydrogen with oxygenates in the feed; the remaining water is introduced to prevent salt formation in the process line. Major contaminant concentrations expected are 1.8 wt % ammonia and 0.9 wt % hydrogen sulfide.

Sour water from the DEA process area will come from a water wash of the gases flashed off in the SRC process area. Expected major contaminant concentrations in the sour water stream are 12.7 wt % carbon dioxide, 4.9 wt % ammonia, and 2310 ppmw hydrogen sulfide.

Beavon sulfur-removal sour water results from a direct water-contact cooler that cools the gas stream entering the sulfur-removal absorbers. The only major expected contaminant is 286 ppmw hydrogen sulfide.

In addition to the expected major contaminants, trace concentrations of metal and complex organics, such as polynuclear aromatic compounds, will probably be present in some of the sour water streams.

About one-third of the total wastewater flow will be from the cooling tower. The most significant contaminant in this stream will be hexavalent chromium, which is added to the cooling system for corrosion control. (Alternatives to the use of chromate anticorrosion chemicals are described in Sects. 2.3.2.2 and C.3.4.) The common inorganic constituents originating in the makeup water to the cooling system will be concentrated and present in the blowdown. Table C.10, listing estimated drift composition from the cooling tower, is also a preliminary estimate of the cooling tower blowdown composition.

The remaining portion of the wastewater will come from various sources: GKT gasifier wastewater, runoffs from raw coal and SRC piles; runoffs from the diked areas where the process equipment, storage, and shipping areas will be located; sanitary waste; metal-sludge landfill leachate; oil-bearing wastes; and such lightly contaminated waters as boiler blowdown and water-filter backwash.

The expected major contaminants in the GKT wastewater are 260 ppmw ammonia, 30 ppmw thiocyanate, 15 ppmw cyanide, and less than 20 ppmw of suspended solids. The high-temperature operation of GKT units acts to incinerate more complex organic molecules before leaving the reactor. Trace concentrations of various inorganic contaminants are also expected.

Appendix P describes the composition of leachates from coal, solid SRC product, and gasifier slag.

A purge stream from the Stretford process will be produced. This stream will contain the following contaminants: 15.8 wt % $\text{Na}_2\text{S}_2\text{O}_3$, 7.1 wt % Na_2SO_4 , 1.2 wt % Na_2CO_3 , 0.8 wt % NaVO_3 , and 0.2 wt % anthraquinone disulfonic acid.

The process area runoff is expected to be contaminated with trace quantities of process liquids, including certain high-boiling point hydrocarbons. The slag landfill leachate is expected to contain the contaminants common to the coal pile runoff. The lightly contaminated wastewater is expected to contain chiefly inorganics and suspended solids.

C.2.1.2 Conceptual design of the wastewater treatment system

The proposed wastewater treatment system will be a zero-discharge system utilizing total recycle to the process but will have the flexibility to fully treat and discharge all wastewater in

the event that process operating conditions do not enable total recycle. An NPDES permit and appropriate State permits will be obtained for the discharge case. A laboratory program is currently underway to determine the treatability of the wastewater expected at the demonstration plant and to support the design of this wastewater treatment system (see Sect. 2.3.2.2). Depending on the results of the laboratory program, the design may be modified as necessary. All wastewaters generated in the plant as well as the contaminated runoff will be sent to the wastewater treatment facility. Sanitary waste will be combined with other plant effluent in the equalization pond and directed to the biological treatment system. Figure C.8 is a conceptual diagram of the treatment facility, consisting of primary, secondary, and tertiary treatment steps. The design goal is to have a liquid effluent leaving the final treatment step that is suitable either for discharge to the Green River or for recycle to the process after an evaporation-condensation step to remove dissolved solids that could not be tolerated within process equipment.

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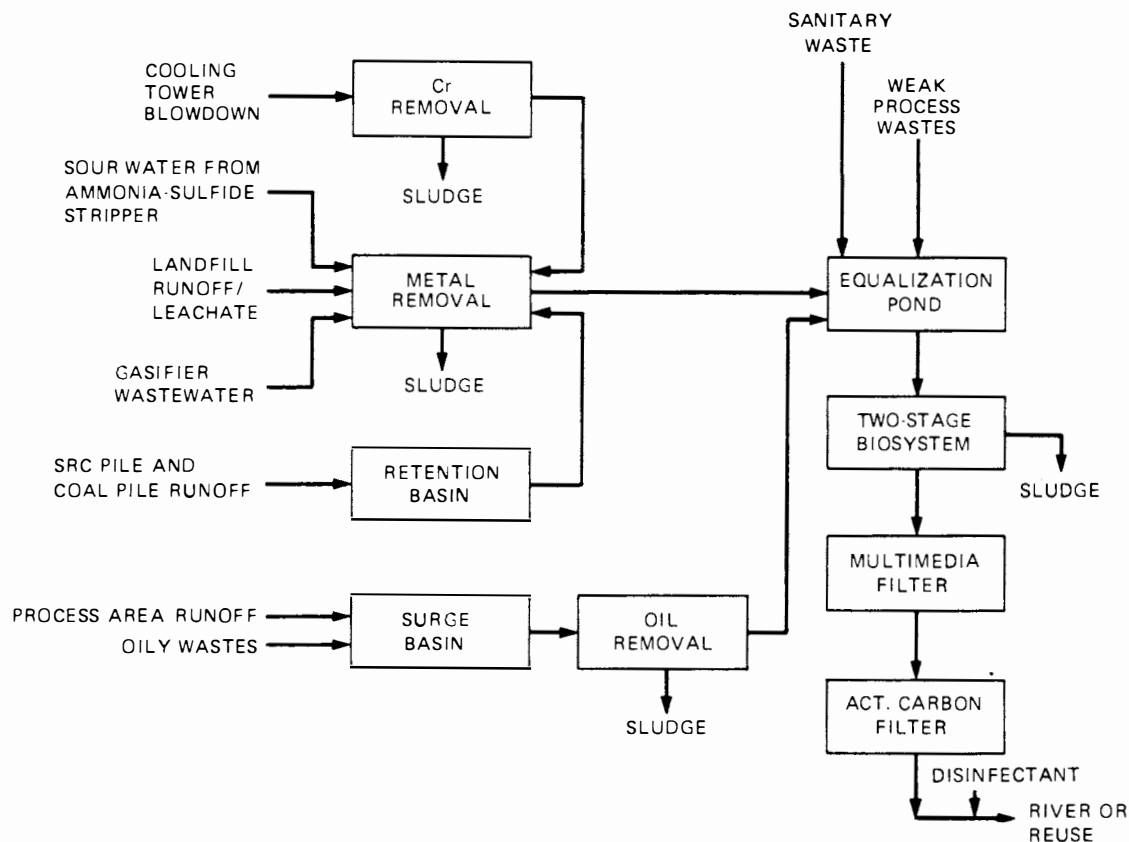


Fig. C.8. A conceptual diagram of the treatment facility.

There is no capability to discharge untreated or partially treated process wastewater. In the event of failure in a given system, use of spare or parallel equipment, holdup capacity in surge ponds and equalization ponds, and ultimately production rate reduction or a plant shutdown will be used until full treatment can be resumed. Consideration is being given to the use of idle ash ponds for emergency storage.

During extended shutdowns of the plant for major repairs, the zero-discharge operating mode could not be practiced because consumptive uses (cooling tower) for the recycled evaporator condensate would not exist but rainfall runoff would continue. Either storage or discharge of treated wastewater would be required. Treated wastewater from the plant described in this section should be suitable for discharge, and the flow would be very small.

The treatment processes will include separation of oily wastes, precipitation and flocculation of toxic metals, pH adjustment prior to two-stage aerobic biological treatment followed by filtration, and final polishing of the effluent by activated carbon (Fig. C.8). The system will provide equalization and retention basins to retain large wastewater flows during rain events (primary runoff and leachates) and to promote mixing, thereby preventing upset of the biological system due to shock by toxic components.

Rainwater runoff from the coal and SRC piles will enter a retention basin to control the flow of these waters to the treatment system. The basin will be constructed in such a manner to permit access for removing solids that will accumulate in the basin. The capacity of the retention basin will handle the rainwater of a 24-h, 10-year-frequency storm. To determine the runoff compositions in the event of a storm, a simulation with a computer model such as EPA's Short Storm Water Management Model (SSWMM) will be performed with results reported in the National Pollutant Discharge Elimination System (NPDES) permit application. Effluent from the retention basin will then enter the metal-precipitation system. The ability to bypass the metal-precipitation system and permit water from the retention basin, after a prolonged storm, to enter the surge basin will also be available.

Rainwater runoff from the process area will be collected in a surge basin to control flow into the treatment system. This basin will be sized to handle rainwater runoff from a 24-h, 10-year-frequency storm. To prevent leakage, materials that are resistant to organic solvent attack will be used to line the basin.

Effluent from the surge basin, along with other oily wastewater generated in the plant or oils from minor spills, will enter an oil-removal system. The design of the oil/water separator will include adequate controlled venting and purging of any collected hydrocarbon gases and vapors to avoid any safety hazard. The oil-removal system will have the ability to remove all floatable and emulsified oils. Depending on the carbon loading of the effluent leaving the oil-removal system, this stream may be bypassed around the equalization basin and biological treatment and permitted to enter the filtration system. Handling and disposal of slop oil from the oil-removal system are discussed in Sect. C.3.2.5.

Wastewater streams containing significant amounts of metals will enter a metal-precipitation system. The GKT gasifier wastewater, coal and SRC runoffs, and landfill leachates will be in this category. If chromate is used as the corrosion inhibitor in the cooling system, blowdown from the cooling tower will also belong to this category. However, the blowdown will enter a chromate-reduction unit in which Cr^{6+} is converted to Cr^{3+} before feeding into the metal-precipitation system. The metal-precipitation system consists of two separate stages; the pH of the first stage would be 11, and of the second, 8.5. Two-stage precipitation may be necessary because some metal hydroxides are amphoteric; the pH optimal for precipitating one metal may not be optimal for another. For example, the optimal pH for nickel is 11, considerably higher than the optimal pH (8.5) for many other metals. The final design of the metal-precipitation system will greatly depend on species of metals present in the waste streams. The metal-precipitation system will generate sludges; disposal of those sludges is discussed in Sects. C.2.3.2 and C.3.2.2.

The sour water streams will initially be steam stripped in the ammonia-sulfide water-stripping (ASWS) unit to remove hydrogen sulfide and ammonia. The ammonia and hydrogen sulfide overhead stream will enter a Claus unit, where the ammonia will be converted to nitrogen and the hydrogen sulfide will be converted to elemental sulfur. The stripper bottoms will contain a high level of phenolics and some other organics. Depending on the amount of metals present in the ASWS bottoms, this stream will either pass through the metal-precipitation system or enter the equalization basin directly. The baseline plant design does not include solvent extraction of phenols; however this process is receiving tradeoff study, and a decision will be made at the detail design stage whether to incorporate it. The potential disposition of phenols would be sale, in-plant fuel, or gasification use.

Spent scrubbing liquor from the coker-calcliner soda ash scrubber will be directed to wastewater treatment, but when the zero-discharge evaporator is operating, it may be routed to the evaporator. The salts will either appear as part of the evaporator salt cake or will eventually be discharged as effluent. If it is discharged, the sulfite will be oxidized, and particulates will be removed by clarifiers and filtration in the wastewater treatment system.

Based on the presently proposed design, the sanitary wastes will be combined and treated with other wastewater streams and ozonated before discharge.

The equalization basin will receive and mix all wastewater requiring biological treatment including weak process wastes, effluent from oil removal, effluent from metal precipitation, and the ASWS bottoms. High phenol levels in some streams (liquefaction) will be diluted by low phenol levels in other streams (gasification, etc.). The equalization basin will be sized for a minimum of a 24-h retention time and will prevent organic, hydraulic, and temperature shock loads to the biological system. Two compartments in the equalization basin will be provided to permit solids removal and cleaning of the basin. The basin will be made of a material that will not be susceptible to solvent or organic attack. An oil-skimming device will be provided to ensure that no oils enter the biological system. Provisions will also be made for addition of nutrients or defoamer to the equalization basin. A recycle stream from the biological-treatment effluent to the equalization basin will be provided to ensure that sufficient water dilution in the equalization basin occurs to keep toxic species below inhibitory levels at the inlet to the biological treatment system. The pH will be adjusted before the biological treatment system.

The purpose of the first-stage biological system will be to remove mostly phenolics and other easily biodegradable materials. Removal of ammonia and thiocyanates, as well as refractory organics, should occur principally in the second-stage biological system. Because the microorganisms in the second stage are usually more sensitive to environmental changes and more susceptible to inhibitions, the first stage should provide stability for the second stage. To further protect the biological system from potential inhibition and toxicity from major spills, provisions will be made for adding powdered activated carbon to the aeration basins. Provisions for reducing and preventing biomass destruction during emergency upsets are addressed in Sect. C.2.1.6. An alternative to the proposed design is being considered: use of oxygen rather than air in the biological systems. Because pure oxygen is readily available in the plant, an oxygen system could be more cost-effective than an air system (see Sect. 2.3.2.1).

A two-stage biological system similar to the biological system proposed for the demonstration plant is operating at the Wilsonville, Alabama, SRC-I Pilot Plant. Consistent operation of the biological system has been achieved at Wilsonville with phenol removal to less than 0.06 mg/liter during the period of January to August 1980, as documented in Wilsonville's monthly discharge monitoring report to the Alabama Water Improvement Commission. Phenol concentrations entering the biosystem in the demonstration plant will be higher than the influent feed stream at Wilsonville but will be controlled to treatable levels by dilution. Also, tertiary treatment will be used as described below.

The effluent from the biological system will be further polished by filtration and adsorption before discharge or reuse. Filtration by multimedia filters will remove residual suspended solids. Backwash water, used to clean the multimedia filters, will be sent to the equalization basin. Adsorption by granular activated carbon (GAC) will reduce trace organics, particularly polynuclear aromatics. Monitoring of the GAC-bed effluent to detect organic breakthrough will determine when a new (spare) GAC bed should be used. Spent GAC will then be replaced with fresh GAC, and this bed will then become the spare. Disposal of spent GAC is discussed in Sect. C.2.3.

Effluent leaving the biological system will be disinfected by ozonation either before or after multimedia filtration. Ozonation before multimedia filtration will prevent the development of microbial growth on the media in both filter-bed systems. To prevent possible formation of chlorinated hydrocarbons, chlorination will not be practiced on this stream.

In the case where treated effluent is discharged to the Green River, an NPDES permit will be required. During preliminary consultation in preparation of the NPDES permit application, EPA, Kentucky, and DOE will jointly develop effluent limitations for the plant. Limitations, either water quality or technology-limited will be based on in-stream water quality standards, the best available treatment technology economically achievable, or appropriate New Source Performance Standards (NSPS), whichever are more stringent.

In the zero-discharge mode where treated effluent is reused in the process, the treated effluent will be used only as partial makeup water to the cooling tower as shown in Fig. C.9. Thus any buildup of high salt concentrations will occur only in the cooling tower recirculating water. The balance of makeup water will come from treated river water and possibly from evaporator condensate. Blowdown from the cooling tower, after chromate removal if chromate inhibitor is used, will enter an evaporator system rather than the metal removal system. The dissolved solids level of the recirculating water can be controlled by adjusting the cooling tower blow-down rate. A small brine stream from the diethanolamine area and a small Stretford purge stream will also enter the evaporator system. The evaporator will concentrate the dissolved solids in the feed stream and will also produce a relatively solids-free condensate stream. The condensate will be used as makeup water in either the cooling tower or the boiler. To prevent any organics from entering these utilities, a backup granular activated carbon bed will be used to adsorb any small residual amounts of organics from the condensate stream. The solids stream leaving the evaporator will be further concentrated in a decanter and then will be disposed by one of several options described in Sect. C.3.2.1.

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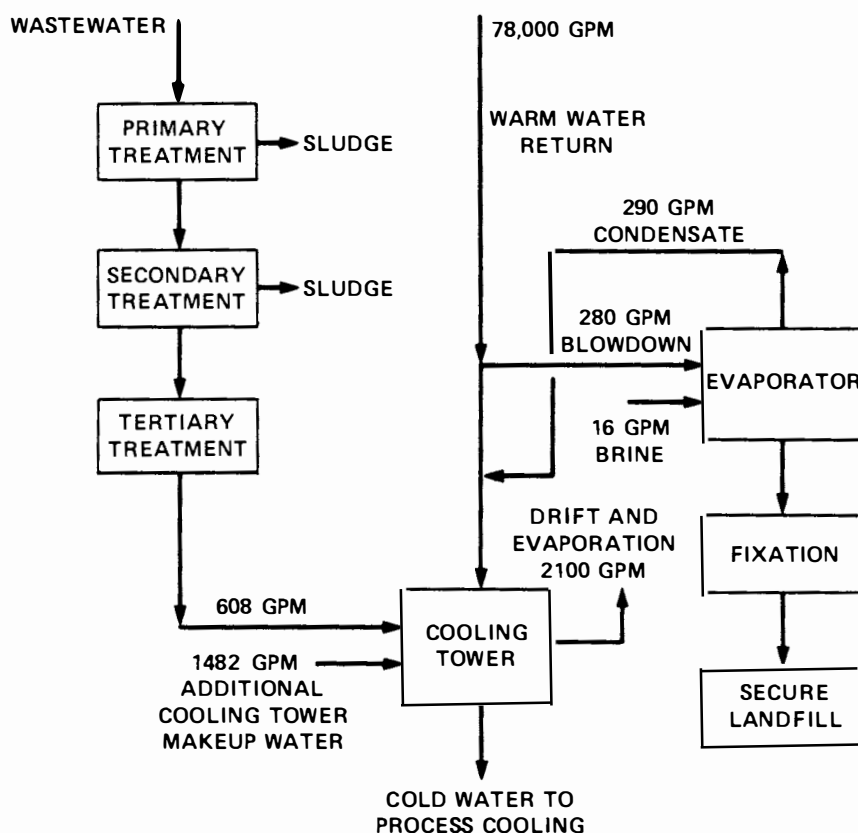


Fig. C.9. Flow diagram for zero-discharge wastewater treatment system.

Advantages of water reuse include no pollutant discharge to navigable waters, reduced river-water intake and overall consumption, simplified wastewater-treatment system design, and potential for integrating the zero-discharge system with other portions of the demonstration plant. Disadvantages include the difficulty in disposing of the water-soluble salts produced by the evaporator, the high capital and operating costs, the additional heat requirement, and the accumulation of rainwater runoff while the plant is not operating.

As discussed in Sect. C.3.3, alternatives for waste-heat rejection, several cooling alternatives have been considered based on the concern that the leakage of heavy hydrocarbons into an evaporative cooling system could pose a potential health hazard. The conceptual design of the zero-discharge system utilizes the cooling tower as the consumer of evaporator condensate. If wet evaporative cooling is not used, another use, such as for boiler feedwater, must be found for this condensate. Such uses might involve pretreatment to match reuse water-quality specifications, as well as retention basins for flow equalization. These factors affect the choice of waste-heat rejection.

C.2.1.3 Disposal of water-soluble solid wastes

Approximately 35 tons per stream day (tpsd) of residue will be produced by the evaporator. Disposal of this highly water soluble solid waste is a major concern for a zero-discharge wastewater-treatment system.

Major waste streams will originate from the gasification section, the dissolver section, cooling tower blowdown, and the boiler feedwater treatment effluent. The compositions of these streams will determine the amount and composition of water-soluble solid wastes from the evaporator. These streams are discussed in greater detail below.

Waste from the gasification section (slag quench) will result from ash leaching. Heavy metals contained in the ash will be leached into this waste stream along with other constituents from the ash. The amount of wastewater blowdown from gasification will be determined by the maximum allowable chloride concentration, which will determine the amount of water-soluble solids in this stream.

Water from the dissolver and letdown separator section will also contain chlorides. The chlorides and other water soluble solids will consist only of those that volatilize in the dissolver. Thus, heavy metals and nonvolatile solids will be in low concentrations compared to the gasification wastewater.

Cooling-tower blowdown and boiler-feedwater treatment residues will contain inorganic compounds (the ions calcium, sodium, magnesium, sulfate, and chloride) in essentially the same proportion as in the entering river water.

Precipitation runoff from the coal pile and from the slag landfill will also contain dissolved inorganic solids.

The residue from the evaporator will be water-soluble since the constituents were originally dissolved in the wastewater. The residue will contain major, minor, and trace elements and will probably be classified as hazardous under the Resource Conservation and Recovery Act (RCRA). Consequently, the solid cannot be disposed of by conventional wet landfill because precipitation on such a landfill would redissolve the solids, causing an endless recycle through the water-reclamation system, or possibly contamination of surface water and groundwater.

Encapsulation of the solid residue with final disposal in a secure landfill is being considered. This and other alternative disposal methods are discussed in Sect. C.3.2.

Disposing of these water-soluble salts is recognized as one of the key engineering considerations of the detailed-design phase.

C.2.1.4 The effect of startup on wastewater treatment

Start-up of the physical-chemical portion of the treatment system will take about one week; normal start-up of the biological portion will take a few weeks. Seeding microorganisms will be obtained from a wastewater treatment plant treating a similar waste to shorten the time period.

Prior to start-up of the process equipment, the biological reactors in the wastewater treatment system will be fed with food such as phenols, obtained externally. Only after the biological reactors have accumulated sufficient biomass will the process equipment be put on-stream. This start-up sequence will help ensure that the treated effluent will meet the established limits.

If a large rainfall (10-year, 24-h storm) occurs during the start-up period, it will be stored in the surge basins and then withdrawn at a steady rate from the basins to the treatment system. The impact of such a storm on start-up is expected to be small. Runoff in excess of the 10-year, 24-h storm will be discharged. The impact should be small because the portion of the runoff to be discharged will be rather uncontaminated, as data on time-variant composition of runoff show.

In the zero-discharge operating mode, normal startup of the evaporator would take about one week. However, because the wastewater-treatment system relies on evaporative loss from wet cooling towers to achieve zero discharge, treated wastewater must be stored, reused in process areas, or discharged until the process heat load reaches the desired level. The treated wastewater will be required to meet the NPDES limits; the impact will be insignificant; and the duration of discharge should be short. If the waste-heat rejection system does not include wet evaporative cooling, then alternate consumptive uses would already exist. These alternatives may also require a period of time before their consumption reaches a level to match the volume of wastewater generated. These considerations are an integral part of the current design effort.

C.2.1.5 The effect of shutdown on wastewater treatment

During shutdown, process wastewater streams entering the treatment facility will be decreasing, while flows of coal- and SRC-pile runoff, secure-landfill runoff, and process-area runoff could continue. The major contaminants in these runoff streams will be inorganics and can be removed by the physical-chemical section of the treatment system as in normal operation. The biological portion of the treatment systems will need an external source of food to sustain the biological organisms which normally exist on pollutants in the wastewater. External food will be added to support the growth during the shutdown period.

The zero-discharge operating mode becomes difficult during shutdown, because uses for the recycled evaporator condensate do not exist. However treated water flow rate should be relatively lower during plant shutdown, and inlet waters to the wastewater treatment system would be lightly contaminated because they do not include process sour watering. Either storage or discharge of the treated wastewater would be required. Treated wastewater should be suitable for discharge during the off-normal period.

C.2.1.6 The effect of emergencies on wastewater treatment

There will be three principal sources of contaminated water during emergencies in addition to those discussed under startup and shutdown:

1. Massive leaks to the cooling-water system could occur. This would require emergency shutdown followed by reclamation or treatment of all the water in the cooling system.
2. Large quantities of oil-water mixtures could be produced as a result of equipment failure such as during a fire. The mixtures must be recycled or incinerated in a controlled manner.
3. Tankage or loading leaks or spills could occur after shutdown of the plant. The spilled materials, which will be contained in the diking system, will be recycled or disposed of in the wastewater treatment system at a controlled rate. The effect on the wastewater treatment should not be drastic.

If any effect should occur, the biological treatment system would be the most susceptible portion of the treatment system. Every precaution has been taken in wastewater treatment design to reduce the probability of biomass destruction. The biological treatment system with completely mixed reactors can tolerate moderate shock loads, but massive spillage of toxic materials could destroy the biomass. This problem can be alleviated by a spill prevention and detection program, coupled with provisions to prevent the toxic material from reaching the biological system. Close monitoring of critical vital signs will be performed frequently, if not continuously, so that corrective measures are taken before problems fully develop. If total destruction did occur, holding capacity of the surge ponds, equalization basins, and possibly the ash ponds would be used to reduce or eliminate flow on a short-term basis. Suspended solids that do not settle will be filtered. A trouble-shooting program would be initiated to determine the cause and required actions to return on-line with new seed sludge.

Provisions for adding considerable powdered activated carbon to the biological system and a granular activated carbon filter to control organic compounds are proposed. Adding powdered activated carbon could, in time of emergency, prevent some irreversible damage to the biomass.

C.2.1.7 Water balance

Figure C.10 shows a plant water balance for the proposed wastewater treatment system when operating in a mode which discharges treated wastewater to the Green River. This figure shows that an average water withdrawal from the Green River will be approximately 3445 gpm. The average wastewater flow rate to wastewater treatment will be 931 gpm. This will consist of cooling tower blowdown at an average rate of 307 gpm and other wastewater streams at a rate of 624 gpm. After returning the treated effluent, the net water consumption will be approximately 2515 gpm.

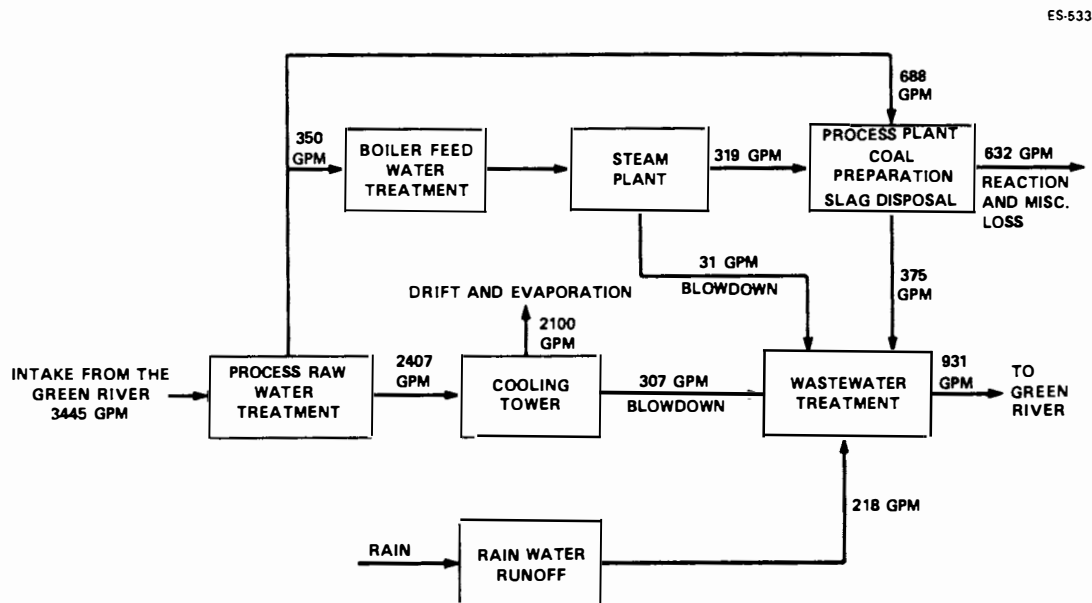


Fig. C.10. Preliminary water balance when treated wastewater is discharged.

Figure C.11 shows a plant water balance for the zero wastewater-discharge treatment system. This figure shows that average water withdrawal from the Green River will be approximately 2520 gpm. Treated wastewater effluent at a flow rate of 608 gpm will be used as makeup water for the cooling tower. Blowdown from the cooling tower will enter an evaporator where solids are concentrated and sent to a secure landfill. Condensate from the evaporator is sent back to the cooling tower as additional makeup water at a flow rate of 290 gpm.

As seen from Fig. C.11 the largest consumer of water will be the cooling tower (1482 gpm of makeup in the zero wastewater discharge case). Most of the water makeup to the cooling tower will be lost through evaporation.

Basis for estimates. The plant's overall water balance can be affected by many factors, including the enthalpy balance, the heat-rejection alternative employed and its operating conditions, the type of gasifiers used, and the rainfall intensity and duration.

The water balances shown in Fig. C.11 and Sect. C.2.1.7 are based on the enthalpy balance presented in Table C.3. The conventional wet evaporative cooling tower is chosen as the primary heat-rejection device for the balance. Evaporation from a cooling tower varies with air

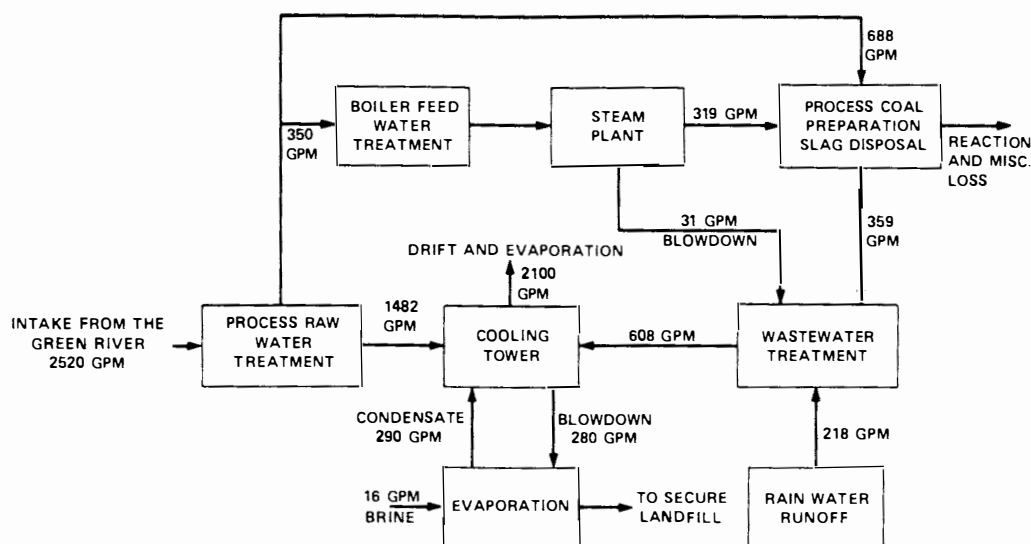


Fig. C.11. Preliminary water balance for the zero wastewater discharge case.

Table C.3. Approximate enthalpy balance

Factor	Heat quantity (10 ⁶ Btu/h)
Input	
Electricity	192
Fuel	914
Heat of reaction	976
Total	2082
Output	
Products	12
Air coolers	667
Cooling tower	1054
Heat and surface losses	133
Stack losses	216
Total	2082

humidity and temperature; the average evaporation of 2100 gpm shown in these figures is for summer conditions found at the site. It is also assumed that the cooling water is operated at about 7 cycles of concentration and that the GKT gasifier is used. The rainfall used for the balance is the 10-year, 24-h storm.

Balancing water use and demand. Balancing of water supply and demand is critical for the zero-discharge system. At this time, insufficient design work has been completed to permit an accurate water balance. A thorough evaluation will be performed of the rate at which the water-retention basin for rainfall can be emptied by cooling tower and process-water consumption. It will also be necessary to evaluate thoroughly rainfall patterns and plant-operation modes and their effect on water consumption to ensure that, under all combinations of weather conditions and operating modes, all wastewater can be adequately consumed within the plant to accomplish zero discharge to the river.

C.2.1.8 Expected frequency and duration of liquid effluent discharge

Discharge of liquid effluent could occur under one or more of the following situations:

1. Precipitation exceeds the 10-year, 24-h storm, or a prolonged wet period occurs.
2. Before the plant reaches the normal on-stream time, or when the plant is completely or partially shut down, and water consumption is less than wastewater generation.
3. Major water reuse equipment is not functional.

Once in 10 years, a rainstorm greater than the 10-year, 24-h storm may occur. Because the surge capacity of the wastewater treatment system is designed to handle the 10-year, 24-h storm, runoff in excess of this storm will have to be discharged. However, the discharge of the excess runoff should not cause a significant degradation of the river water quality. Data on runoff characteristics have shown that contaminant concentrations decrease sharply with time; most contaminants are flushed off during a brief period at the beginning of a storm. Plant design calls for the selective collection and treatment of the most contaminated portion of the runoff; only the lightly contaminated portion will be discharged. Because the discharge will probably coincide with a high flow in the Green River, the increased mixing capacity would result in a negligible impact. For the same reason, the impact during a prolonged wet period will be minimal.

Achieving zero-wastewater discharge requires a delicate balance of heat load and treated wastewater flow. Before the demonstration plant reaches the normal on-stream time, it may be impractical or impossible to evaporate all the treated effluent. Again, the impact on the river water quality will be small because the wastewater must be fully treated before discharge. Estimated on-stream time for the plant after the shakedown phase is 90%; 10% of the time the plant could be entirely or partially shut down for maintenance and repair. During complete shutdown, a very small amount of wastewater will be generated, which will be fully treated before discharge. Thus, its impact on the river should be minimal. In case of a partial shutdown, it is possible that some treated wastewater will be discharged because it may be impractical to completely consume it. However, because the quantity should be small and the duration short, no significant impact is expected.

The third scenario involves malfunctioning water reuse equipment. The on-stream time of such equipment is considered to be comparable to that of the SRC-I process. The exact frequency of this scenario cannot be accurately predicted because of a lack of experience. In the event of equipment failure, discharge of treated wastewater could occur. The treated wastewater, which must meet the effluent limits set forth in the NPDES permit, should not result in significant impact on the Green River during normal flow. Although some impact could result if the discharge coincides with a low river flow, the probability that discharge and low river flow occur simultaneously is small.

Long-term monitoring data for the treated wastewater effluent may prove that it is environmentally acceptable or even environmentally preferable to zero-wastewater discharge. Zero-wastewater discharge, although preferable from a surface water quality protection standpoint, generates highly soluble solid wastes, which exert a potential for impact on land resources and groundwater quality. The recycling equipment (including evaporators) will require considerable energy to operate, which imposes indirect impacts on the environment. When judging the environmentally preferable wastewater control system, the impact on the environment must be considered for all media.

C.2.2 Air pollution controls

The pollution-control technology employed is highlighted below for each pollutant: sulfur oxides, particulates, hydrocarbons, nitrogen oxides, carbon monoxide, and reduced sulfur compounds. Section C.3 elaborates on these systems.

C.2.2.1 Sulfur-oxides control

Sulfur-oxide control alternatives were considered for various parts of the plant and are discussed in Sect. C.3.1.1. Fired heaters are potentially major sources of sulfur oxides;

however, the fuel normally fired in the plant is a process-generated, low-sulfur fuel gas (~ 5 ppmv H_2S). The alternate fuel is oil; it is also process generated, but has a much higher sulfur content (0.8 wt %). During normal operation, sufficient gas will be available to meet all fuel requirements; thus oil is the backup fuel. During initial start-up, petroleum-based oil is to be used.

Two parallel Claus units are incorporated in the plant design for sulfur recovery, the second unit being a full-capacity spare. The tail-gas cleanup of the Claus unit is accomplished by a Beavon sulfur-removal unit (BSRU). The vented gases from the molten-sulfur storage and handling operations will be treated by small Stretford scrubbers to prevent release of sulfur compounds. If the Beavon unit should go off-line, the Claus tail-gas will be flared through the thermal oxidizer of the flare/controlled combustor system (Sects. C.2.2.6 and C.3.1.5).

The flue gas from the calciner will be incinerated and scrubbed to minimize SO_2 and particulates. Alternative particulate and SO_2 scrubbing technologies are being evaluated. These include a dry system utilizing a sodium carbonate spray drier and fabric filters, and a wet Venturi scrubber system utilizing sodium carbonate absorption and cyclone-type separation of liquids and particulate from flue gas.

C.2.2.2 Hydrocarbon control

Most liquid storage tanks will be equipped with fixed roofs; any vapors evolved will be directed to a vapor-recovery system where most of the vapor will be condensed and sent back to storage. All uncondensed vapors will be combusted in the enclosed thermal oxidizer of the flare/controlled combustor system (Sect. C.2.2.6). Liquid storage tanks for volatiles will be equipped with a floating roof, with vapors purged from the space between double seals and combusted in the flare system. Fugitive hydrocarbons will be minimized by providing liquid film seals and double mechanical seals (with a barrier-fluid system between the seals) on pumps and compressors, or by use of a system of an equivalent control nature. Use of flanged connections will be minimized. Sampling connections and drains will be equipped with caps, blind flanges, or double valving and will be drained into closed containers or through a sump into the closed sewer system to minimize fugitive hydrocarbon emissions. Also, thorough inspection, maintenance, and repair programs for process fittings will be implemented at the plant during operation to check the fugitive emissions.

During process upsets and emergencies, pressure-relief streams containing hydrocarbons will be flared by the system described in Sect. C.2.2.6. The hydrocarbons will be condensed as much as possible; the uncondensibles will be flared, and the condensibles will be fed to a holding tank that feeds the controlled combustor at a controlled rate to ensure that heavy hydrocarbons are adequately combusted. Some condensed hydrocarbons may be recycled to the process, depending on the upset situation. All hydrocarbons should be combusted before release to the atmosphere. Entrainment of heavy hydrocarbons with the light gases to the ground flare field will be minimized by designing blowdown tanks to allow sufficient disengagement of vapor and liquid phases. Alternative designs for this system are still being evaluated.

Hydrocarbons volatilized from the coal-drying operation will be vented to the atmosphere. The extent of volatilization will be minimized by controlling the drying temperature at less than $400^\circ F$ and designing the pulverizer/drier to minimize the residence time. A study is under way to determine the amount of devolatilization and contents of the volatilized matter at drier conditions.

Hydrocarbon control in the cooling tower is discussed in detail in Sect. C.3.1.5.

C.2.2.3 Particulates control

At rail car unloading points and the transfer to the storage pile, water sprays will be used as required for dust suppression. Conveyors transferring coal to storage piles will be covered. Underground reclaim from the storage piles will be totally enclosed and ventilated through a baghouse. After reclaim, prior to pulverization, transfer points and conveyors will be totally enclosed to the extent possible. Any ventilation of these enclosures will be exhausted through a baghouse to the atmosphere. Provision will be made to install water spray at transfer points should monitoring during operation indicate this is necessary. After pulverization all conveyors, transfer points, and coal processing equipment will be totally enclosed and ventilated

through baghouses. Fugitive emissions from the coal piles will be minimized by utilizing pre-washed coal and by spraying the piles with water, or in the case of the reserve piles, with a polymer crusting agent.

Vent gas from coal pulverizing/drying operations will also be filtered in a baghouse. Particulates will be removed from the calciner flue gas by the SO_2 scrubbing system described in Sect. C.2.2.1. The molten elemental sulfur from the sulfur-recovery area will be stored in a closed insulated tank to prevent emission of fugitive dust from open piles and solid sulfur handling. The anode coke from the calciner will be stored in silos, handled by a closed conveyor system with dust control, and transported in hopper cars. The SRC solid product conveying system will be totally enclosed. Section C.3.1.2 discusses alternative particulate-control systems.

C.2.2.4 Nitrogen-oxides control

The principal source of nitrogen oxides will be combustion of fuel in the process-fired heaters, the boiler, the calciner, and the controlled combustor.

Process-derived fuel gas, containing no known fuel-bound nitrogen, will be the fuel normally fired. Thus, by virtue of the clean fuel, fuel- NO_x formation will be eliminated.

Thermal NO_x formation will be controlled by utilizing low- NO_x burner design and combustion techniques, without compromising the fuel efficiency to the point where the amount of plant-derived gas would be insufficient to provide heat requirements. When plant gas is unavailable, plant-derived fuel oil will be used in the heaters.

All burners will be low- NO_x type, utilizing the concept of staged combustion, whereby combustion initially takes place in a fuel-rich region followed by complete combustion in a fuel-lean region. The staging effect is achieved by feeding the primary combustion air to the burner at a substoichiometric rate, thus creating a reducing atmosphere that inhibits NO_x formation. The remaining air requirement for complete combustion is then allowed to enter the burner flame zone slightly downstream from the reducing flame zone. The combustion is completed as the oxygen diffuses into the flame. Staged combustion results in low oxygen availability at peak flame temperatures and lower temperatures in oxygen-rich zones, which cause a reduction in the temperature-dependent NO_x formation reaction.

The combustion air will probably be preheated, especially in the large fuel-consuming heaters, because the effect of preheat on increasing fuel efficiency outweighs its potential for NO_x formation.

The controlled combustor will be burning heavy hydrocarbon compounds that are potentially toxic and/or carcinogenic. To ensure complete combustion, the unit will be designed and operated for high flame temperatures and long residence times. This type of combustion may favor NO_x formation. The normal combustion load on this combustor is low, perhaps less than 3 million Btu/h. Therefore, even though the NO_x evolution is relatively high on a Btu basis, it is (averaged annually) a small source of NO_x (no quantitative estimates of emissions are available).

C.2.2.5 Other sulfur species control

Reduced sulfur species (principally COS and H_2S) are noncriteria pollutants that would be converted to sulfur oxides after release by atmospheric oxidation; these are constituents of many process streams. These are removed from process streams in the acid-gas removal areas, then converted to elemental sulfur. Some residual reduced sulfur compounds remain in the Beavon tail gas (<100 ppm) and in the CO_2 stream (~150 ppm). The tail-gas from the Beavon unit has a design concentration of H_2S of less than 5 ppm. Impact analyses (plume modeling) discussed in Sect. 4.2.3.1 indicate that the concentration of H_2S in the Beavon tail-gas would have to be 50 ppm (ten times more concentrated in H_2S) to violate Kentucky H_2S standards. Such a condition would not be expected to occur. However, if this condition should occur, proper measures, such as operating the plant at a reduced rate, will be taken to ensure compliance. Flaring of the Beavon tail-gas does not appear to be necessary.

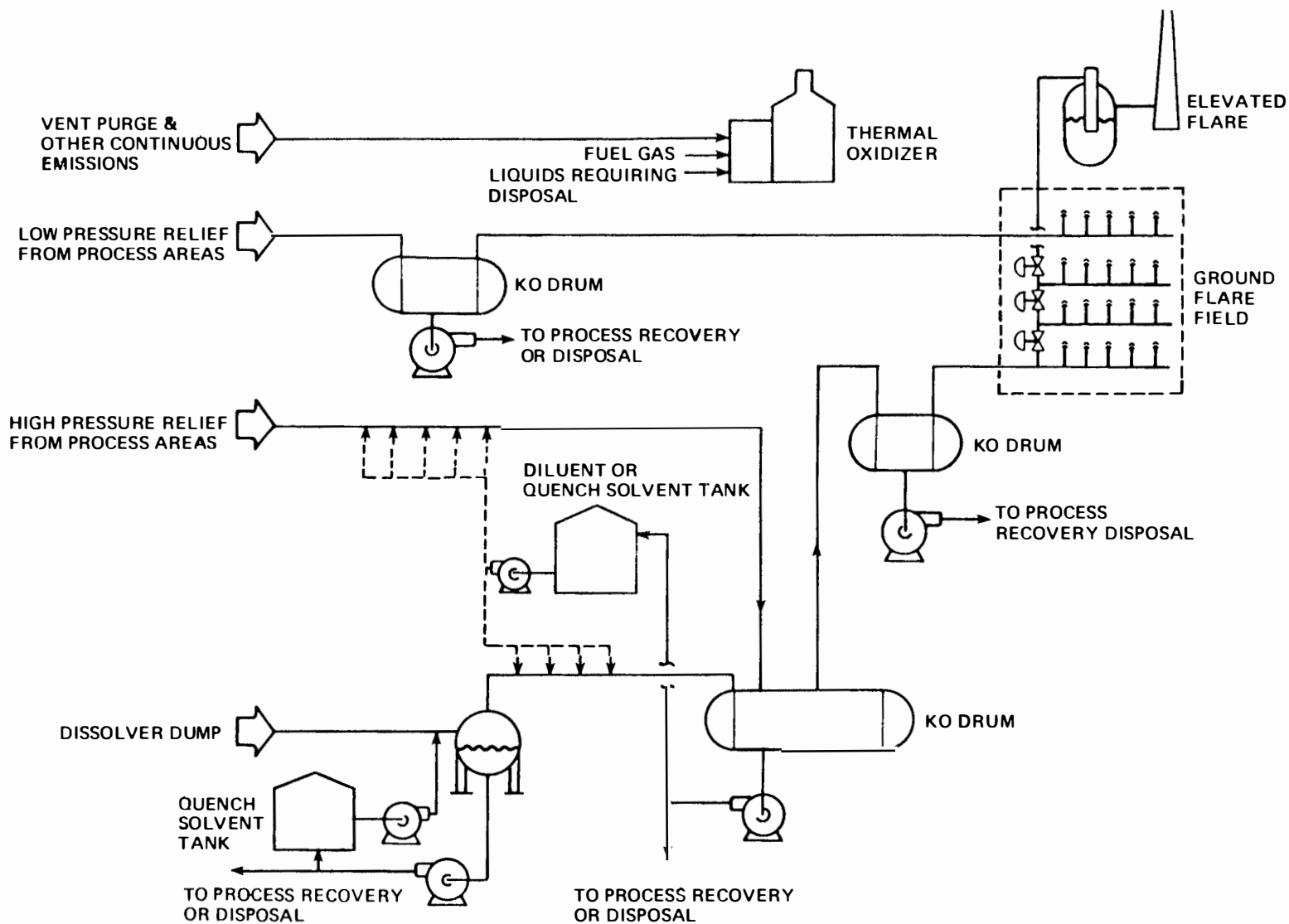


Fig. C.12. Proposed controlled combustor/flare system.

C.2.2.6 Proposed flare and controlled combustor system

Several combustible gases must be destroyed by combustion prior to release to the atmosphere. These gases arise from several sources within the demonstration plant. Some are continual emissions; others occur only under upset conditions and still others only during emergency conditions. A few of the process areas have a single-purpose dedicated combustion system as part of the ordinary design of that process. These combustors are not within the scope of this discussion.

Many pieces of process equipment handle hydrocarbon compounds that have the potential to cause health effects (including carcinogens). Hydrocarbon emissions from these sources will be treated in a common combustion systems designed to achieve high combustion efficiencies. The conceptual design (Fig. C.12) of the proposed system is presented here, along with a description of alternate control systems being evaluated.

Hydrocarbon streams to be destroyed by combustion

Detailed description of the various hydrocarbon streams to be combusted cannot be made until detailed engineering design has been completed. It is, however, possible to identify types of hydrocarbon emissions by category, and to estimate the magnitude of these emissions. On the basis of these preliminary estimates a combustor system has been proposed and several alternates have been selected for evaluation. The emissions fall into five categories:

- continually occurring emissions at low concentrations and pressures (e.g., gases from storage tank venting, purge gases from process equipment, condenser vents, continuously collected fumes),
- emissions resulting from minor upsets in operating conditions on various pieces of process equipment (e.g., intermittent pressure relief from pressure vessels to maintain safe operating pressures),
- materials produced during start-up and shutdown that must be purged because the next stage of normal processing is not ready to handle them,
- materials that must be purged rapidly and in large quantities because of a major process emergency (e.g., dissolver blowdown resulting from line blockage), and
- liquids collected from the system that cannot be recycled for reprocessing but which can be stored for combustion at whatever time and rate is appropriate (e.g., slop oils from wastewater treatment; liquids from flare-system knockout drums).

The appropriate combustion treatments for these various emissions differ, and consequently the combustion system proposed consists of a number of different components. A major factor in the design of the system is the degree of compatibility of the various emission for common treatment. This compatibility is influenced by several factors:

- pretreatment required prior to combustion,
- pressure levels that are caused in common headers because of emissions from a single source,
- continuity of emissions, and
- nature of material being combusted.

It is considered a goal of the system design to combust only gases containing C₅ or lighter hydrocarbons in open flames. Hydrocarbon releases from processes whose normal operating temperatures and pressures are high will require pretreatment to remove heavy hydrocarbons prior to combustion of the remaining gases.

Large releases (or many simultaneous smaller releases) from equipment operating at high pressures can cause flow rates in common headers large enough to raise the back pressure in the header. Processes served by this common header must not have a normal operating pressure below the anticipated maximum pressure in the common header. Otherwise, elevated pressures in the manifold could prevent relief of low pressure process equipment, which may overpressure the equipment. This principle affects selection emission sources to be served by a common header, and the number of different operating pressure levels required by the multiple headers.

Many sources can be expected to produce a more or less continuous emission and will not have major upsets that may greatly increase the rate of emissions (for example, storage tank vents and fume collection hoods). These emissions can be treated in a system designed so that extreme turndown ratios are not required. Liquids that can be stored indefinitely before combustion can be fed at a controlled rate to the combustor. Such streams whose flow rate is either inherently uniform or controllable are suitable for enclosed combustion under optimum combustion conditions.

Some materials requiring destruction have never been in contact with or do not contain the heavy hydrocarbons of greatest concern. These gaseous streams are generally easily combusted by well developed technology, and are routinely controlled by flaring. Such emissions are suitable for direct open combustion in properly designed smokeless flare systems.

Detailed design emissions characteristics

Although preliminary design concepts can be selected and evaluated based on current emission characterization, detailed system design cannot be completed at this time. To establish pre-treatment operating conditions, capacities, and turn-down ratios of individual elements of the combustor system and to select combined flow rates break points at which different types of combustion equipment are employed requires detailed information not currently available. This required information includes:

- complete heat and material balances for all process equipment,
- detailed summary of relief valve locations and relief conditions,
- reliability estimates to establish probability of failures or normal relief of individual equipment,
- detailed estimates of magnitude and duration of hydrocarbon releases resulting from specific types of emergency conditions, and
- probability estimates for frequency and duration of routine (nonemergency) upsets leading to relief valve emissions.

This information depends on completion of specific elements of the detailed engineering currently being carried out. As this information becomes available, it will be analyzed to provide an estimate of the frequency at which the combustion system will have to deal with flow rates of different magnitudes. This will make it possible to design maximum capacity and turn-down ratios for each element of the total combustion system.

System components being evaluated

The controlled combustor and flare system is expected to be composed of several different types of combustion devices. There has been some confusion over the use of the term "controlled combustor." As used in this document "controlled combustor" is a combustion system for which the flow rate, combustion conditions, flame mixing conditions and stoichiometry can be adjusted to maintain efficient combustion over a wide range of feed conditions. It will be composed of several individual equipment types. It is distinguished from the uncontrolled combustion conditions of an open elevated flare, which must handle a wide range of feed conditions and flow rates and which offers very little option for adjustments to maintain combustion conditions close to optimum.

The various types of combustion equipment which have been evaluated for inclusion in the controlled combustor and flare system are described below. Standard nomenclature for identifying these types of equipment has not been established. However, to be consistent within the scope of this document, the various equipment will be identified as:

- thermal oxidizer (nuncatalytic),
- thermal oxidizer (catalytic),
- ground flare field,
- contained flare,
- elevated flare (smokeless), and
- elevated emergency flare.

In addition to the combustion devices above, three other critical system components must be evaluated:

- collection manifold systems,
- emissions pretreatment and liquid knockout systems, and
- turndown flow control systems.

The various elements and alternatives for all of these components are described in Sect. C.3.1.5.

Thermal oxidizer. The thermal oxidizer is an enclosed combustion chamber. It is lined with refractory material, and the walls are kept hot. The combustion volume is designed to provide a long residence time in a high-temperature environment, even after gases leave the hot flame zone. Combustion air and secondary air can be controlled to provide a favorable stoichiometry for highly efficient oxidation. Combustion can be assisted by an oxidation catalyst.

Highly efficient destruction of hydrocarbons (to CO_2) can be achieved, even with heavy hydrocarbons that are difficult to oxidize. A destruction efficiency of 99+% is an achievable goal. Gases fed to this device will not require pretreatment to knock out heavy hydrocarbons. This component is very suitable for treating continuous gas flows such as storage tank vent gases, equipment purge gases, and fume collector gases. It is also compatible with liquids that have been collected and are fed at a controlled rate. Combustion conditions can be designed to achieve the design goal with heavy hydrocarbon liquid and gaseous feeds. The oxidizer is, thus, compatible with both gaseous and liquid fuels.

The walls must be kept hot, and the combustion volume must be chosen according to the maximum feed rate. When the feed rate is significantly lower than the maximum rate or when feed is intermittent, supplemental fuel must be added to keep the refractory walls hot. The maximum size of thermal oxidizers is limited by the state of the art. Furthermore, capital costs are highest for thermal oxidizers of all other components being evaluated.

Because of excessive auxiliary fuel requirements and maximum size limitations, the thermal oxidizer is not suitable for complete treatment of large emergency upset emissions or highly variable minor upset emissions.

Ground flare field. The ground flare field consists of a large array of small flare tip fuel nozzles. These are manifolded together in rows in such a way that as flow to the system increases additional flare tips are brought into service. Each burner row has its own pilot igniter. The range of flow rates that must be handled by each individual flare is small. Wide turn-down ratios can be achieved by controlling the number of flare tips in service at any instant.

To prevent damage to adjacent equipment and injury to personnel in case of a large energy release, the flare field is enclosed by a high wall or dike, which is lined with refractory material, or by a combination of a pit and wall. The design of the flare field could enable it to be divided into subsections separated by refractory barriers capable of protecting workers performing maintenance from heat radiation in neighboring sections. Thus maintenance could be carried out in a single zone without shutting down the entire flare field. This would allow the flare field to be kept continually available at nearly its maximum rated capacity. The maximum capacity is limited primarily by ground space availability.

Because each combustion tip sees only a limited range of flow rates, it is possible to keep combustion conditions relatively stable and near optimum. However, because the flame is not enclosed, a long residence time similar to that for the thermal oxidizer cannot be maintained. Conditions can be kept nearly optimum for an open flame and high stoichiometric ratios of air-to-fuel can be maintained in essentially all parts of the flame. In this way, it is possible to design for smokeless combustion of light gases.

It is very difficult to measure combustion efficiency in an open flame. Percentage of destruction of heavy hydrocarbons is less certain than for a thermal oxidizer. Furthermore, smokeless combustion requires only lighter hydrocarbons be present in the fuel. Therefore, it is necessary to pretreat emissions to knock out heavier hydrocarbons prior to combustion of the remaining ground flare field. If the concentration of C_5+ hydrocarbons in the gases is kept in the ppm range, it is expected that 99+% destruction of these gases can be achieved.

Because of the wide turn-down capabilities, the ground flare is suitable for combustion of hydrocarbon releases ranging from the maximum anticipated flow down to the continuous levels treatable by the thermal oxidizer, provided the feeds are pretreated to reduce heavy hydrocarbons (which include most of the compounds of carcinogenic concern).

Design of a compatible manifolding system for equipment operating at various pressure levels is a critical factor (discussed later). The flow control system that makes additional burner tips available as the flow increases is also critical. Capital costs for this system are much lower than for a thermal oxidizer of equal capacity. If the turn-down ratio is large, operating costs are also much lower. Capital costs can be competitive with and sometimes lower than an elevated flare of equal capacity. Because of the need for supplemental fuel in an elevated flare with wide turn down, operating conditions will also be lower for a ground flare field.

Contained flare. The contained flare is a single large-diameter refractory lined stack located at or near ground level. Hydrocarbons to be burned are premixed with a small amount of primary air and injected to the flare stack. Secondary combustion air is supplied by convection. Mixing of secondary air may be assisted by air or steam jets at the flare tip to achieve smokeless combustion of lighter hydrocarbon gases. The single nozzle must handle gas flows from its maximum rated capacity down to its minimum turn-down ratio. Enough compressed air or steam must be available to provide combustion assistance even at the maximum rated capacity.

Flaring activity takes place completely within the stack. The inside diameter of the refractory-lined stack is sufficient to allow some convective circulation of air from the open end of the cylinder down to the flare tip at or near the base. Primary combustion air is convected through ports at the bottom of the cylinder. The refractory lining protects nearby personnel and equipment from heat radiation during large heat releases. It also eliminates visibility and reduces to some extent noise associated with open flares.

The performance of the contained flare is intermediate between that of a thermal oxidizer and an open elevated flare. The refractory lining provides for somewhat prolonged high-temperature combustion beyond the flame. It also eliminates effects of crosswinds on the flame. However, combustion cannot be precisely controlled as in a thermal oxidizer. It is difficult to measure destruction efficiency or guarantee high-percentage conversion of heavy hydrocarbons to CO_2 . It is, therefore, necessary to knockout heavies by pretreatment, as for the ground flare field. The maximum rated capacity of a single contained flare is somewhat limited by the state of the art. Large heat releases would require multiple units in parallel and a flow distribution and manifolding system similar to the ground flare field. With such a distribution system, the contained flare is suitable for the same type of service as the ground flare field.

Elevated smokeless flare. The elevated smokeless flare is similar to the contained flare. It consists of a single flame propagation point. It can be either steam-assisted or air-assisted and can achieve smokeless combustion of lighter hydrocarbons. The flame is elevated to protect equipment and personnel from heat radiation. If the maximum heat release rate is large, it is sometimes necessary to maintain a large clear zone at the base of the flare tower.

Because the flame is open, and because it must handle a large turn-down ratio, optimum combustion conditions are difficult to maintain. Combustion efficiencies are hard to measure but are expected to be lower than for a contained flare because the residence time in a hot zone is lower and the flame configuration is less stable. Consequently, emissions must be pretreated to knockout heavier hydrocarbons. Sufficient steam or air must be available to assist combustion at maximum anticipated flaring rates if smokeless combustion is to be maintained.

The elevated smokeless flare is intended to operate in the smokeless mode at all rates except the maximum emergency conditions. Sufficient steam capacity must be available to assist combustion at all rates except maximum emergency conditions. If this exceeds the normally available plant steam, additional capital costs will be required for the boiler. Otherwise, the availability of plant steam will limit the smokeless performance of the flare.

Adding steam to the combustion process increases the noise generated by the flare; this effect is more noticeable at high flaring rates.

The maximum energy release rate anticipated determines the height of the flare, hence the capital costs. A single flare that which can handle a worst-case upset is expected to be very tall with a large clear zone at the base, and would require a large capital expense. The steam-assisted flare is most suitable for smokeless combustion at flow rates up to that limited by available plant steam and non-smokeless emergency releases at higher rates.

Elevated emergency flare. The elevated emergency flare is simpler than the smokeless steam- (or air-) assisted flare. It is designed to provide for safe release of energy in a worst-case upset. Because combustion conditions are essentially uncontrolled and energy release rates are high, combustion is generally not smokeless and hydrocarbon destruction efficiency is probably the lowest compared to all other components being evaluated.

Capital and operating costs are both lower than for a steam-assisted smokeless flare. Pre-treatment of gas streams to knockout heavy hydrocarbons is necessary. Even in emergency conditions knockout should be as complete as possible, as long as rapid high-volume flaring of gases is also maintained. The elevated emergency flare is suitable for a backup device to safely release gases only in extreme emergencies at flow rates that cannot be predicted well enough to allow for proper design of one of the more efficient components.

Collection manifold systems. A collection manifold system must be designed to collect emissions at their sources and deliver them to the controlled combustor system. The critical design feature of the manifold system is the existence of back pressure resulting from high gas flow rates. This determines the physical dimensions of the gas transfer lines and the manifold pressure levels at which successive elements of the controlled combustor system come into play.

Emissions from equipment with normally low operating pressures or low safety valve relief pressures cannot be collected into a manifold where the back pressure at maximum flow exceeds the equipment pressure. This condition probably dictates the use of multiple collection manifolds. Choice of pressure levels and detailed design of these manifolds cannot be completed until detailed engineering of the process equipment has reached an advanced stage.

Emissions pretreatment and liquid knock-out. The goal of the emissions pretreatment system is to reduce the concentration of C_5+ hydrocarbons to ppm levels in gases fed to any controlled combustor component other than a thermal oxidizer. This requires a system of holding tanks, quench cooling of gases, and liquid knockout drums to collect entrained liquids and condensed gases in transfer lines. The problem is complicated by the presence of liquid SRC in some potential hydrocarbon releases, which can solidify if the temperature falls too low.

The first element of the system being evaluated is a blowdown tank for each piece of high-pressure equipment that would need to be evacuated during an upset (e.g., the dissolver vessels). This tank would accommodate the initial contents of the equipment and any additional feed during a period long enough to safely shut off that feed. As material is dumped to this tank, it would be quenched by spray cooling using a cold, compatible solvent. The blowdown tank would contain sufficient volume to separate most liquid from gases, except for small entrained droplets. The operating pressures and temperatures of this blowdown tank would be intermediate between those of the equipment being relieved and the manifold to which the gases discharge. Solvent addition rates and temperatures would be designed to prevent solidification in the blowdown tank and liquid transfer lines.

Hot gases from the blowdown tanks and relief of other equipment not requiring blowdown tanks will be further quenched by spray cooling with a diluent solvent. Solvent addition rates and quench temperatures will be chosen to give a low-equilibrium concentration of C_5+ hydrocarbons in the quenched gas. Immediately after this quench, gases will pass through a knockout drum to eliminate entrained solvent and condensed liquids.

Further condensation of light liquids will occur in the transfer lines to the controlled combustor. The lines will be designed to prevent accumulation of condensate; a final liquid knockout will be placed just ahead of the controlled combustor system.

Liquids collected at various stages of the knockout system will be held for later treatment. Liquids will be recovered at a later time for recycle to the process or other valuable end use whenever possible. Otherwise, these will be sent to the thermal oxidizer.

Turndown flow control systems. As the flow rate to the controlled combustor system increases, the back pressure in the collection manifold will correspondingly increase. This pressure variation can be used to actuate flow controls to introduce gases to additional elements of the controlled combustor system (e.g., additional rows of burners in a ground flare field).

Two fundamental approaches to this flow control are being considered. The first is automatic gas flow control valves (e.g., butterfly valves). Pressure sensors in the headers would

transmit signals to an automatic control system to position the feed valves. As successive predetermined pressure levels are reached, valves would be opened to introduce additional combustor elements.

The second approach is a series of liquid seals of gradually increasing depth. As pressure in the manifold increases, the gas will break these liquid seals, enabling flow to additional combustor elements.

Selection of flow control system depends greatly on the controlled combustor design as well as estimated gas flow rates in the manifold system. Final selection cannot be made until detailed engineering design is at a more advanced stage.

Proposed integrated system

The integrated system design presently being evaluated is shown schematically in Fig. C.12. Continuous low-pressure gaseous emissions will be fed without pretreatment to a thermal oxidizer. These gases will not enter the manifold system for the ground flare field. Liquids which cannot be reclaimed for process use will also be fed to the thermal oxidizer.

Contents from the dissolver will be discharged to a blowdown sphere, along with a quench solvent. Gases from the blowdown tank and other high-pressure equipment will be further quenched by diluent sprays, and liquids will be collected in knockout tanks. After liquid knockout, these gases will proceed to the variable-pressure manifold of a ground flare field. Gases from low-pressure equipment will go through liquid knockout and then directly to a low-pressure manifold of a ground flare field.

The low-pressure manifold will have a separate set of burner tips in the flare field independent of those used for the variable-pressure manifold. A series of pressure-actuated flow controls (valves or water seals) will send gases from the variable-pressure manifold to the appropriate number of rows of burner tips of the ground flare field.

The ground flare field will be sized to handle the largest anticipated flow (after analysis of probability and magnitude of emergency release events). In the design of the ground flare, the feasibility of dividing the rows of burner tips into zones that would enable routine maintenance without significantly reducing the rated capacity will be examined.

To protect against the possibility of extreme emergencies, when the rated capacity of the ground flare is reached, further increases in flow will be diverted to an elevated emergency flare (not steam assisted).

Design goals for components of controlled combustor and flare system

The design goals and criteria for individual components of the base case controlled combustor system are summarized below.

Thermal oxidizer

- 99+% destruction of hydrocarbons to CO_2 and H_2O
- Capacity for all continuous low-pressure emissions
- Designed to handle both gaseous and liquid streams

Liquid knockout

- Blowdown system to handle all contents and feed until shutdown for major high-pressure equipment
- Liquid quench to reduce all hydrocarbons heavier than C_5 to less than 1% of gas flow
- Dilution of streams containing SRC by appropriate solvent to prevent solidification in lines or knockout drums
- Velocities in transfer lines and knockout drums to eliminate entrained liquids from combustor

Collection manifold

Multiple operating pressure levels
 Separate low-pressure system
 Flow controls to keep flow rates to individual combustor components within narrow ranges for performance

Ground flare field

99+% destruction of light hydrocarbons to CO₂ and H₂O
 Sized to handle total emissions from worst-case predicted upset (e.g., dissolver blowdown)
 Sequential addition of burner rows depending on back pressure in manifold
 Essentially complete conversion of C₅ or lighter hydrocarbons to CO₂ and H₂O
 Smokeless combustion when burning pretreated gases (C₅ or lighter)
 Essentially noiseless operation not visible at ground level
 Zoned for maintenance operations while on-stream; redundant capacity for maintenance

Elevated emergency flare

Capacity to handle all anticipated gas flow for a major emergency
 Does not see gas feed except in major emergency
 Elevation and cleared zone at base designed to protect personnel and equipment from heat radiation

C.2.3 Solid waste disposalC.2.3.1 Types, quantities, and classification

Five major types of solid waste resulting from the SRC-I process will be (1) slag and fly dust from the gasifier, (2) metal-bearing inorganic solids and water-soluble solids from wastewater-treatment processes, (3) biological solids, also from the wastewater treatment facility, and (4) water-soluble solid wastes from the zero-discharge treated wastewater evaporator, and (5) slop oil from the process area, various plant wastewater streams, and the flare/controlled combustor systems. In addition, there will be minor quantities of other types of solid waste, including a water-soluble waste from the flue-gas desulfurization system on the calciner, spent catalysts, spent activated carbon, and process area, coal pile, and SRC pile runoff solids. Section C.4 provides additional discussion of solid-waste characteristics.

The quantities and probable RCRA classification of the solid waste are estimated below in Table C.4.

Disposal of the gasifier slag has been a key environmental issue facing the synfuel technologies. A sample of Kerr-McGee ash concentrate from a pilot-scale SRC-I plant was gasified in a pilot-scale GKT gasifier. The slag and fly dust from the gasifier were then sent to the Oak Ridge National Laboratory where the proposed RCRA leaching experiments were performed. The preliminary results reported in Appendix P indicate that this slag is not hazardous under RCRA regulations.

No leaching tests have been conducted on the metal-sludge, but it is a fair assumption that toxic trace metals and organics will be present in these sludges and they will accordingly receive a hazardous RCRA classification. In addition, the quantities of these sludges are relatively small. For these reasons, they would be stored in a secure landfill as illustrated in Fig. C.13.

Table C.4. Identification of potential hazardous and nonhazardous solid wastes

Type of waste	Quantity (dry metric t/y)	Wet volume (m ³ /y)	Probable RCRA classification ^a	Moisture assumed (%)	Specific gravity
Gasifier slag and fly ash	209,520	285,200	Nonhazardous ^d	20 (50) ^c	1.6 (1.3) ^c
Water soluble solids ^d	10,430	25,730	Assumed hazardous	70	1
Metal Precipitation sludge	2,400	8,950	Assumed hazardous	80	1
River water treatment sludge	2,400	8,950	Nonhazardous	80	1
Slop oil	1,815	1,990	Assumed hazardous	15	
Spent activated carbon ^e	910	2,680	Assumed hazardous	17	0.4
Biological sludge	600	2,980	Assumed hazardous	80	1
SRC and coal pile runoff solids	135	150	Assumed hazardous	25	1.2
Equalization basin sludge	135	150	Assumed hazardous	40	1.5
Process area runoff solids	10	12	Assumed hazardous	50	1.6
Spent catalysts	1		Assumed hazardous		

^aResource Conservation and Recovery Act.^bSee Appendix P for leaching test results.^cValues for fly ash.^dFrom zero-discharge evaporator system.^eFrom tertiary water treatment system.

The classification of the biological solids will depend on the composition; they may or may not be hazardous but will be treated as hazardous (see Table C.4) until proven otherwise. The characteristics of the sludge may be similar to that of a municipal wastewater treatment system. Municipal sludges have been classified as nonhazardous in the May 19, 1980, RCRA regulations. Incineration of biological sludges is being considered as an alternative to landfilling.

Water-soluble solids produced by the zero-discharge evaporators have the potential to contaminate any groundwater they may contact. These solids will be isolated by disposal in a secure landfill such as illustrated by Fig. C.13. In addition, techniques for stabilizing these waters and dispersing in an impermeable solid medium within the landfill are being evaluated (Sect. C.3.2.1).

C.2.3.2 Methods of handling and disposal

The disposal sites will be constructed and maintained in accordance with applicable Federal and State solid waste guidelines and regulations. Because the guidelines and regulations have not been finalized, the design discussed herein will be subject to modifications. EPA and Kentucky agencies will be consulted regularly as detailed design is formulated. Consultation with the regulatory agencies will be imperative because final regulations may not be promulgated before the detailed design phase or specific design standards may not be included in the promulgated regulations. Indications are that the EPA will promulgate performance rather than design standards. The hazardous waste landfills and the slag/ash ponds will have the capacity to store the waste produced during a 5-year demonstration phase.

The currently proposed design for the hazardous waste landfill is based on the proposed RCRA design standards published on December 18, 1978. Although the final standards will most likely be different, the proposed standards do show the basic features that a hazardous waste landfill should have: double liners, leachate collection, leachate detection and monitoring, and diking for prevention from flood inundation. As Fig. C.13 shows, the hazardous landfills will have embankment dikes constructed with excavated materials from the plant process area and will have a 0.9 m (3 ft) thick clay liner above a 20-mil thick synthetic liner. The hazardous landfills

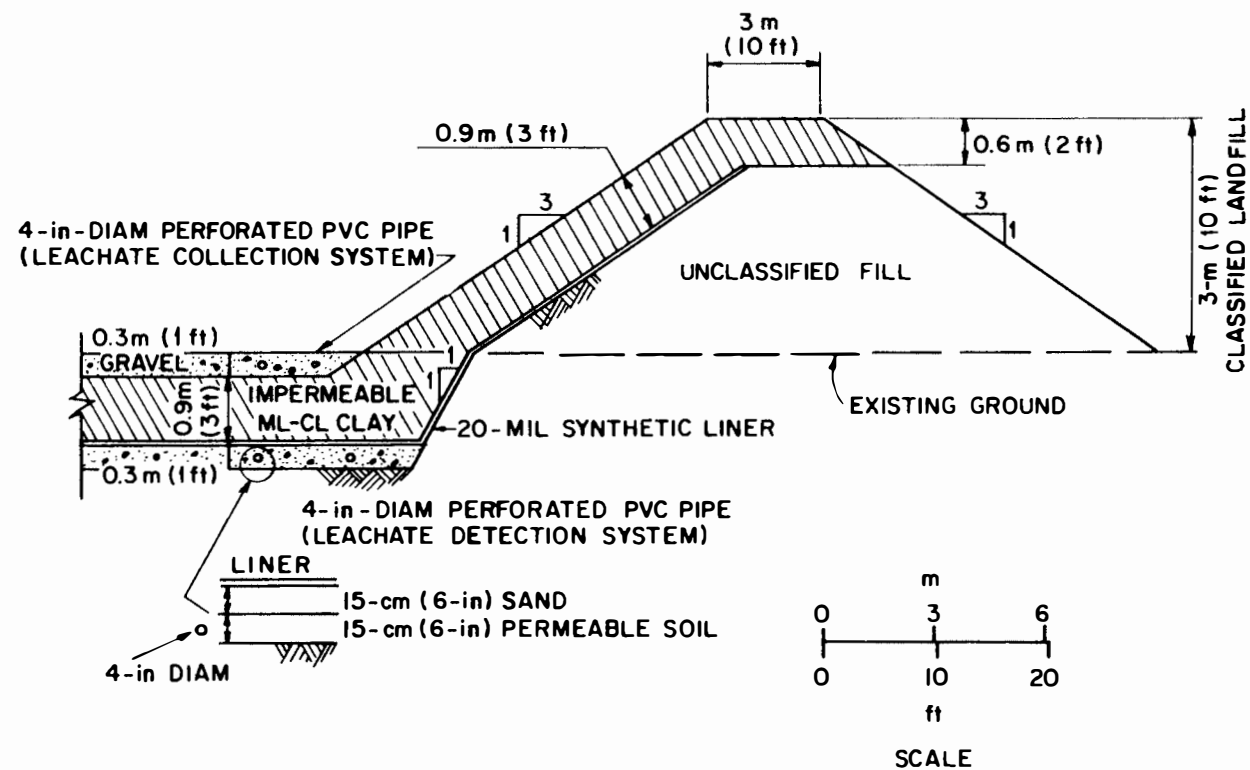


Fig. C.13. Cross-sectional diagram of the proposed hazardous waste landfill.

will be used to store metal-bearing sludges, spent catalysts, activated carbon, equalization basin solids, zero-discharge solids, and process area, coal pile, and SRC pile runoff solids. A leachate collection and removal system on top of the clay liner will collect and remove leachate generated in the landfill. The top clay liner will provide primary containment of the waste and protection for the synthetic membrane liner. The synthetic liner will provide containment of any waste that migrates or leaks through the clay liner. A leachate detection and removal system will be located beneath the synthetic bottom liner. The bottom elevation for this landfill will be above the 100-year flood level, and the dike above the 500-year level. As the repropoed regulations published on February 5, 1981, require, the bottom elevation of the landfill must be 2 m above the historic high groundwater table. This proposed requirement, if eventually promulgated, will be met.

Testing of compacted onsite clay indicates that its permeability is about 10^{-7} cm/s. Consequently, subject to other testing for compatibility, this material will be extensively used. The process area will also include curbed concrete pads for areas likely to be contaminated. Additional evaluation is being made in the disposal areas regarding the use of synthetic liners and/or clay liners.

Synthetic liners such as high-density polyethylene, reinforced hypalon, butyl rubber, neoprene, and others will be evaluated and tested. The EPA document "Lining of Waste Impoundment and Disposal Facilities," of September 1980 will be used as a guide.

Synthetic liner testing will be conducted as part of the selection process. Preliminary selection of liner materials will be based on knowledge of the expected compatibility of the material with the leachate that will be generated by the wastes. Testing on the preliminary liner materials will be conducted by exposing the liner to leachate generated by the wastes for a finite period of time. The specimens are subjected to a variety of tests before and after exposure to the wastes to determine the adequacy of the materials. The types of tests included are thickness (swell), tensile strength, elongation at break, hardness, and tear strength measurements; water absorption, extraction tests, seam strength, puncture resistance, water vapor transmission, density measurements, and leachate absorption tests. Liner testing is an integral part of the detailed landfill and slag/ash pond design.

Dikes are expected to be constructed with compacted clay. Synthetic liners, where applicable, will be extended from the bottom (within the diked areas) over the inside face of the dike and fastened at the top.

In accordance with RCRA regulations, a groundwater monitoring system will include monitoring wells hydraulically downgradient and some distance upgradient from the facility (see Sect. 4.5). The landfill will be divided into several cells. In the event of liner leakage, the faulty cell can be isolated (see Appendix HH, Contingency Plans for Liner Breaching). The environmental effects of solid waste disposal are discussed in Sects. 4.2.2.2 and 4.2.1.2.

Laboratory tests on gasifier slag and flydust (Appendix P) indicate that these materials are nonhazardous under RCRA criteria, suggesting that these solids could be acceptably stored in a nonhazardous landfill. The phase zero conceptual design proposed storing the wastes in a nonhazardous landfill having a 6-in.-thick clay liner. During preparation of the DEIS, DOE/ICRC evaluated alternatives to this landfill design and proposed constructing the first slag landfill as a hazardous waste disposal facility having a 3-ft-thick clay liner. At this time several alternatives are under consideration and EPA and KDNREP are providing guidance to DOE/ICRC. The design alternatives being evaluated relate to liner thickness, liner permeability, and the elevation of the landfill base relative to the groundwater table. Regardless of the alternative finally chosen, the slag/ash ponds will have the same key features as the hazardous waste landfill, i.e., double liners, leachate collection system, leachate monitoring system, and diking to avoid inundation during major floods.

The gasifier wastes will be pumped to the pond as a slurry. Supernatant will be drawn from the pond and recycled to process areas. A blowdown stream will be directed to the wastewater treatment plant to control the buildup of dissolved solids.

In the event of a 100-year flood, groundwater levels could approach or attain surface-water levels, causing the clay liner system to "float." This will not be a problem for the hazardous materials landfill whose base is above the 100-year floodplain. Such an event could, however, cause a breach in the liner of the gasifier slag pond. Engineering provisions to avoid "floating" of the ash landfill liner, such as placement of water barriers, are being evaluated.

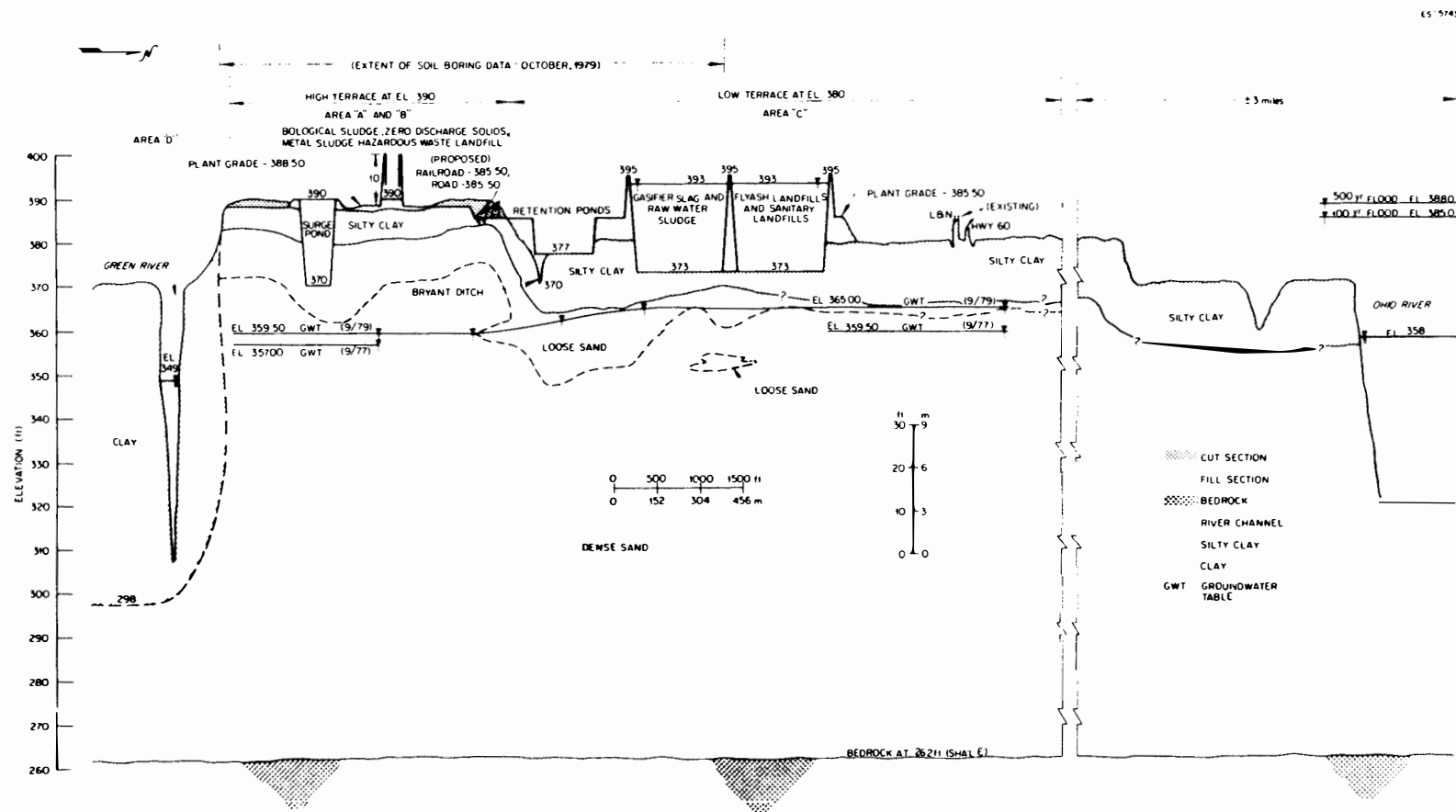


Fig. C.14. Cross section of the proposed site showing the grading plans and the relative elevations of waste facilities, clay, and groundwater table.

(see Sect. 4.2.2.2 of Vol. I). Tracking of groundwater levels regularly will provide sufficient warning of a high water table condition. The use of construction methods specifically designed to avoid soil liquefaction problems will also be evaluated.

Figure C.14 shows a cross section of the proposed site showing the grading plans and the relative elevations of the waste handling/disposal facilities, clay, and groundwater table. Solid waste handling alternatives are discussed in Sect. C.3.2.8.

C.2.3.3 Closure plan -- hazardous waste landfill

The current final regulations under 40 CFR 267 dealing with new hazardous waste treatment storage and disposal facilities are performance based standards. Previously the EPA had proposed standards that applied generic design criteria. However, because of the great diversity in site characteristics, the EPA now believes a case-by-case review of each facility design and its respective site will provide greater assurance of protecting the ground and surface waters from potential long-term adverse environmental impacts. To this end, the closure plan for the SRC-I facility will be developed in conjunction with both the USEPA and KDNREP and will be submitted for review and approval to these agencies prior to construction of the hazardous waste facilities.

The plan will address both design and operational considerations for the closure and post-closure activities. The purpose of the plan will be to ensure (1) prevention of adverse effects on the groundwater quality, (2) prevention of adverse effects on the surface water quality, (3) prevention of adverse effects of air quality, and (4) prevention of adverse effects from migration of waste constituents in the subsurface environment.

The design of closure facilities will reflect a detailed consideration of many factors including, but not limited to (1) the type and amount of waste in the particular facility; (2) the mobility and expected rate of migration of the waste(s); (3) the site location, its topography, and the surrounding land uses, both current and projected; (4) the climatic conditions in the area and the region; (5) the characteristics of the cover including material to be used, final surface contours, thickness, porosity and permeability; (6) slope, and length or run of slope; (7) the use and life of synthetic liners; (8) type of vegetation; (9) geological and soil profiles; and (10) surface and subsurface hydrology of the site.

In addition to the design considerations listed above, the closure plan will address procedures that will be used to monitor and maintain the site after closure. These procedures will include at a minimum: monitoring and evaluation of groundwater quality at the facility site; regularly scheduled inspections of the site to review integrity of the cover material from disturbances or erosion, health of the cover vegetation, condition of the groundwater monitoring system wells and changes in surrounding land use with specific attention to new groundwater withdrawal and surface water control systems; and an explanation of actions to be taken in the event of damage to the site or contamination of the environment from the closed site.

C.3 PLANT DESIGN AND ENVIRONMENTAL CONTROL ALTERNATIVES

C.3.1 Air emissions control alternatives

C.3.1.1 Alternatives for controlling emissions of sulfur oxides (SO_x) and reduced sulfur (S) compounds

Sulfur-recovery plant

Sulfur enters the plant as a component in the coal. Approximately 93.6% of the total sulfur entering in the coal feed will be recovered as elemental sulfur in the sulfur-recovery area. Nearly all of the remaining sulfur in the coal remains as residual sulfur in the plant products. The total sulfur emitted to the atmosphere is estimated to be 1,209 lb/d, or 0.3% of the total sulfur entering the plant. This includes sulfur in the fuel gas to be used in plant (8 lb/d), in the effluent from the flare and controlled combustors (48 lb/d), sulfur recovery area (46 lb/d, mostly reduced sulfur compounds), the scrubbed flue gas from the calciner (217 lb/d), and the vent from the gas treatment system (890 lb/d). Emissions from the calciner scrubber account for 14% of the total atmospheric sulfur emissions, but approximately 74% of the sulfur dioxide emissions. See Fig. C.4 for the plant-wide sulfur balance.

Through a series of processing steps in the SRC, gasification, coking, and expanded-bed hydrocracking areas in the plant, sulfur which was contained in the coal is hydrogenated to H_2S .^{*} The H_2S is contained in these various process streams in small quantities. These process streams are sent to the gas treatment area for acid-gas removal. Two parallel acid-gas removal processes are planned to remove H_2S , COS , and CO_2 from the process streams: the Selexol process, which uses a proprietary physical selective solvent; and a diethanolamine (DEA) solvent process. Both these processes produce a concentrated H_2S/CO_2 stream which is sent to the sulfur-recovery area. No atmospheric emission is evolved from the DEA unit; however, some carbonyl sulfide and H_2S are emitted to the atmosphere from the Selexol unit in a CO_2 and nitrogen waste stream (890 lb/d sulfur).

The selection of the acid-gas treating process depends upon the acid-gas partial pressure, the ratio of CO_2 to sulfur compounds, feed stream impurities, hydrocarbon content, and the treated stream purity requirement. The shifted syngas from the shift unit has about 360 psi acid-gas partial pressure and contains no heavy hydrocarbons.

Physical solvent processes such as Selexol and Rectisol are considered more favorable for treating this kind of gas stream than are chemical absorption processes. However, of the chemical processes, a hot carbonate process such as Benfield's Hi-Pure system is considered the most likely.

A screening study of these processes was conducted by the industrial partner. Selexol was found to be more economical than Rectisol on a nonselective acid-gas removal basis and more economical than the Benfield's Hi-Pure process from an operating standpoint.

The sulfur-recovery plant in the selected design will consist of two three-stage straight-through Claus units (one being a 100% spare) and a Beavon-Stretford system. The concentrated H_2S stream from Selexol and DEA units will be converted to elemental sulfur in one of the Claus units; and the tail-gas from the Claus unit will be further treated in a Beavon-Stretford system. Provisions will be made to incinerate the Claus plant tail gases in the thermal oxidizer of the flare and controlled combustor system (Sects. C.2.2.6 and C.3.1.5) when the BSRU is not operating. This is expected to occur only rarely (see below). Based on data of several operating plants, typical concentrations of total sulfur compounds in the Beavon-Stretford effluent should be in the 50 to 100 ppmv range, normally at the low end of this range. The concentration of H_2S specifically is expected to be less than 5 ppmv.

While many alternative processes for sulfur removal are available, the combination of Claus and Beavon sulfur removal was chosen as the preferred alternative because it has been well demonstrated in full-scale operation in similar services with a high degree of reliability and high removal efficiency. Beavon sulfur removal units have been sufficiently demonstrated; 35 units are in operation, serving approximately 7000 long tons per day of Claus capacity. This is approximately one-half the 1980 sulfur recovery in the United States. No operating problems have been observed, and greater than 99% operating reliability is expected. Stretford absorber plugging was an early problem that occurred when packed tower absorbers were used, but it has since been solved by design changes which include a preabsorber venturi. Trace species or metals that may enter the unit are not expected to cause operating problems. Ammonia has not posed a problem to Beavon Stretford units, and any HCN passing the Claus plant would be converted to ammonia and carbon monoxide by the Beavon Stretford system. In the Prevention of Significant Deterioration (PSD) permit review, the EPA will decide whether this is best available control technology (BACT).

One of the alternatives considered, a combination of Claus and Shell SUPERSHOT, was not selected because it has a higher sulfur-emission rate, because the tail gas concentration is typically about 250 ppmv, and because of its high energy consumption. Another alternative, Giammarco-Vetrocoke could replace the Stretford unit in the proposed Beavon-Stretford system, reducing the SO_2 concentration further. A major drawback is the use of arsenic compounds which would appear in trace quantities in all effluents, including the sulfur product.

Two commercially available alternative technologies exist which could potentially replace the Claus sulfur-recovery system: Stretford and Giammarco-Vetrocoke. Both of these systems have demonstrated lower sulfur emissions than Claus systems in some applications, although they would be considerably more costly for the sulfur throughput of this plant. The performance of

^{*} COS is also produced according to the equilibrium $CO_2 + H_2S \rightleftharpoons COS + H_2O$.

these systems is sensitive to feed-stream composition, and the feed stream in the proposed plant may contain process contaminants that would preclude the effective use of these alternative systems. They are best suited to dilute inlet H_2S levels, such as the tail gas cleanup application. Another method of ammonia disposal/recovery would also be required.

Use of a tail gas oxidizer and the Chiyoda Thoroughbred 101 or 121 process is a potential alternative which would provide a gypsum product from the remaining sulfur in the tail-gas instead of elemental sulfur. Sulfur dioxide in the off-gas would be higher than with the proposed system. Other potential alternatives for SO_2 removal from an oxidized system include the Dual Alkali process, the Cleanair process, the Wellman-Lord system, the IFP-2 system, and a lime-limestone slurry system. These alternatives were rejected because of either lower efficiency or more difficult operation, and in some cases generation of solid wastes. As an example, Wellman-Lord has only been used by Chevron for Claus tail cleanup and has switched to Beavon-Stretford in the existing plant and is contracting it for other plants.

Fuel burning

Operation of the SRC-I process and supporting processes will require significant quantities of heat, which must be supplied by combustion of fuel in indirect heat exchangers (fired heaters). Four alternative fuel sources were considered: purchased gaseous fuels (natural gas or LPG), purchased petroleum-distillate fuels, coal, and process-generated fuels. Purchased gaseous and distillate fuels would consume resources which are already in short supply, and their use was rejected for this reason. Use of process-generated heavy distillate fuels or coal would require extensive facilities for control of sulfur dioxide and particulate emissions, and less efficient combustion to control NO_x formation. Utilization of process-generated gaseous fuels is environmentally cleaner than combustion of heavy fuels and allows compliance with applicable environmental standards without requiring a great deal of additional control equipment. For both environmental and process considerations, gaseous fuel was selected as the preferred alternative.

Further reductions in sulfur-oxide emissions could be achieved through further reductions in fuel-gas hydrogen-sulfide content, but only at the expense of increased capital investment, operating costs, and energy consumption. The economic and energy penalties of incremental reductions in sulfur content are not justified in view of the fact that fuel-gas hydrogen sulfide concentration is only 5 ppmv, and plant SO_2 emissions are primarily from the coker/calcliner.

In conjunction with use of the clean fuels, minimizing energy consumption will indirectly reduce SO_2 emission. Energy-conservation practices, such as use of power-recovery turbines, optimum use of high-pressure steam, and air preheat to large heaters have been incorporated in the design of the facilities.

Coker-calcliner

The flue gas from the calcliner will be incinerated to destroy virtually all of the hydrocarbons and reduced sulfur compounds. Most of the SO_2 in the incinerator effluent will be removed by a scrubber before discharge to the atmosphere. Sending the flue gas to the gas-treatment system would not be a feasible alternative because the gas would be too voluminous and the concentration of SO_2 would be too dilute for effective removal.

Several wet-scrubber alternatives were considered, including Wellman-Lord, lime/limestone, and soda ash. Wellman-Lord is technically feasible but is more expensive than the soda ash. Lime/limestone is (for this application) not technically feasible. The soda ash appears to be the best alternative among the wet scrubbing systems. In the PSD permit review, the EPA will determine whether this is BACT.

In addition to wet scrubbing, dry scrubbing with soda ash or lime, and cloth filters is also being considered. Dry scrubbing could potentially provide a higher particulate-removal efficiency than wet scrubbing, at the potential expense of less certainty in the level of SO_2 control achieved.

C.3.1.2 Alternatives for controlling emission of particulates

Process emissions

In general, three particulate-control alternatives are suitable for this plant: cyclones in combination with baghouse collectors, scrubbers, and baghouses (or filters). Although cyclones could probably achieve compliance with applicable emission standards in some applications, they generally produce only moderate particle-collection efficiencies, especially with small particles. Baghouses provide significantly higher collection efficiencies and were selected for use in the proposed demonstration plant for particulate control, except for the cleanup of the calciner flue gas, if a wet scrubber is selected. Scrubbing may be used for this stream because the stream also contains a significant quantity of SO_2 . A wet scrubber can remove both the SO_2 and the particulates. As discussed in the preceding paragraph, a dry scrubber is being evaluated, which would incorporate a baghouse for particulate removal. In the PSD permit review, the EPA will determine whether this is BACT.

Coal receiving and storage

Receiving. Coal will be shipped to the demonstration plant by rail car and also possibly by barge. (Appendix Y includes the pollution control equipment proposed for barge delivery of coal, should barge delivery be used.) Coal unloaded from rail cars will be dropped from beneath the rail cars through a grizzly into hoppers located in a tunnel beneath the rail tracks. The coal from the hoppers will be discharged onto an underground conveying system for transport to the two reserve coal piles, or to the six active coal piles.

Emissions from the unloading station will be controlled by using dust-suppressing agents and by semienclosing the unloading station. Underground transport tunnels will be continually ventilated by an exhaust fan discharging through a filter to the atmosphere.

Total receiving and tunnel transfer emissions will be reduced by these systems from uncontrolled levels by approximately 90%, to less than 2 tons per year. Further control systems are being evaluated.

Coal storage. The four major sources of fugitive particulate matter from storage piles are loading onto the piles, vehicular traffic on piles, load-out from piles, and wind erosion. Emissions during load-on will be controlled by limiting coal freefall to no more than 1 m (3 ft) above the pile peak and by using retractable loading spouts on booms and tripper conveyors. Pile traffic will be limited as much as possible, with the major reclaim occurring by gravity flow from beneath the active storage piles.

The storage systems will be designed for the use of polymer crusting agents to control wind erosion for reserve storage piles and for the use of water sprays on the active piles. Surface crusting agents and adjustable loading chutes should reduce emissions by 99% on the reserve piles. The use of the pre-washed coal and water sprays should reduce wind losses by 99% on the active pile.¹ Originally, chemical wetting agents, or surfactants, were considered for use on the active piles. No data exists to indicate that adding surfactants to water sprays will further reduce dust emissions. Surfactants will, however, reduce overall water consumption as a result of their wetting characteristics. If a reduction in water consumption is desired during plant operation, surfactants could be added to the water spray systems. Prewashing coal essentially eliminates silt, which is the airborne portion of coal particulates ($<72 \mu m$). Unwashed coal typically contains 6% silt, and washed coal is reported to be reduced to approximately 0.18% silt, a 97% decrease in the airborne particulate fraction of coal dust. The active piles are expected to be higher in fugitive particulates than the inactive pile because they will be disturbed continually.

The proposed design will reduce fugitive emissions from coal storage piles and transfer operations to less than 3 tons per year.

SRC storage and load-out

SRC storage. The solid SRC product will be stored outside in storage piles and sent to hoppers for load-out in rail cars. Reclaim from the seven storage piles will be from hoppers located beneath each pile. Provisions will be made for the use of water sprays to control dust from

open piles, and load-on emissions will be reduced by the use of tripper conveyors with retractable loading spouts to limit freefall of the product to the storage pile. The dust-suppressing liquids and under-pile reclaim should reduce fugitive particulate emissions by up to 90%. Total emissions from SRC solid-product storage piles and SRC transfer are estimated at less than 10 tons per year.

SRC load-out. Load-out of the SRC product will be from hoppers located above the rail cars. The rail cars will be moved into place beneath the SRC storage hoppers, and the SRC will be gravity fed to the rail cars through retractable loading spouts. Vents from the SRC product storage silos will be equipped with fabric filters. Crusting agents will be sprayed onto rail cars after loading for dust suppression during rail transit. Load-out emissions should be less than 1 ton per year.

Water sprays were considered previously for SRC loadout to railcars, but it has been determined that in the case of coal loadout retractable spouts provide an essentially dust-free loading operation to railcar beds. If the SRC product is found to be dusty during loadout, water spray capability will be added to the handling system.

Coke storage

Because of the small volume and powdery nature, coke will be stored in silos. There will be virtually no fugitive emission. This represents the most effective alternative available.

Sulfur storage

The elemental sulfur by-product will be stored in the molten state in closed tanks. This is standard commercial practice for by-product operations and is the environmentally preferable alternative.

Coal drying

Two methods of coal drying are available. The currently proposed design will use conventional technology, with wet coal obtained from the stockpile simultaneously ground and dried to 2% to 5% moisture in one of two 50%-capacity enclosed systems of mill, size classifier, furnace, duct work, cyclones, and baghouse. Drying temperatures in the mill will be well below the oxidation temperature of the coal and metallic sulfides and limited to as low a temperature as possible to minimize volatilization of hydrocarbon compounds from the coal. The exhaust gas will contain the combustion products of the furnace, the water removed from the coal, entrained particulates, volatiles from the coal and, potentially, entrained sulfurous water present in the feed coal. The baghouse will be designed to remove 99+% of the particulates.

An alternative is flash drying, with wet coal crushed and dried separately. In the flash-dryer system, crushed coal is injected into warm solvent. The coal-solvent mixture flows to the slurry mixing vessel, where a hot process recycle solvent and a recycle slurry are added and slurried. The water flashes off as steam and is later condensed, leaving a hydrocarbon gas that would then be injected into the vapor-recovery system. The flash-drying system would not produce a particulate emission, whereas the proposed conventional dryer would generate approximately 12.4 lb/h of particulates (37% of the plant's overall particulate-emission rate from point sources); however, the larger-sized particles, especially rock, could settle in various parts of the process, resulting in plugging and coking. This type of system has potential economic and environmental advantages but has not been tested sufficiently for inclusion in the construction of the SRC-I demonstration plant. A modification of this alternative would be the addition of a ball or rod mill to grind the coal-solvent stream before or after mixing it with the hot slurry. The conventional drying-pulverization system is the selected method for the initial operation of the SRC-I demonstration plant because flash drying is still in the developmental stage. To demonstrate flash-drying technology, such equipment could be installed at a later time, should a decision be made to do so. Flash drying could then be considered in the expansion to a commercial SRC-I facility.

In both systems, feed coal is obtained from an outdoor stockpile. The washed feed coal (1.25 in. x 0.0 in.) will have a moisture content varying from 10 to 15% during rainy or snowy seasons. This coal will be fed to a ball mill and reduced to nominal 200 mesh.

The present design allows for any volatile matter driven from the coal in the drying process to be vented to the atmosphere. A program has been initiated to determine the composition and amount of the volatilized matter. Volatilization will be kept to a minimum by employing design and operating techniques which minimize drier residence time and temperature without compromising process requirements.

Because the flash-drying system retains potential pollutants within the process, it would appear to be the most environmentally desirable alternative. However, all the several types currently being considered require further information from testing in a pilot plant. Additional tests will define process design and operating parameters which, in turn, allow choice of the best system. Choice will involve trade-offs between capital cost, environmental impact, maintenance, process benefits, and operational reliability. Until more information is obtained about the alternatives, conventional drying-grinding, with a baghouse for particulate control, is incorporated into the current design.

Coal and product transferring. At rail car unloading points and the transfer to the storage pile, water sprays will be used as required for dust suppression. Conveyors transferring coal to storage piles will be covered. Underground reclaim from the storage piles will be totally enclosed and ventilated through a baghouse. After reclaim, prior to pulverization, transfer points and conveyors will be totally enclosed to the extent possible. Any ventilation of these enclosures will be exhausted through a baghouse to the atmosphere. Provision will be made to install water spray at transfer points should monitoring during operation indicate this is necessary. After pulverization all conveyors, transfer points, and coal processing equipment will be totally enclosed and ventilated through baghouses. All coal, coke, and SRC storage silos and bins will be enclosed and vented to dust collectors. Transfer of coke will be in totally enclosed conveyors and vented to dust collectors.

C.3.1.3 Alternatives for controlling emissions of nitrogen oxides (NO_x)

Fuel-burning

The NO_x in flue gas is the result of oxidation of nitrogen in combustion air and of the chemically bonded nitrogen in the fuel. In most combustion processes, the primary oxide of nitrogen is NO, which is oxidized in air to NO₂.

The present demonstration plant design includes the following considerations in determining NO_x control:

- Fuel gas containing no chemically bound nitrogen. The fuel choice for normal operation is plant-derived fuel gas. It contains no chemically bound nitrogen. Therefore, no fuel-NO_x will be formed. To put this fact into perspective, an estimated 50% of the fuel-bound nitrogen is typically converted to NO_x; this rate can vary greatly depending on other parameters.
- Fuel conservation. An effort will be made to provide heat to the process as efficiently as possible in order to minimize fuel use. Since the fuel is process-derived, it is not available in unlimited quantities; therefore efficient firing methods will be used so that it does not become necessary to supplement fuel needs with fuels containing chemically-bound nitrogen (such as plant-derived oils). Combustion efficiencies are increased by air preheat and minimum excess air. Minimum excess air tends to decrease NO_x formation because fewer oxygen molecules are available for reaction with the nitrogen. However, air preheat tends to increase NO_x formation because it increases flame temperatures and the NO_x formation rate increases with temperature. Large heaters will operate with preheated air, but small heaters may not.
- Fuel composition variability. The plant-derived fuel gas is subject to variability in composition and heat content depending on the operating conditions of the plant. The fuel variability in heat content dictates that the burner and heater be flexible in operation. This fact eliminates the ability to use some low-NO_x designs such as those which are tailored to special flame patterns and physical staging (i.e., two combustion chambers). Delayed-mixing burners are more appropriate for NO_x control because their ability to reduce NO_x is not expected to be greatly affected by increasing the volume of fuel to the burner. This type burner will probably be used throughout the plant. The expected NO_x emission will be approximately 30% less than that of a standard burner.

- Process reliability. The largest fuel consumer, the coal slurry heaters, are required to be reliable and flexible under all operating conditions. The behavior of the process stream (coal slurry) is heavily dependent upon controlling the heat flux in this heater. Inability to control this heater may result in solidification and blockage of the process line. Therefore, it is critical that the system be easy to operate and maintain. This need precludes additionally complicating the NO_x control system by adding flue gas recirculation where it is not feasible.

In evaluating the various NO_x control technologies with the above-mentioned considerations in mind, low-NO_x burners, which utilize the concept of staged combustion, and low excess air are most suitable for the demonstration plant requirements. The NO_x reducing theory behind this combustion technique is described in Sect. C.2.2.4.

Other methods that provide a much greater reduction in NO_x emissions are available, but they have not been commercially demonstrated in the United States. Furthermore, technical considerations make some techniques infeasible for critical applications such as the coal slurry heaters. Reduction of NO_x has been realized by ammonia injection into the flue gas. Both catalytic and noncatalytic processes are available. Noncatalytic ammonia injection is effective only over a narrow temperature range; this would be difficult to control because of the fuel variability. Catalytic ammonia injection is effective over a wider range of temperatures, allowing for easier control. However, this process tends to precipitate ammonium-sulfate salts out of the flue gas as solids, resulting in equipment corrosion. Ammonia leaks in the plant would be toxic.

Flares and Incinerator

No control techniques exist for reducing NO_x emission from elevated flare combustion. Steam injection, which is used primarily for smokeless operation, may have the side effect of reducing NO_x emissions by quenching the flame. Low flame temperatures reduce NO_x formation. The normal emissions from combustion of the elevated flares are a small fraction of the pollutants from all plant combustion processes.

The controlled combustor (incinerator) must be operated at conditions which favor complete combustion of heavy and/or complex hydrocarbons. Unfortunately, these conditions promote NO_x formation. Destruction of complex heavy-hydrocarbon compounds will not be compromised for lower NO_x emissions. The normal emissions from combustion in the incinerator is a small fraction of the pollutants from the entire plant's combustion processes.

C.3.1.4 Alternatives for controlling emissions of carbon monoxide (CO)

The principal sources of CO will be the vents from the gas-treatment system and the Beavon sulfur-removal unit. These are emitted from the CO₂ vent stack (see Table C.6 in Sect. C.4.1). They will emit about 70% of the total CO emissions from the entire plant. The CO could be reduced in two ways: replacing Selexol with other solvents, such as Benfield solution, with a lower solubility for CO, or installing an after-burner to combust the CO to CO₂. However, the other solvents could not concentrate H₂S as much as Selexol does, leading to increased sulfur emissions. Also, the feed stream to the Claus unit would be more dilute in H₂S, substantially increasing the cost of the sulfur-recovery system. Combusting the CO with an after-burner* would consume additional fuel, and emissions of NO_x would increase.

Other sources of CO will be the fired heaters, but the quantities will be very small. Also, there are no satisfactory control measures for reducing CO emissions beyond efficient fired heater operation, which also minimizes fuel consumption. Most control techniques for reducing CO emission result in increased NO_x emission. The EPA's policy has been to stress control of NO_x even when this might result in increased CO emissions. In the PSD permit review, EPA will determine whether the proposed design represents BACT.

* The use of a catalytic rather than thermal afterburner to reduce temperature levels and fuel consumption may not be feasible because of the stream composition and possible catalyst degradation.

C.3.1.5 Alternatives for controlling emissions of nonmethane hydrocarbons (NMHC)

Fuel-burning devices. Nonmethane hydrocarbon emissions from fuel-burning devices will be controlled by proper applications, installation, operation, and maintenance of all related combustion equipment and by minimizing fuel consumption.

Flares and controlled combustor. Several alternatives will be evaluated and compared to the base case controlled combustor and flare system described in Sect. C.2.2.6. The most important alternative is the use of (1) a thermal oxidizer at all flow rates up to a preselected maximum and (2) a ground flare field at higher flow rates. The crossover flow rate would be selected based on analysis of reliability data for safety valves and other equipment. If combined random emissions from a large number of individual components yield a relatively continuous total emission, it would be appropriate to treat this with a thermal oxidizer. This could be done by designing the thermal oxidizer in the base case for a larger capacity or by using a separate thermal oxidizer. The higher assured percentage destruction in the thermal oxidizer must be balanced against the increased probability of continued trouble-free operation for the ground flare field.

Some alternatives in the base case design must be evaluated. For example, the thermal oxidizer can be either catalytic or noncatalytic. Quench solvents, solvent rates, and operating conditions for the quench system must be established. The use of one large elevated steam-assisted flare or several contained flares instead of the ground flare field will be evaluated. The control system to distribute flows must be selected.

Mitigation of fugitive emissions

Process line and equipment fittings. Fugitive NMHC emissions from process line and equipment fittings may be controlled through both design considerations and thorough maintenance. A recent study by Radian Corporation² involving a number of petroleum refineries found that over a third of the valves encountered leaked, contributing 60% of the "baggage" source emissions. Preliminary studies showed that good maintenance would significantly reduce these emissions. To minimize fugitive emissions associated with leaks, a directed monitoring and maintenance program will be implemented and strictly enforced at the plant to quickly detect and repair the leaks.

The EPA is currently conducting studies in refineries to determine (1) methods and procedures for directed maintenance programs and (2) criteria for determining when maintenance is needed. When these studies are developed into standards, these standards will be followed as applicable. In the interim, a site program will be developed and followed.

Unless the fittings can be operated with no detectable emissions as defined by the Environmental Protection Agency, stemmed valves in gaseous or light-liquid service will be checked quarterly or semiannually as experience dictates. Flanges in all services and stemmed valves in heavy-liquid service will be inspected regularly. Screening values will be 10,000 ppmv for gaseous and light-liquid service fittings and 1000 ppmv for heavy-liquid service fittings. Pumps and compressors will be visually inspected for leaks. Fittings found to be leaking will be tagged with dates indicating when leaks were found, and will be repaired within 15 d when feasible and will be monitored during maintenance to determine when repair is adequate. When attempts to repair could result in an increase in emissions, repair may be delayed until a plant shutdown. All repaired fittings will be rechecked for repair adequacy within one month of maintenance on the leaking component. Table C.5 is a listing of the predicted number of fittings in the SRC-I plant and the efficiency of emissions control based on the Radian studies conducted for the EPA and the control measures discussed. In some cases, redundant multiple equipment will be utilized on process streams that are expected to have higher rates of failure and that could lead to losses of hazardous fluids (e.g., pumps for some abrasive slurry services). This will allow an individual piece of equipment to be removed from service and repaired without complete system shutdown, thus enabling more rapid repair of leaks after detection.

Typical mechanical-design controls to be used are:

- Centrifugal compressors, centrifugal pumps for gaseous, light-liquid hydrocarbon service: Compressors will be equipped with a mechanical contact or liquid film seal or system of equivalent control nature and pumps will be equipped with double mechanical seals. Each will be equipped with a compatible barrier fluid held at a higher pressure than the pump

Table C.5. Process line fittings and predicted control efficiencies

Fittings	Total number	Uncontrolled emission factor	Control efficiency (%)
Pump seals			
Light liquid	125	0.25	100
Heavy liquid	80	0.046	100
Valves			
Gas/vapor	2,600	0.059	98
Light liquid	1,300	0.024	85
Heavy liquid ^a	6,000	0.0005	33
Safety relief	460	0.19	100
Compressor seals	20	1.4	100
Drains	430	0.070	100
Sampling connections	80	0.005	100
Flanges	13,200	0.00056	55

^aBecause of the low volatility of heavy liquids, emissions from heavy-service fittings are typically very small when compared with gas/vapor service. Inspection and maintenance of leaks at 1000 ppmv should reduce 35% of total mass emissions from valves in heavy-liquid service.

discharge or process gas pressure. Any leaks in the seal system will result in barrier fluid being forced into the process stream. Double tandem seals will be used in some applications where slurry service is too abrasive for the conventional double mechanical seal.

- Reciprocating compressors: Enclosure, and nitrogen purging of distance pieces or an equivalent system. Degassing and flaring of volatiles.
- Safety/Relief valves that do not vent into the closed flare system will be operated in a state of no detectable emissions, as defined by the EPA, except during an emergency release.
- Flanges: Number of flanged connections will be minimized.
- Drains, sampling connections: Doubling valving, caps, or blind flanges will be used to control sampling or draining from process lines. Drained liquids will be stored in closed containers, will be properly disposed of, or will drop through a sump into the closed plant sewer system.

Tank truck and rail tank car loading and unloading. Fugitive NMHC emissions from loading of process liquid products into tank trucks will be controlled by the use of bottom loading combined with vapor recovery. Liquid products from the vapor-recovery system will be returned to storage tanks. The efficiency of control on liquid load-out emissions is expected to be 90-98%.

The only liquid products used in the process which will be brought in by tank truck are the DEA and Selexol solvents, and sulfuric acid for cooling tower pH control. All of these liquids have very low vapor pressures and require no vapor recovery, either on storage tanks or during truck unloading to storage tanks.

Cooling tower. An evaporator handling a 280-gpm blowdown stream from the cooling tower will be used to control total dissolved solids (TDS) in the zero wastewater discharge system. Inorganic and organic constituents may tend to build up as cooling water is continuously recirculated through the process. Organic components, volatilizing in the evaporator and collected in the overhead condensate, will be controlled by passing the condensate through a granular activated-carbon bed prior to reentering the cooling tower as makeup water. Spent activated carbon will either be combined with coal and recycled through the SRC process or be disposed of in the secure landfill with the wastewater treatment metal-bearing sludges. The quantities of spent activated carbon are expected to be small. The buildup of inorganic salts or dissolved solids in the recirculating water of the cooling tower will be controlled by the evaporator system as well. Salts concentrated in the evaporator will be collected and disposed of in a hazardous waste landfill. This water soluble waste stream is discussed in Sects. C.2.3 and C.3.2.

Releases of phenolics and volatile organic compounds from the cooling tower will be controlled by the wastewater treatment plant that treats process wastewaters for use in the cooling system. The concentration of organics entering the wastewater treatment system, and ultimately the cooling tower, will be controlled by use of equalization to dampen organic loading fluctuations, effluent recycle to the wastewater influent to dilute materials possibly inhibitory to the biological system, and the use of completely mixed biological reactors to dilute the wastewater throughout the basin. In addition to relying on biological degradation of phenolic compounds, the capability of adding powdered activated carbon directly to the aeration basins to absorb organic compounds, including phenolics, will also be incorporated into the wastewater design. Finally, tertiary granular activated carbon adsorption should remove most of the remaining organics in the plant wastewater.

Wastewater treatment. The primary potential source of fugitive hydrocarbons in the wastewater treatment plant is the oil/water separation unit. Fugitive emissions will be controlled by covering this system.

Ammonia and hydrogen sulfide contained in process wastewaters will be removed by an initial stripping process. This stripping process will also remove volatile hydrocarbons in the sour waters. Stripped gases, containing ammonia and hydrogen sulfide, will be directed to the Claus unit for treatment. The stripping process is expected to reduce the levels of H_2S and NH_3 in the wastewater to 3 ppm and 30 ppm, respectively, thus reducing potential emissions of the contaminants in the open basin and clarifiers of the wastewater treatment plant.

Powdered activated carbon will be added to the aeration basins if an unexpected process-upset condition occurs resulting in high organic loading to the wastewater treatment system. The activated carbon will adsorb organics, thus reducing the potential for air stripping of the contaminants from the aeration basins.

Tankage. Vapor recovery systems will be provided on all fixed hydrocarbon storage tanks and at truck and railroad loading racks. The recovered vapor will be reclaimed to liquid storage or sent to the controlled combustor for combustion. No better technology exists for controlling these emissions.

Coal drying. Some NMHC emission is expected from the conventional coal-drying system. A coal drying test will be performed to determine the quantity. Pollution control will be provided, if necessary.

With the above measures, the total fugitive-emission rate for the entire plant is estimated to be less than 60 tons per year. Less than 15 tons per year of this value is expected to be NMHC material with a boiling point above 500°F. Uncontrolled emission factors were obtained from Table B2-23, p. 266 of ref. 2. A more detailed description of fugitive NMHC emissions control will appear in the BACT section of the PSD permit package for the plant.

C.3.2 Solid waste management alternatives

C.3.2.1 Water-soluble solid wastes

Several options are being considered for disposal of the soluble salt cake to be generated by the evaporators in the zero wastewater discharge operating mode. The primary intent of all these options is to prevent soluble salts from becoming dissolved in surface water and groundwater by rainwater runoff or leaching from the landfill. The liner system in the landfill is expected to prevent the leachate with its dissolved salts from reaching the groundwater. In some processes, chemical fixation of the salt cake will provide additional protection by reducing the leaching of salts as rainwater percolates through to the liner and leachate-collection system. Some processes also reduce the permeability of the landfilled material itself, thus reducing the amount of leachate to be collected and recycled.

Four alternative technologies are being investigated for treatment of this soluble salt cake prior to disposal. A brief description of these systems follows.

1. In the first process the salt cake, as a partially dewatered sludge, will be mixed with a proprietary mixture of chemicals in a continuous mixing process. The chemical additive mixture is formulated in such a way as to react with the components of the sludge, including water, to create a cementitious solid, which is essentially insoluble. Much of the water initially present is taken up as water of hydration of compounds in the solid. The soluble salts are dispersed throughout the insoluble matrix. As the cementation reactions take place over a period of several days (i.e., curing) the waste gradually changes from a wet sludge to a dry granular solid.

Individual granules of this solid are essentially impervious to water, but the bulk material is permeable. (Thorough compacting is expected to reduce but not eliminate this permeability.) Although the process is claimed to prevent soluble salts trapped within the granular solid from getting into the leachate, the final disposal will be into a specially constructed and clay-lined landfill as described in Sect. C.2.3.2 and shown in Fig. C.14.

2. The second process involves two steps. In the first (pretreatment) step, a small amount of a chemical additive precipitates any heavy metal salts as insoluble silicates. Anions, as well as soluble monovalent metals such as sodium, are not affected. In the second step, pozzolanic materials, siliceous ashes such as fly ash or pulverized slag, and lime are added to form a wet slurry. This slurry is pumped to a disposal site. Over the next few days a cementation reaction takes place between the pozzolans and calcium hydroxide to produce a monolithic, high-strength, solid material. Water initially present in the slurry is taken up as water of hydration. The final solid product is essentially a synthetic rock, impermeable to water except at fractures, should any occur. The heavy-metal salts (in the form of essentially insoluble silicates) and the soluble salts are dispersed throughout the bulk of the impermeable solid where they cannot be leached by groundwater.

Although this material will essentially prevent soluble salts from being leached, it is expected that final disposal will still be in a clay-lined landfill with leachate collection and monitoring. However, the amount of leachate collected is expected to be negligible and will not contain significant amounts of dissolved solids. The volume of the final product can be as much as 30% greater than the original salt cake that is being treated and will therefore require somewhat greater landfill area.

3. The third process is not intended specifically for disposal of salt cakes or toxic metals. Rather, it is designed for disposal of fly ash and FGD scrubber sludge. It is thought that this process may have potential for disposal of the gasifier slag and fly dust and, in context of this application, might also be used for disposal of the zero wastewater discharge salt cake.

In this process, fly ash and scrubber sludge are mixed with a lime additive in predetermined proportions and allowed to partially cure for a few days. During this period cementation reactions convert the material to a partially dry, granular state which can be handled easily. The partially cured material is then transferred to a final disposal point where it is graded and compacted. Cementation reactions continue after final placement and compaction, and can result in a low permeability solid mass.

It is felt that the gasifier ash and slag could replace fly ash and FGD sludge in this process. In this case the zero-discharge salt cake, which is a relatively small stream, could be dispersed in the slag-ash-lime mixture. After final product solidification, it is anticipated that the leaching of salts would be small due to the low permeability of the final product. A volume increase is expected, compared to the volume of the salt cake if it were landfilled separately.

4. The fourth process is another process for disposal of gasifier fly ash and scrubber sludge. The chemistry is essentially the same as the third process, but the final product is not compacted but left in a granular state. It is, therefore, not impervious to water and might have some leaching potential. This option also depends on the use of gasifier slag and ash for disposal of the salt cake.

The primary purpose of the first and fourth processes discussed above is to convert the soluble salt cake to a form which cannot be easily leached by water when disposed of on land. Since these salts are not rendered insoluble by the process, but merely encapsulated within solid

granules, there will still be some potential for leaching. There is also a question whether the solid product will continue to immobilize soluble salts even after long-term storage. (Factors such as weathering, oxidation, attack by biological agents, etc., could perhaps gradually release some soluble salts into the leachate resulting from rainfall.) It is therefore prudent to dispose of these fixed solids in a secure landfill, at least initially.

C.3.2.2 Stabilization of metal-bearing sludges

In addition to the currently proposed design discussed in Sect. C.2.3.2, stabilization of the metal-bearing sludges by one of the processes for soluble-salt disposal discussed in the previous section will be evaluated. The stabilized wastes would be disposed of in a secure clay-lined landfill as previously described. This would reduce the amount of toxic heavy metals in the leachate collected by the landfill, thus reducing the load for recycle to the wastewater treatment system. It would also further reduce the probability of impact on the environment due to solid-waste disposal. Either disposal alternative will require dewatering of the waste before stabilization or landfilling.

C.3.2.3 Stabilization of gasifier slag and flyash

Stabilization of gasifier slag and flyash by these processes will also be evaluated. Those processes which produce an impermeable, rock-like product are especially attractive, should they prove to be technically feasible. This would perhaps make available options such as the use of the fixed slag for land reclaiming, construction aggregate, or other valuable end use.

C.3.2.4 Unified solid waste management system

Another alternative to be evaluated is a unified solid-waste management system based on one of the stabilization processes. In this alternative, all solid wastes would be converted to a nonleachable form not classified as hazardous under RCRA. These wastes would then be utilized for landfill or land reclaiming. This option has the potential for being cost-effective compared to secure clay-lined landfilling, with low environmental impact. Initially for the demonstration plant, disposal of the chemically fixed and solidified material would be on the plant site. This alternative is especially attractive for possible commercialization, when the volume of solid wastes to be disposed increases greatly.

C.3.2.5 Slop oil

It is expected that slop oil generated at the demonstration plant will contain some heavy hydrocarbons and therefore will be classified as a hazardous waste and regulated under RCRA. The quantity of slop oil is expected to be about 6 tons/d. Emission rates listed in Table C.7 include the predicted slop oil incineration emissions. Incineration, recycle (such as gasification), and landfilling are the disposal alternatives under consideration for this waste as well as for the biological sludges from the wastewater treatment plant. The quantities and characteristics of these streams are now being evaluated. If incineration is chosen, and the levels of halogens, sulfur species, or heavy metals are unacceptably high, the tail-gas contaminants will be controlled by a separate tail-gas treatment system, or by combination of the stream with other streams in the plant for tail-gas cleanup. A separate incineration system and the thermal oxidizer in the controlled combustor and flare system are being considered for slop oil disposal. Section C.2.2.6 discusses the proposed controlled combustor and flare system. More detailed design information will be included in the final PSD permit package if incineration is chosen as the disposal method for slop oil and/or biological sludges.

C.3.2.6 Spent catalysts

Spent catalysts will be either returned to the vendor for reactivation or disposed of in the landfill. The quantity is small compared to the other wastes. Chemical fixation of spent catalysts along with other potentially hazardous solid wastes will be evaluated as part of the demonstration plant operation.

C.3.2.7 Spent activated carbon

Activated carbon will be used for wastewater treatment. The quantity of spent carbon is expected to be about 3 tons/d. The spent carbon waste will be removed from filter columns and will be incinerated, gasified, or landfilled. These alternatives are being evaluated.

C.3.2.8 Methods of solid waste handling

Gasifier flyash and slag

Gasifier wastes will be removed from the process area and dry- or wet-conveyed or sluiced to ash ponds as a slurry. Supernatant will be drawn from the pond and recycled to process areas. A blowdown stream will be directed to the wastewater treatment plant to control the buildup of dissolved solids.

Water-soluble solids

Zero-wastewater discharge system sludge will be removed from the evaporators, solidified, and trucked to a hazardous waste landfill or stabilized and trucked to a landfill. Stabilization, discussed in Sect. C.3.2, may be used to render the sludge nonhazardous.

Metal precipitation sludge

Metal-bearing sludge from the wastewater treatment area will be removed from process clarifiers, dewatered, solidified, and trucked to the hazardous waste landfill. Stabilization is also being considered for the metal sludge.

River water treatment sludge

Sludge from the raw river water treatment system will be removed from clarifiers, dewatered, temporarily stored in containers, and trucked and disposed of in an onsite, nonhazardous landfill. The principal components of this sludge should be suspended solids removed from the river water and calcium or aluminum hydroxide, depending on the flocculant used in water treatment.

Slop oil

Slop oils will probably be pumped from sources such as oil/water separators or knockout drums back to process areas for recovery or to the thermal oxidizer for incineration.

Spent activated carbon

These solids will be removed from filter columns and regenerated or trucked to hazardous waste landfills. The solids are presumed hazardous and are expected to be putrescible. Laboratory testing will be conducted to verify the hazardous classification.

Biological sludge

Biological sludge will be removed from clarifiers, dewatered, temporarily stored in containers, and trucked to hazardous waste landfills or incinerated with the slop oil. Laboratory testing will be conducted to determine if the sludge is hazardous. Pending laboratory determination, the sludge will be placed in a hazardous waste landfill, or it will be incinerated with the plant slop oils.

SRC and coal pile runoff retention basin solids

These solids will be removed as required from the retention basin by front-end loaders and trucks. Materials suitable for recovery will be used in the gasifier operation. Material that must be wasted will be disposed of with the slag and flyash from the gasifier operation.

Equalization basin solids

Solids from the equalization pond (Fig. C.8) will be removed as required from the equalization basin by front-end loaders and trucked to appropriate landfills. Because of the possible presence of hazardous materials, the solids will be deposited in the hazardous waste landfill. Subsequent disposal would depend on the results of laboratory analysis.

Process area runoff solids

Rainwater runoff from process areas will be diverted to surge basins. The collected solids will be removed as required from the surge basin by front-end loaders and trucked to the hazardous waste landfill.

C.3.3 Waste-heat rejection alternatives

C.3.3.1 Available cooling tower alternatives

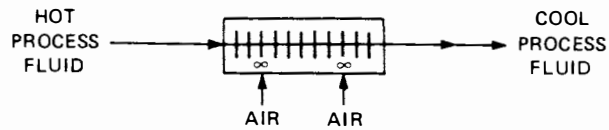
Several alternative waste-heat rejection methods are available. Six types of cooling systems are considered in this section because each involves different amounts of water usage and different risks of hydrocarbon release to the atmosphere. Figure C.15 shows these alternative configurations. As discussed in Sect. C.2.1.2, the choice of cooling system has a large effect on the choice of wastewater treatment system.

Aerial coolers are feasible for cooling process streams down to about 150 or 140°F, which reduces the size of the cooling-water system and thus the makeup-water requirements. Process fluids would flow inside finned tubes, and atmospheric air would be circulated around them by motor-driven fans. Aerial coolers require an extensive plot area. By using welded connections as much as practical, the possible leak points at flanges could be minimized. Because of the significantly lower volatility of heavy liquids, gaseous emissions due to leaks from fittings of lines in heavy-liquid service are quite small when compared with leaks from fittings in gaseous or light-liquid service. A large leak in the aerial-cooling system will be detected by process monitoring and control instrumentation and will result in dripping liquids that would be readily detectable. Smaller leaks would not be expected to result in significant total mass emissions because of the heavy nature of the process fluids, but will be detected by analyzing aerial cooler exhaust gases for total hydrocarbons with a gas chromatograph on a quarterly basis. Exhaust gases will either be (1) collected in individual bags for analysis at a centrally located instrument or (2) analyzed at the individual locations by a portable instrument. Analyses of the exhaust gases will identify smaller leaks that might go undetected by visual inspection or process instrumentation. For these coolers, performance depends on ambient conditions and varies according to season.

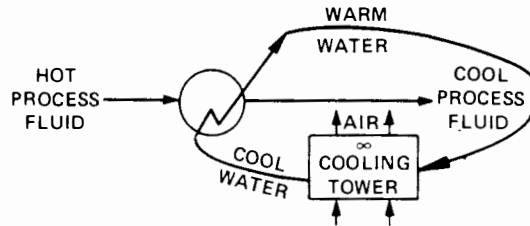
Wet evaporative cooling towers are the most widely used type. Cooling water would be circulated through exchangers to remove heat from the process fluid and then cooled by contacting air in a cooling tower open to the atmosphere. The circulating water could become contaminated with process materials introduced through cooling-system leaks from higher-pressure process environments. These contaminants could escape to the atmosphere through the cooling-tower evaporation and drift. Drift losses could be minimized by high-efficiency drift eliminators. This type of system would be the lowest in overall cost and suitable for cooling down to 85 or 95°F, depending on atmospheric wet-bulb temperatures. It would also have the highest makeup-water requirements to replace evaporative loss.

Dry indirect cooling is a method in which the process heat exchangers would be cooled by a circulating heat-transfer fluid isolated from the environment. The circulating heat transfer fluid would then be cooled in an aerial cooler. The dry indirect-type system eliminates evaporation and drift losses of water to the air with the advantage of reducing the plant makeup-water requirements and any subsequent impact on the river supply. The heat-transfer fluid would be low-pressure, moderate-temperature, corrosion-inhibited water. If a leak occurs, the process materials would be separated from the heat-transfer fluid in a disengaging drum, vapors would be flared, and liquids would be recovered until the plant could be shut down for repairs. Any contaminated heat-transfer fluid (water) would be sent to the water treatment system, so that leakage into this water would not be a problem. The dry indirect-type system thus prevents risk of contaminating the atmosphere by leaks of process hydrocarbons into the circulating cooling water.

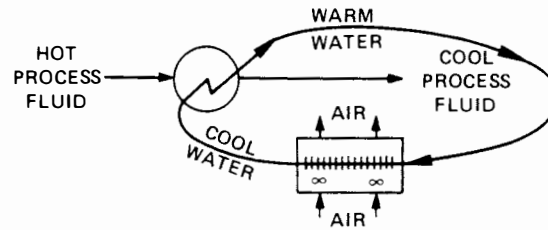
AERIAL COOLING



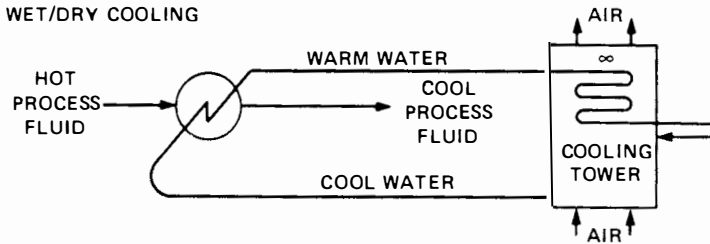
EVAPORATIVE COOLING



DRY-INDIRECT COOLING



WET/DRY COOLING



DIRECT CONTACT AFTERCOOLER (DCAC)

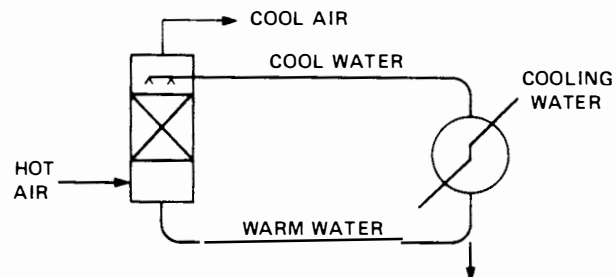


Fig. C.15. Alternative cooling systems. [Wet-indirect cooling (not pictured) is similar to dry-indirect cooling except that it uses a wet evaporative cooling tower instead of an aerial cooler.]

Three major disadvantages of the dry indirect system are (1) the increased complexity of the system; (2) the cost involved, considerably more than that of the conventional wet evaporative cooling system; and (3) the probability that extensive use could decrease the plant's water evaporation rate requiring that an alternative use be found for zero-discharge wastewater treatment evaporator condensate.

Wet indirect cooling. Wet indirect cooling is similar to the dry indirect method described earlier, except that heat is rejected indirectly to a second circulating evaporative cooling water system rather than to the air. Its use would result in the same net evaporative rate as would conventional wet evaporative cooling. Thus, the risk of contamination would be eliminated, and the drift and the effect on plant water balance would be the same as for wet evaporative cooling (Fig. C.8).

Wet/dry is a type of cooling tower that has a dry upper section (cooling water in tubes, cooled by upward air flow) and a lower wet evaporating cooling section, with the water in open contact with air in order to cool by evaporation. The principal advantages of this type are:

- Diminishes visible water-vapor plume and reduces fog.
- Obtains a colder fluid temperature that approaches ambient wet bulb.
- Conserves makeup water as compared with the 100% wet evaporative cooling tower.

The risk of hydrocarbon contamination of the cooling water and emission to the atmosphere would be essentially the same as the wet evaporative system.

Direct contact after cooler (DCAC) is a method of cooling the compressed air feeding into the air separation plant. In this method, air would be passed up a packed or tray tower and cooled with a recirculating water stream passing countercurrently down the tower. The circulating water in turn would be cooled with the cooling-water system through a heat exchanger.

Cooling process water requirements for the DCAC heat exchanger on the air separation plant would be only 3% of the total process-water requirements of the Demonstration Plant. The use of the DCAC would not significantly affect the water balance in the zero wastewater discharge operating mode.

C.3.3.2 Base-case and alternative designs

The extensive, long-term toxicological testing program underway on SRC intermediates and products will provide information for final selection of the cooling system. The base-case design is based on available preliminary results. The final results could possibly require reappraisal of the base-case design.

Preliminary results show that Ames test effects are minimal with cuts boiling below 600°F and begin to be noticeable above 760°F. The base-case calls for aerial coolers or indirect cooling for the streams containing 5.0% or more by weight of coal or SRC-derived material having boiling point greater than 500°F. An exception would be where cooling water has a pressure higher than that of process fluids. For streams that are not carcinogenic or mutagenic, wet evaporative cooling towers will be used, and the circulating water will be closely monitored for hydrocarbon leak detection (except for the air separation plant, which will use a direct-contact-after-cooler).

Environmental concerns with the evaporative portion of the proposed cooling system are: blowdown disposal, drift losses and river makeup-water consumption, visible plumes, and noise. By providing a separate aerial-cooling or indirect cooling system for the part of the process handling heavy hydrocarbons, the possibility of releasing such hazardous hydrocarbons to the atmosphere through the cooling system can be essentially eliminated. The sections served would include the coal dissolver, hydrogen recovery, expanded-bed hydrocracker, and coker-calciner.

Alternative A. By using dry indirect systems for rejecting the heat load of the entire plant, the risk of atmospheric contamination with hydrocarbons by the cooling-water system would be essentially eliminated. Since there would be no consumptive use for the treated and recycled wastewater, this system would affect the design of the zero-discharge wastewater treatment system. This system would also be expensive and require a significant amount of plant area.

Alternative B. Dry indirect cooling systems would be provided for all the process cooling-water users, with a wet/dry cooling-tower system for the air separation plant. The advantages and disadvantages are similar to Alternative A.

Alternative C. Dry indirect coolers would be provided for cooling process streams that have appreciable concentrations of objectionable hydrocarbon materials (polynuclear aromatics, PNA). A conventional wet cooling-tower system would be provided for the rest of the process users, and a wet/dry cooling tower for the air separation plant. The virtual elimination of heavy hydrocarbon emissions would be possible; the evaporative losses of water would provide a consumer of zero wastewater discharge system recycle but would produce a visible plume, and the release of lighter hydrocarbons from the process would be possible.

Table C.6 is a preliminary comparison of several factors for the base case and the three alternatives. Based on these factors, the base case and Alternative C appear to be the preferable alternatives. However, only a preliminary evaluation has been made at this time. Before a final decision is made, a more detailed engineering and environmental review will be conducted, which may include other combinations of the cooling methods described above.

Table C.6. Summary of base case and alternate cooling systems

Design load is 1.72×10^9 Btu/h in all cases

Cooling system description	Base	Alternate A	Alternate B	Alternate C
Main process	Wet (evaporative)	Dry indirect	Dry indirect	Wet (evaporative)
Air separation plant	Direct contact after cooler	Dry indirect	Wet/dry	Wet/dry
Heavy hydrocarbon processing equipment	Aerial	Dry indirect	Dry indirect	Dry indirect
Water makeup requirement	High	Negative	Low for O ₂ plant cooling only	Moderate for all requirements except high pressure process cooling
Water rates, m ³ /d (gpm)				
Circulated	370,668 (68,000)	539,649 (99,000)	479,688 (88,000)	408,825 (75,000)
Evaporated	7,631 (1,400)	0 (0)		5,015 (920)
Drift	273 (50)	0 (0)		218 (40)
Fits with zero discharge	Yes	No	No	Yes

C.3.3.3 PNA isolation

As discussed above, PNA isolation has been the most important consideration in selection of the cooling systems. Other design considerations to be adopted for the purpose of PNA isolation are the following:

1. Mechanical design will be chosen to minimize mechanical failures.
2. Materials of construction will be chosen for appropriate resistance to corrosion and erosion.
3. Thermal stresses in water coolers will be minimized by placing heat-recovery exchangers and aerial coolers ahead of water coolers to limit the inlet temperatures as much as practical.
4. A monitoring system at the cooling tower will alert the operators so that the plant can be shut down with negligible loss to the environment if a major leak into the cooling water occurs. (A complete description of the control of volatile organics is included in Sect. C.3.1.5.)

During detailed design work, repeated evaluations will be made to obtain an optimum, feasible, and operable overall combination of types to prevent environmental impact due to escaping PNA hydrocarbons.

C.3.4 Wastewater treatment alternatives

Several alternatives to the proposed wastewater treatment system are described below. An evaluation of those alternatives is under way by the industrial participant, as part of the detailed engineering-design phase.

1. Holding of the untreated process-area runoff and wastewater for natural evaporation was considered not feasible because the natural evaporation rate is lower than the precipitation rate for the proposed plant site.
2. If the coal storage were inside silos, the quantity of runoff requiring treatment would be reduced from 218 to about 80 gpm. This alternative was rejected because of high costs, as well as the safety hazards caused by silo fires.
3. A 100% treated wastewater discharge system to replace the proposed zero-wastewater discharge system is being evaluated; evaluation is also found in Sects. 4.2.2.3 and 4.2.2.4.
4. The economics of using air or oxygen for the activated-sludge wastewater treatment system in the demonstration plant were compared. The cost analysis showed that the total annual cost for the air-supplied system was 11.6% less than that for the pure oxygen system. The difference in capital costs for the two systems was insufficient to firmly recommend one over the other. Technical merits and limitations of both will be reviewed before a final decision is made.
5. Preliminary cost estimates on the removal and recovery of phenolic compounds from highly contaminated sour water streams indicated that capital costs for phenol recovery range from \$5 million to \$13 million. Subsequent capital savings in the wastewater treatment system from a reduced phenolic load are only 3 to 7% of the total capital costs for phenol removal. Therefore, phenol recovery is not being considered. The following methods will be included in wastewater treatment design to prevent high phenol loading to the bioreactors: equalization of wastewaters to dampen loading fluctuations, recycling treated effluent to dilute bioreactor feed if necessary, use of completely mixed reactors to dilute contaminants uniformly, and use of carbon adsorption to remove residual phenolics.
6. Other plant alternatives being considered are use of a phosphate cooling-tower corrosion inhibitor rather than chromate.

C.4 EFFLUENTS

C.4.1 Air

C.4.1.1 Air emissions during normal operation

Basis for emission estimates

Pollution control devices were chosen based on the present demonstration plant design. The pollutant-removal efficiencies of the commonly used control devices are well known, in many cases (such as baghouse efficiencies of 99+%). In other cases, where the control device is more process-specific (such as low-NO_x burners), control efficiencies were obtained from vendors, as their best estimate of the device's effect on the plant's specific operating constraints.

Pollutants formed from combustion were estimated using AP-42's emissions factors for natural gas firing. Adjustments to these factors were a NO_x reduction of 30% and a SO₂ emission rate corresponding to the fuel gas sulfur content (5 ppmv H₂S). Particulate emissions from baghouses in the coal-handling area are assumed to be 0.01 grain per standard cubic foot. The carrier-gas flow rate is, of course, the ventilation rate of the coal-handling equipment. Emissions from small holding tanks are due to breathing losses, and emissions before controls

were estimated by emissions factors from AP-42; these tanks are nitrogen-blanketed and typically have a small hydrocarbon evolution rate. Most tank breathing losses are vented to the flare system. The coker/calcliner scrubber assumes (worst case) 85% removal of SO₂ and 92% removal of particulates. Although the scrubbing system has not yet been chosen, it will provide removal efficiencies at least this high.

Sources used to estimate fugitive volatile-organic compound emissions from standard process line fittings are refs. 2 and 3.

The estimates for fugitive total suspended particulates (TSP) are based on ref. 1.

Emissions summary

Table C.7 summarizes the predicted normal operating emission rates of sulfur dioxide (SO₂), nitrogen oxides calculated as nitrogen dioxide (NO₂), carbon monoxide (CO), suspended particulates (TSP), and nonmethane hydrocarbons (NMHC).

Table C.7. Estimated emissions to air for normal operation

Type	Rate (g/s)					
	CO	SO ₂	TSP ^a	NO _x	NMHC ^b	H ₂ S COS
Flue gas from combustion						
Raw material handling	0.22	0.008	0.120	1.82	0.040	
SRC process and deashing	1.03	0.053	0.613	11.59	0.062	
Coke and liquid fuels	0.14	0.008	0.081	1.78	0.018	
Gas systems	0.002	0.0001	0.002	0.05	0.0001	
Utilities ^c	0.74	0.569	0.660	10.2	0.043	
Baghouse emissions						
Raw material and product handling and storage			1.750		^d	
Coke and liquid fuels			0.493			
Gas systems			0.024			
Offsites			trace			
Storage tanks and bin						
Raw material and product handling and storage					0.0002	
Coke and liquid fuels					0.008	
Gas systems	0.0001				0.0001	
Miscellaneous types						
Cryogenic system					0.03	
Gas systems (CO ₂ vent)	21.1					
Coker/calcliner flue gas	0.13	2.28	0.613	0.73	0.025	
Gas treatment and sulfur recovery						0.3 9.0 0.3 9.0
Fugitive emissions			0.37		1.77	
Total	23.3	2.92	4.72	26.2	2.0	0.3 9.0

^aTotal suspended particulates.

^bNonmethane hydrocarbons.

^cIncludes flares and controlled combustors.

^dCoal volatiles will be added after studies are complete.

Additional emissions. In addition to these criteria pollutants reported in Table C.7, emission of the following noncriteria pollutants are added: 0.3 g/s of hydrogen sulfide (H₂S) and 9 g/s of carbonyl sulfide (COS). These pollutants are emitted from the gas treatment and the sulfur-recovery sections. Table C.8 provides the coal composition and shows the sulfur content for comparison.

Table C.8 Feed coal composition

Values are measured on a
moisture-free basis

Feedstock	Composition (wt %)
Carbon	71.0
Hydrogen	5.0
Nitrogen	1.5
Oxygen	8.4
Sulfur	3.4
Pyrite	(1.50)
Organic	(1.80)
Sulfate	(0.10)
Chlorine	0.2
Ash	10.5
Total	100.0

Fugitive emissions

In contrast to point-source emissions, such as from baghouses and combustor stacks for which relatively precise emission factors and design material balances are available, fugitive emission cannot be easily quantified. Fugitive emissions from equipment leaks and open coal and product-storage piles are less precise because they depend on many factors which vary from one facility to another. Estimates used here are from literature references based on historical performance at installations many of which were not controlled as thoroughly as will be done at the demonstration plant. These are therefore believed to be conservative.

Although current and projected environmental quality standards and emission limitations require state-of-the-art pollution control techniques, it must be recognized that these standards and limitations do not exist for most of the classes of compounds included as nonmethane NMHC to be found in the process streams of the proposed SRC-I Demonstration Plant.

Table C.7 shows that the fugitive NMHC gas emissions are estimated to be less than 1.77 g/s. Table C.7 also shows that the fugitive total suspended particulate (TSP) emissions are estimated to be 0.37 g/s. Information on mitigation of fugitive emissions is given in Sects. C.2.2.2, C.2.2.3, and C.3.1.

Tables C.9 and 2.2 compare the emission rates of the criteria pollutants from point sources in the SRC-I facility (normal operation after control) with emission rates of a nearby, 600 MW(e) power plant that has about the same coal throughput. The power plant uses a low-sulfur coal without flue gas desulfurization (FGD). As Table C.9 shows, the power plant emits significantly larger quantities of the pollutants than the SRC-I facility emits. This would still be true even if FGD were employed at the power plant. FGD could typically remove 90% of sulfur oxides and particulates and 20% of nitrogen oxides.

Table C.9. Emission inventory of criteria pollutants from SRC-I point sources after control and nearby power plant

Contaminants	SRC-I		Nearby power plant	
	tons per year	metric tons per year	tons per year	metric tons per year
Sulfur oxides, as SO ₂	92	84	125,600	114,150
Particulates	140	130	13,900	12,600
Hydrocarbons	7	7	no data	
Nitrogen oxides, as NO ₂	830	750	73,240	66,590
Carbon monoxide	741	671	5,300	5,000

Cooling-tower drift quantity and composition

Drift will be discharged from the evaporative cooling tower. The drift portion of the water balance will be about 60 gpm. Minerals in the drift will normally consist of those in the treated river water concentrated seven times. The estimated composition of the drift is shown in Table C.10.

Table C.10. Estimated drift composition^a

Components	Quantity (mg/liter)	
	Average	Maximum
Calcium	190	380
Magnesium	50	100
Sodium	60	120
Manganese	1	2
Phosphorus	1	2
Potassium	0	0
Zinc	13	26
Aluminum	0.5	1
Bicarbonate	144	288
Sulfate	600	1200
Nitrate	7	14
Chloride	100	200
Ammonia	0	0
Organic phosphate inhibitor ^a	10	10
Silica	0	0
Total dissolved solids	1100	2200
Total suspended solids	5	10
pH	7.2	6.5-7.5

^a If chromate inhibitor is used, replace with 10 mg/liter chromium.

Concerns have been raised about the potential of carcinogens contaminating the cooling water as a result of leaks in the proposed cooling system and ultimately escaping to the atmosphere through cooling-tower drift and evaporation. Air coolers or indirect cooling will be used for streams containing more than 5% hydrocarbons and having a boiling point greater than 500°F. Alternative designs, which are discussed in Sect. C.3.3, would further preclude contamination of the cooling water by the process. Decisions as to their use will be made during final design.

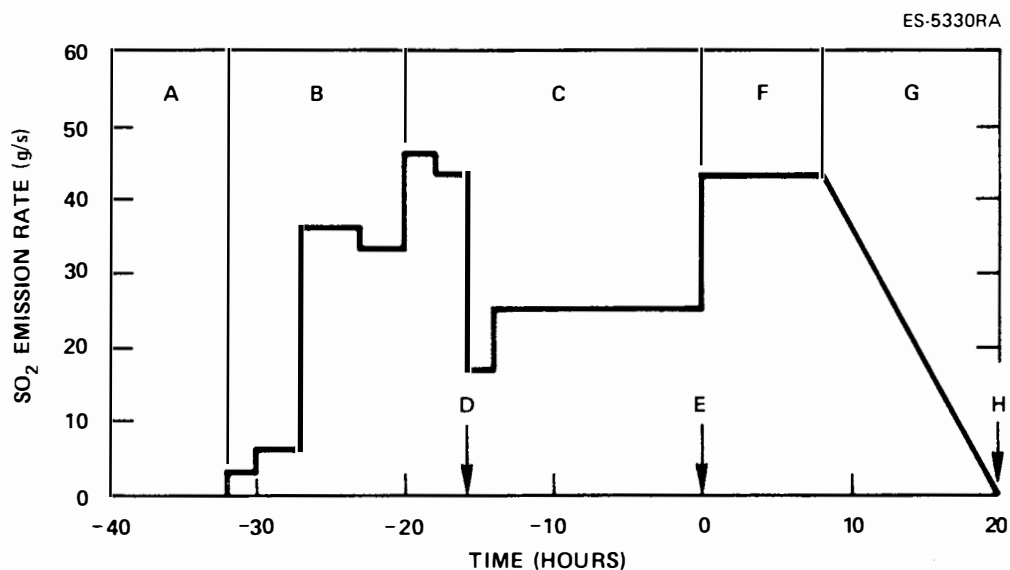
C.4.1.2 Air emissions during startup

The objective of the startup plan is to minimize pollutant emissions without compromising the safety and control of the plant. A startup sequence was chosen which would minimize emissions from combustion. The present startup schedule allows for approximately 50 h to achieve normal operations of the SRC process and support processes (such as gasification, gas treatment). Startup of auxiliary processes (coking and expanded-bed hydrocracking) can begin at any time after the SRC and supporting processes are on-stream. Emissions generated during startup of auxiliary processes are not significantly higher than normal emissions. Reevaluation will be made as detailed design proceeds to ensure that the emissions during startup are minimized and that they meet applicable environmental standards.

Air emission during startup of SRC and support processes will be significantly higher than normal for two reasons: (1) heaters will be fired with process-derived oils which have a higher sulfur content than the process-derived fuel gas used during normal operation; and

(2) process control requires flaring of streams in the gasification area until the process stream compositions can be stabilized before the gas is fed to the gas treatment processes. This step is required for control and equipment protection.

The startup fuel to plant heaters is process-derived fuel oil. Emissions of all criteria pollutants from combustion will be greater for oil firing. The startup oil contains 0.8 wt % sulfur. As shown in Fig. C.16, the normal emission rate of SO_2 from combustion (in SRC and support process areas) is less than 1 g/s (period H). The SO_2 emission rate during startup reaches 45 g/s when oil is combusted (periods C and F).



- A. PRESTARTUP; NO EMISSIONS.
- B. START UP GASIFIER AND GAS TREATMENT AREA AT 50% CAPACITY.
- C. HEAT SRC PROCESS AREA.
- D. REPLACE SOME OIL WITH HYDROGEN FIRING.
- E. FEED H_2 TO DISSOLVER.
- F. FEED COAL TO DISSOLVER AT 60% CAPACITY.
- G. INCREASE PLANT CAPACITY TO 100%.
- H. NORMAL OPERATION (<1 g/s).

Fig. C.16. Emission levels of SO_2 from heaters during startup.

Sulfur dioxide emissions from combustion are kept to a minimum by burning available hydrogen (produced in the gasifier) in the large process heaters. For this reason, the startup sequence begins by bringing up the gasifier. Once the gasifier and downstream equipment are operating, the fuel oil to large heaters is replaced by hydrogen; therefore total SO_2 emissions are greatly reduced (point D). The two largest plant heaters, the boiler and the coal slurry heaters, burn the excess hydrogen produced during startup. Initially all heat is provided from oil combustion; then hydrogen partially replaces the oil; then, as the plant begins producing gas, the oil is totally replaced by gas.

The other major source of high emissions of pollutants during startup is the flare. Approximately 280 g/s of H_2S is flared at peak flaring of the gasifier products. This syngas flaring lasts approximately 8 h until all units are stabilized; the estimated average SO_2 emission rate is 250 g/s. Table C.11 contains a list of the estimated flarestack emissions during this period.

Table C.11. Estimated flarestack emissions during 8-h startup

Pollutant	Average rate (g/s)	Total	
		(kg)	(lb)
SO_2	250	7,200	16,000
NO_x	30	900	2,000
CO	2	60	100
NMHC ^a	1	30	60
TSP ^b	2	60	100

^a Nonmethane hydrocarbons.

^b Total suspended particulates.

Flaring the syngas is required for a safe and controlled startup. The gasifier is coal-fed during startup. All the sulfur contained in the coal is assumed to form H_2S , which is then flared with the syngas until the shift and Selexol units are on stream and operating at steady conditions. Conservative estimates of the timing and SO_2 emissions during startup of this section are listed in Table C.12.

Table C.12. Sulfur dioxide emissions from flarestack during startup

Condition	Rate (g/s)	Duration (h)
Gasifier startup	500	0.5
Shift startup	500	3.5
Selexol startup	asymptotic approach to 0	4

C.4.1.3 Air emissions during shutdown

The emission rates during shutdown will be similar to those during normal operation, but they will taper off to zero. The flared emissions during shutdown will be on the same order of magnitude as during startup, but the duration of the large flow rates will be only 2 h.

C.4.1.4 Air emissions during upsets and emergencies

The most frequent causes of upsets that will result in an increase from normal air-emission rates are compressor shutdowns, let-down valve failure, and line blockage. These occurrences will send gases to the flare system. To ensure that these gases (some of which contain heavy hydrocarbons and/or reduced sulfur compounds) are fully burned, a flare system consisting of elevated flares, a ground flare field, and a thermal oxidizer is being evaluated (Sects. C.2.2.6 and C.3.1.5).

During upsets, the flare system is used to quickly release gases in a safe manner to prevent equipment damage and personnel hazard. The rate of release of combustion products such as SO_2 may be large, but the duration is short.

Major upset conditions

One of the largest possible single emergency releases is blowdown of the dissolvers (Table C.13). About 1,400,000 lb (200,000 ACF) of hydrocarbon gas would need to be flared. The gas composition varies from hydrogen to hydrocarbons with boiling points above 950°F. Heavy liquid components of these gases will be separated out by a system of knock-out tanks and cooling steps designed to collect the bulk of these heavy hydrocarbons. The lighter components and perhaps trace quantities of entrained heavy liquids would be treated by the controlled combustor and flare system; heavier components, which will be condensed out, will be collected and recycled to the process or combusted in the controlled combustor (see Sects. C.2.2.6 and C.3.1.5 for more information).

Table C.13. Sulfur dioxide emissions from flarestack during emergency upsets

Condition	Total emissions (lb)	SO ₂ emissions (lb)
Dissolver unit blowdown	1,400,000	7,000
Gasification upset	500,000	12,000
Solvent column blowdown	300,000	300
Expanded-bed reactor upset	150,000	200

Other emergency situations that result in large releases to the flare are also listed in Table C.13. These upsets all contain heavy hydrocarbons except for the gasification upset that contains light, readily combustible compounds.

Beavon unit upset

One other potential minor upset condition resulting in sulfur compound emissions would occur if the Beavon unit goes off line. During such an upset, about 125 g/s of sulfur would be emitted to the atmosphere. The form of sulfur would be SO₂ (thus, 250 g/s SO₂) because the Claus tail-gas stream would be flared through the thermal oxidizer of the flare and controlled combustor system. The low-pressure fuel gas stream, the second independent stream normally treated in the Beavon unit, would be sent to the fuel header with 200 ppmw H₂S to be mixed with clean fuel, giving an overall concentration of 60 ppmw of H₂S in the plant fuel gas. The impact of resulting sulfur emissions from a Beavon upset is discussed in Sect. 4.2.5.1.

C.4.1.5 Vehicular emissions during operation

Mobile plant equipment

Approximately twenty-five plant vehicles, including trucks, cranes, and maintenance vehicles, will be utilized by the SRC-I Demonstration Plant. Estimated air emissions evolved from these mobile plant equipment are shown in Table C.14. Each vehicle is assumed to travel about 8 miles per day and consume one-half gal of diesel fuel per mile.

Highway vehicles

During operation of the plant, the total average work force is conservatively estimated to be 500, including contract maintenance personnel. Assuming an average of two persons per vehicle and a round-trip commuting distance of 30 miles, plus an 8% additional allowance for delivery vehicles, would result in 2,200,000 vehicle miles per year, with estimated emission rates shown in Table C.15.

Only a small portion, perhaps 10% of the highway vehicle emissions, would occur at the proposed plant site. Also, the traffic has been conservatively assumed to be heavily congested, with a traveling speed of 10 miles/h throughout the entire trip length. This assumption tends to overestimate CO and NC and to underestimate NO_x.

Table C.14. Emissions from mobile plant equipment during operation

Pollutant	Emissions		
	lb/10 ³ gal ^a	kg/year (lb/year)	tons/year
CO	92.2	1,542 (3,400)	1.7
HC	300	4,990 (11,000)	5.5
NO _x	524	8,618 (19,000)	9.6
SO _x ^b	31.2	499 (1,100)	0.6
TSP ^c	17.7	295 (650)	0.3

^aData from U.S. Environmental Protection Agency, *Compilation of Air Pollutant Emission Factors*, Report AP-42, Office of Air Quality, Planning, and Standards, Research Triangle Park, N.C., August 1977, Table 3.2.7-1, p. 3.2.7-3

^bAs SO₂

^cTotal suspended particulates.

Table C.15. Emissions from highway vehicles during operation

Pollutant	Emissions		
	g/km (g/mile) ^a	g X 10 ⁶ /year	tons/year
CO	42.3 (67.7)	166	162
HC	5.7 (9.2)	20	22
NO _x	2.07 (3.32)	7	7
SO _x ^b	0.13 (0.20)	0.4	0.5
TSP ^c	0.27 (0.44)	0.9	1.0

^aData from U.S. Environmental Protection Agency, *Compilation of Air Pollutant Emission Factors*, Report AP-42, Office of Air Quality, Planning, and Standards, Research Triangle Park, N.C., August 1977, Table 3.2.7.1, p. 3.2.7.3.

^bAs SO₂.

^cTotal suspended particulates.

C.4.2 Water

Table C.16 shows the estimated composition of the treated wastewater from the system described in Sect. C.3 (931 gpm, 1.3 mgd). The estimated trace organics (PNAs) concentrations are listed in Table C.17. The values shown in these two tables have been extracted from the literature. More definitive composition estimates cannot be determined until completion of the wastewater characterization and treatability study. Based on this information, the proposed wastewater treatment system should be effective in reducing major and trace-contaminant concentrations to low levels. Polynuclear aromatics should also be substantially removed in the biological treatment and the activated-carbon adsorption systems.

During preliminary consultation in preparation of a National Pollutant Discharge Elimination System (NPDES) permit application, EPA and Kentucky will jointly develop effluent limitations based on water quality in the Green River. Specific limitations for the point-source discharge from the demonstration plant will be selected to ensure protection of the Green River's indigenous aquatic life and the designated uses for the stream established by the Kentucky Department for Natural Resources and Environmental Protection. The following procedures will be used to establish limitations for each conventional, nonconventional, priority, hazardous, and unlisted pollutant identified as being discharged from the plant.

Table C. 16. Estimated treated wastewater contaminants and levels after all treatments

Values are in mg/liter unless otherwise indicated

Parameter	Value	
	Average	Maximum
Temperature, °C (°F)	16 (61)	38 (100)
pH, units	6-9	6-9
Biological oxygen demand	20	30
Chemical oxygen demand	150	300
Total organic carbon	150	300
Oil and grease	10	20
Total suspended solids	20	35
Total dissolved solids	TBD ^a	TBD
Chlorides	TBD	TBD
Phenolics	0.1	0.6
Ammonia, as N	5	20
Phosphate, as P	5	10
Nitrate	TBD	TBD
Sulfide	0.04	0.09
Arsenic	0.1	0.25
Barium	1	2
Cadmium	0.15	0.30
Chlorine, residual (total)	0.5	1.0
Chromium (total)	1	2
Cyanide	0.45	0.9
Fluoride	TBD	TBD
Lead	0.25	0.4
Selenium	0.35	0.7
Silver	0.1	0.2
Zinc	1	2
Nickel	0.5	1.6
Iron	2	4
Vanadium	1	5
Copper	1	2
Manganese	2	4
Mercury	0.001	0.002
Beryllium	0.005	0.01
Fecal coliform	TBD	(below 400/100 ml)
Boron	TBD	TBD
Alkalinity	TBD	TBD
Thiocyanate	TBD	TBD
Sulfate	TBD	TBD

^aTo be determined

Permissible amounts will be either water-quality or technology-limited. If no water-quality limits apply, the limit will be based on the best available treatment technology economically achievable or an appropriate New Source Performance Standard, whichever is more stringent.

Where an appropriate water-quality limitation exists, the effluent limitation will be chosen to ensure protection of that limit. The discharge will be credited for dilution only during the 10-year, 7-d low-river flow, rather than for any assimilative capacity of the river. Also, if current water quality is found to be nonattainment for a specific pollutant because of natural or background pollution sources, the associated discharge limit will be selected to prevent further significant degradation of stream quality.

Table C.17. Organic compounds in the projected SRC-1 effluent

Chemical compound	Untreated effluent concentration, ^a (mg/liter)	Bio-unit effluent ^b (mg/liter)	After activated carbon filtration, 75% reduction ^c (mg/liter)	After dilution by 7-d, ten-year low flow (μg/liter)
Methyl-indane	15	2.4-8.4	2.1	13
Tetralin	0.1	0.5 (15%) ^d	0.01	0.1
Dimethyltetralin	0.5	0.08-0.4	0.10	0.6
Naphthalene	5	0.81 (80%) ^e	0.20	1.2
Dimethylnaphthalene	0.3-2	0.05-1.12	0.28	1.7
2-Isopropylnaphthalene	0.7	0.11-0.39	0.10	0.6
1-Isopropylnaphthalene	2	0.32-1.12	0.28	1.7
Biphenyl	0.2	0.03-0.11	0.03	0.2
Acenaphthalene	<0.1	0.01-0.06	0.02	0.1
Dimethylbiphenyl	0.2-0.5	0.79-1.1	0.28	1.7
Dibenzofuran	0.6	0.09-0.32	0.08	0.5
Xanthene	0.1	0.01-0.06	0.02	0.1
Dibenzothiophene	1.5	0.24 (60%)	0.01	0.4
Methyldibenzothiophene	<0.1	0.01-0.06	0.02	0.1
Thioxanthene	0.1	0.01-0.06	0.02	0.1
Fluorene	0.3	0.08 (64%) ^e	0.02	0.1
9-Methylfluorene	0.3	0.05-0.17	0.04	0.2
1-Methylfluorene	0.2	0.04 (76%) ^e	0.01	0.1
Anthracene/phenanthrene	1.1	0.26 (70%) ^d	0.07	0.4
Methylphenanthrene	0.2-0.3	0.05-0.11	0.03	0.2
C ₂ -Anthracene	<0.05	0.01 (62%) ^e	0.003	0.02
Fluoranthene	0.4	0.06-0.63	0.16	1.0
Bihydrompyrene dihydrompyrene	<0.05	0.007-0.03	0.008	0.1
Pyrene	0.6	0.24 (50%) ^e	0.06	0.4
Dimethyldibenzothiophene	<0.05	0.007-0.03	0.008	0.1

^aData from Table 3, J. S. Fruchter, M. R. Peterson, J. C. Laul, P. W. Ryan, *High Precision Trace Element and Organic Constituent Analysis of Oil Shale and Solvent Refined Coal Materials*, Battelle Pacific Northwest Labs, BNWL-SA-6001, 1976, 31 pp.

^bA 30-80% degradation is assumed unless otherwise noted (from Table Q.1, Appendix Q, ER).

^cTaken from W. G. Schlenger, "Coal Gasification Development and Commercialization of the Texaco Coal Gasification Process," presented at the 6th International Conference on Coal Gasification, Liquefaction and Conversion (no date or place).

^dIsolated organisms known to degrade naphthalene and/or phenanthrene (from Table Q.1, Appendix Q, ER).

^eRemoval efficiencies for a sludge that degrades petrochemicals in Colgate Creek, La. (from Table Q.1, Appendix Q, ER).

Source: Modified from Table Q.1, ER, Appendix Q.

Zero- or reduced-effluent discharge systems, as selected in Sect. C.2.1, will lead to much smaller quantities of effluent; hence, the impact is expected to be smaller.

A wastewater characterization and treatability study is being conducted to obtain more definitive information on the treated effluent composition. A major emphasis will be made to identify the trace contaminants and to determine their removal efficiencies. The laboratory program will characterize the contaminants in the streams expected in the demonstration plant and identify organic and inorganic constituents. In addition, the laboratory program will determine how effectively the proposed wastewater treatment system can control trace toxic metals and the complex trace organic materials that may be toxic and/or carcinogenic. Pilot plant wastewaters from the following operations have been obtained: GKT gasification of mineral ash residue obtained from SRC-I operation, expanded-bed hydrocracking of SRC-I, and SRC-I production. Coal and SRC runoff wastewater and oily wastewater from SRC-I operation were also obtained.

The treatability study will evaluate the proposed pretreatment methods, including separation of emulsified and floatable oils from oily wastewater and precipitation of metals from metal-containing wastewaters. After these methods are evaluated, a recommended method and removal efficiency will be identified. The treatability study will also evaluate the use of a biological system to degrade contaminants in the various wastewater streams. This study will consist of a series of flow reactors operated as completed mixed activated sludge systems. These flow reactors will evaluate the effect of sludge age, temperature, and powdered activated carbon on the biological system and recommend a preferred method of biotreatment. Finally, the treatability study will evaluate tertiary treatment processes, including filtration, granular activated carbon adsorption, and ozonation.

The wastewater characterization program should continue throughout the study, and preliminary treatability information should be available in the summer of 1981. The study is scheduled to be completed at the end of 1981 or early in 1982.

C.4.3 Solids

When subjected to rain, all solids stored outdoors onsite will generate leachates. Coal, solid SRC product, and several solid waste residues will be stored as such. Leachate collection is provided for all solids storage areas, and the plant's wastewater treatment plant has been designed to receive and treat these leachates. Appendix P details the procedures and results of an experimental program for generating and analyzing leachates from coal, solid SRC products, and gasifier slag-flydust. The results are also summarized in the following paragraph and in Table C.4.

The three principal types of solid wastes generated at the SRC-I Demonstration Plant will be flydust slag from the gasifier (700 tons/d), metal-bearing sludges from the wastewater treatment area (8 tons/d), and biological sludge also from the wastewater treatment system (2 tons/d). In the zero-discharge operations mode, 35 tons/d of water-soluble solid wastes are also generated. Table C.4 identifies the solid wastes, their probable quantities, and their assumed classification under the Resource Conservation and Recovery Act (RCRA). Disposal methods were described in Sects. C.1 and C.2. Disposal methods were chosen after evaluating the wastes to determine if they will be classified as hazardous or nonhazardous under the RCRA, which outlines disposal guidelines based on this classification. Some wastes were not available for direct testing. Where the possibility existed for a hazardous classification, wastes were assumed hazardous.

C.4.3.1 Slag and flydust leachate

Preliminary findings completed as of April 25, 1980, on gasifier slag and flydust indicate that the materials are within the bounds of the nonhazardous criteria defined by RCRA. Table C.18 gives a general chemical composition of the gasifier slag and flydust. Table C.19 shows a breakdown of selected elements in both the Kentucky No. 9 coal feedstock and the resulting slag and flydust.

The EPA-EP batch-leaching tests were carried out on the slag and flydust samples. This test meets the toxicity testing criteria outlined in the May 19, 1980, RCRA regulations.

The results of the chemical analysis of leachates for the eight trace elements included in the Primary Drinking Water Standards and in the RCRA standards appear in Table C.20. In addition to the eight priority trace elements, copper, nickel, vanadium, and zinc are also analyzed because of their environmental importance and the consequential possibility that they may be added to the list of eight trace hazardous elements in future legislations. The RCRA standards listed as a comparison basis in Table C.20 are the Primary Drinking Water Standards multiplied by a factor of 100.

C.4.3.2 Coal leachate

Field leachate testing of five proposed feedstock coals has been performed at Oak Ridge National Laboratory (ORNL). Coal samples were placed in lysimeters and were exposed to natural rainfall events during a three-month period. Leachate samples were collected during and after each rainfall event and were analyzed for potentially hazardous metal content.

Table C.18. Chemical composition of slag and flydust from GKT gasifier (SRC-I residue)

Element	Concentration (%)		
	Slag Run 179	Flydust	
		Run 179	Run 175
Aluminum	14.78	7.16	5.99
Calcium	0.50	0.43	0.40
Iron	11.80	8.89	7.66
Potassium	0.85	0.73	0.63
Magnesium	0.38	0.36	0.30
Sodium	0.34	0.29	0.25
Titanium	0.36	0.32	0.26
Silicon	21.74	18.13	14.91
Sulfur ^a	0.50	3.74	4.04
Carbon	0.53	22.44	35.71

^aThe sulfur content in the flydust from the prototype plant will be significantly lower because of different operating conditions.

Table C.19. Trace element concentrations in gasifier coal feedstock and gasifier slag and flydust

All concentrations are in ppm

Element	Kentucky #9 coal	Slag Run 179	Flydust	
			Run 179	Run 175
Arsenic	8.9			
Barium	83.0	383.00	3.16	250.00
Beryllium	1.3	8.7	7.4	6.0
Chromium	21.0	3500.00	890.00	749.00
Copper	8.5	57.00	106.00	84.00
Manganese	42.0	298.00	159.00	138.00
Lead	2.9	4.00	287.00	192.00
Nickel	10.7	1860.00	260.00	213.00
Silver	0.02	2.00	0.7	0.3
Zinc	55.0	33.00	365.00	253.00

Table C.20. Environmental Protection Agency extraction procedure results for ash and flydust produced by GKT gasifier on SRC-I residue

Concentrations are in ppb unless otherwise indicated

Element	Slag Run 179	Flydust		RCRA standard ^a
		Run 179	Run 175	
Arsenic	4	4	5	5,000
Barium	3.3	73	125	100,000
Cadmium	0.098	45	27	1,000
Chromium	0.46	8.5	5.3	5,000
Lead	1.1	78.5	13.5	5,000
Mercury	0.022	0.047	0.053	200
Selenium	5	5	5	1,000
Silver	0.01	0.01	0.01	5,000
Copper	0.0013	1.53	0.58	<i>b</i>
Nickel, ppm	0.10	3.71	1.82	<i>b</i>
Zinc, ppm	0.012	7.9	2.1	<i>b</i>
Vanadium, ppm	0.27	1.6	2.0	<i>b</i>

^aResource Conservation and Recovery Act standard is based on 100 times the limits set in the Primary Drinking Water Standards.

^bElements not listed in the Interim Primary Drinking Water Standards.

Results of field leaching tests performed on the Kentucky No. 9 and Illinois No. 6 coals are presented in Tables C.21 and C.22 respectively. Mean concentrations of each parameter were compared with Primary and proposed Secondary Drinking Water Standards of the U.S. Environmental Protection Agency (EPA). Leachate from both coals exceeds the Primary Drinking Water Standards for the elements As, Cd, Cr, and Se. Leachate from both coals also exceeds proposed Secondary Drinking Water Standards for pH, iron, and sulfate content. The amount by which measured parameters exceed the standards is shown in the table. It is clear from these data that special handling of coal pile leachate is required to avoid contamination of surface water and groundwater.

C.4.3.3 SRC solid product leachate

Leaching tests were performed on two samples of SRC-I product which were crushed to pass through a 3/8-in. sieve. The American Society for Testing and Materials (ASTM) leaching Method A, using deionized water, was used because this method most nearly simulates exposure of stored product to natural precipitation.

The shaking procedure calls for a liquid to solid ratio of 4:1, and a shaking period of 48 h. The leachate is then filtered through a 0.45-micron membrane filter and preserved for analysis.

For our samples, 200 g of SRC-I product were contacted with 300 ml of the extractant fluid for 48 h.

Primary and proposed secondary drinking water standards are included in Table C.23 for comparison. Leachate concentrations are well below the recommended levels for all the primary standards. The leachate exceeds the proposed secondary drinking water standard for manganese and is more acid than the pH range recommended in the secondary standard. Organic constituents of the leachate are under study and will be reported at a later date.

The SRC solid product does not appear to present a hazard to water quality, based on testing and analyses performed to date. Upon completion of the leaching tests, which involved agitation of the sample, the leachate remained black and opaque. The coloration was caused by fine particulates which remained in suspension but were retained on 0.45-micron membrane filters. Runoff from the SRC storage area will be collected and routed through the wastewater treatment

Table C.21. Summary of leachate data collected from Kentucky No. 9 coal

Parameter	Observations	Mean	Standard deviation	Minimum	Maximum	Mean exceeds DW std by
Runoff, % of rainfall	8	71	29.5	65	100	
Percent transmission before filter	20	32.5	21.6	0.9	86.3	
Percent transmission after filter	19	48.0	21.6	13.3	87.1	
pH	20	2.1	0.2	1.8	2.5	4.4
Acidity, mg/liter as CaCO ₃	15	33,100	22,400	7,760	78,200	
Electrical conductivity, μ mhos/cm	20	10,500	4,650	4,480	20,000	
Sulfate, mg/liter	20	27,300	18,100	5,820	72,600	109X
Iron, mg/liter	20	9,850	7,250	1,780	26,200	32,833X
Arsenic, μ g/liter	8	9,050	6,130	2,040	17,500	181X
Barium, mg/liter	8	<0.2	<i>a</i>			0
Cadmium, μ g/liter	8	166	106	47	386	16.6X
Chromium, μ g/liter	8	724	296	330	1,220	14.4X
Lead, μ g/liter	8	12	10	7.2	35	0
Selenium, μ g/liter	8	829	1,000	56	3,000	82.9X
Silver, μ g/liter	8	0.05	<i>b</i>			
Mercury, μ g/liter	8	0.20	0.20	0.05	0.60	0

^aBarium concentration <0.2 mg/liter for all samples.^bSilver concentration <0.05 μ g/liter for all samples.

Source: E. C. Davis, *A Laboratory and Field Analysis of Factors Affecting Quality of Leachate from Coal Storage Piles*, Ph.D. dissertation, Dept. of Environmental and Water Resources Engineering, Vanderbilt University, Nashville, Tenn., 1980.

Table C.22. Summary of leachate data collected from Illinois No. 6 coal

Parameter	Observations	Mean	Standard deviation	Minimum	Maximum	Mean exceeds DW std by
Runoff, % of rainfall	6	73	6.7	65	83	
Percent transmission before filter	11	80.1	20.8	19.1	94.2	
Percent transmission after filter	11	88.6	6.2	81.9	97.9	
pH	11	2.2	0.1	2.1	2.4	4.3
Acidity, mg/liter as CaCO ₃	6	21,200	7,270	6,500	25,400	
Electrical conductivity, μ mhos/cm	11	15,200	5,640	6,500	21,700	
Sulfate, mg/liter	11	21,500	10,900	5,850	37,200	86X
Iron, mg/liter	11	7,710	3,870	2,090	12,000	25,700X
Arsenic, μ g/liter	5	147	90.8	9.4	258	2.94X
Barium, mg/liter	5	0.2	<i>a</i>			0
Cadmium, μ g/liter	5	268	165			26.8X
Chromium, μ g/liter	5	438	234	21	560	8.7X
Lead, μ g/liter	5	14	5.6	7.2	21	0
Selenium, μ g/liter	5	438	370	19	908	43.8X
Silver, μ g/liter	5	0.35	0.31	<0.05	0.81	0
Mercury, μ g/liter	5	0.12	0.12	0.03	0.30	0

^aBarium concentration <0.2 mg/liter for all samples.

Source: E. C. Davis, *A Laboratory and Field Analysis of Factors Affecting Quality of Leachate from Coal Storage Piles*, Ph.D. dissertation, Dept. of Environmental and Water Resources Engineering, Vanderbilt University, Nashville, Tenn., 1980.

Table C.23. Chemical analysis of leachates produced from SRC-I product using the ASTM Type "A" leaching procedure

Constituent	Sample No.		Drinking water standards ^a
	1	2	
Arsenic, ppb	0.5	0.1	50
Barium, ppm	0.10	0.03	1
Cadmium, ppb	0.07	0.33	10
Chromium, ppb	0.22	0.18	50
Lead, ppb	17	0.7	50
Mercury, ppb	0.024	0.001	2
Selenium, ppb	3	3	10
Silver, ppb	0.02	0.02	50
Copper, ppb	4.0	1.8	1000
Nickel, ppb	3.4	1.2	NS ^b
Zinc, ppb	5.0	0.44	5000
Calcium, ppm	0.54	0.44	NS
Chloride, ppm	1.1	6.6	250
Iron, ppm	0.012	0.0012	0.3
Magnesium, ppm	0.12	0.06	NS
Manganese, ppm	0.1	0.1	0.05
Potassium, ppm	0.5	0.5	NS
Sodium, ppm	2.05	1.62	NS
Sulfate, ppm	1.5	1.0	250
pH (final)	5.5	5.6	6.5-8.5
Electrical Conductivity (μ mhos/cm)	1.6	2.0	NS
Alkalinity, ppm	4	3.75	NS
Total dissolved solids, ppm	64	68	500
Total filterable residue, ppm	2440	2520	NS
Total organic carbon, ppm	7.5	6.3	NS
Chemical oxygen demand, ppm	23	21	NS

^aEnvironmental Protection Agency primary and secondary drinking water standards.

^bNS—no standard promulgated or proposed.

Source: Written communication from W. J. Boegly, Environmental Sciences Division, ORNL, June 2, 1980.

facility. Due to the brittle nature of the product, shipping and handling activities are expected to generate dust which may cause local surface water quality impacts if the product is stored without dust suppression. The proposed design includes dust suppression and leachate collection and treatment.

C.4.4 Emissions during end-use combustion

The SRC-I process produces both solid and liquid fuel products that are intended to replace existing fossil fuels for combustion without the need for extensive particulate and SO₂ control. Emissions from combustion of the solid products have been studied extensively during a full-scale demonstration burn test at Georgia Power Company's Plant Mitchell.⁴ Equivalent full-scale burn tests have not been carried out for the SRC-I liquid products. However full-scale tests have been carried out using liquid products from the SRC-II process. In addition, many smaller tests of both liquid and solid products have been done.

C.4.4.1 Solid products burn test

A full-scale test burn of the solid SRC-I product was carried out at Plant Mitchell of Georgia Power Company in 1977. The purpose of this test was to demonstrate that the solid SRC-I product could be utilized effectively in an existing utility boiler. An extensive program was carried out prior to the burn test to develop equipment modifications to such equipment as

pulverizers and burners. The test burn was sponsored by EPRI, under the direction of Southern Company Services, utilizing approximately 3000 tons of solid SRC supplied by DOE. The fuel was produced at the Fort Lewis, Washington, pilot plant and shipped to Albany, Georgia, for the tests.

The test boiler was a 22 MW converted B&W maritime boiler, with side-wall firing. Burners, pulverizers, and other auxiliary equipment were of B&W design. The burn test consisted of three phases: burning of coal using the original burners to establish a baseline for comparison, burning of coal using the modified burners, and burning of SRC-I solids using the modified burners. The SRC-I phase lasted 18 days, during which combustion conditions were adjusted to obtain optimal combustion and emission monitoring was carried out.

When firing SRC, the operating characteristics of the dual register burners were good. Once the appropriate flame type had been obtained, the performance of the modified dual register burners when burning SRC was excellent. A series of tests was performed to determine the relative effect of SRC compared with coal on the efficiency of the boiler. Efficiencies were essentially the same when burning coal or SRC in the new dual-register burners, except for medium load conditions, where efficiencies were slightly lower when burning SRC.

York Research Corporation was contracted to conduct a major portion of the emissions testing work related to the SRC burn test. During each phase of the program, emissions measurements were performed with the boiler operating at full load (22 MW), medium load (14 MW), and low load (7.5 MW). The following measurements were made:

1. Continuous monitoring of opacity, O_2 , CO_2 , CO, NO_x , and SO_2 in the precipitator outlet flue gas.
2. Manual SO_2 and NO_x tests using EPA methods 6 and 7, respectively, at selected full load conditions.
3. Particulate loadings at both the inlet and outlet to the primary precipitator by EPA Method 5 and ASME Power Test Code PTC27.
4. Particle size distributions of the flyash at the inlet and outlet of the precipitator.
5. Percent combustibles in the precipitator inlet flyash.
6. Resistivity of the inlet flyash (performed by Southern Research Institute).

Test results for SO_2 and NO_x emissions are summarized in Table C.24. These emissions reflect operation of the boiler after adjustments had been made to achieve optimal flame conditions. Complete monitoring results for other parameters are summarized in Table C.25.

**Table C.24. Gaseous boiler emissions
from dual register burners**

Conditions	SO_2 (ppm)	SO_2 (kg/ 10^6 Btu)	NO_x (kg/ 10^6 Btu)
Coal combustion			
Low load	188	0.63	0.21
Medium load	217	0.43	0.23
Full load	319	0.46	0.21
SRC combustion			
Low load	222	0.49	0.19
Medium load	255	0.45	0.20
Full load	335	0.44	0.18

Table C.25. Summary of emissions monitoring results

Parameter	Coal: original burners Phase I				Coal: modified burners Phase II				SRC: modified burners Phase III			
Load, MW	22.5	15	7.5		21	14	7.5	21 ^a	21	14	7.5	21 ^a
Fuel rate, kg/h	10,831	7,322	4,087		9,378	6,706	4,314	9,510	8,035	5,524	3,316	8,019
Excess O ₂ , %	4.7	6.0	11.0		4.4	6.2	11.6	4.6	6.0	7.5	11.3	6.2
Particulate loading in, kg/10 ⁶ Btu	4.49	4.92	4.45		3.35	4.12	4.06	2.14	0.47	0.87	0.80	0.44
Particulate loading out, kg/10 ⁶ Btu	1.04	0.21	0.05		0.75	0.37	0.15	0.03	0.41	0.64	0.43	0.02
Carbon in ash, %	13.9	14.5	19.5		22.33	20.6	16.9	28.1	77.4	88.7	89.4	74.7
Carbon efficiency, %	97.70	87.47	97.07		98.00	97.18	97.18	97.87	98.51	96.98	97.07	98.60
SO ₂ , kg/10 ⁶	0.88	0.98	1.11		0.54	0.71	0.82	0.43	0.43	0.44	0.48	0.42
NO _x , kg/10 ⁶ Btu	0.46	0.21	0.40		0.22	0.21	0.22	0.21	0.19	0.20	0.19	.021
Average opacity, %	41	18	7		30	22	12	66	32	29	16	40
kWh/10 ⁶	78.05	78.67	67.85		79.30	75.81	64.97	80.22	78.98	76.18	65.77	78.88
Fuel input SO ₂ , kg/10 ⁶ Btu ^b		0.89				0.63				0.44		
Emissions SO ₂ , kg/10 ⁶ Btu ^b						0.64				0.45		

^aSecondary precipitator test.^bAverage of all tests.^cEquipment malfunction.

Although particulate loadings entering the primary precipitator when burning SRC were only 10% to 15% of the loadings when burning coal, the particulate concentrations leaving the primary precipitator were higher than EPA standards, but still lower than when burning coal. However, this precipitator, installed in 1946, does not conform to current precipitator design standards. The design flaws, coupled with the high carbon content of the SRC ash that made the ash resistivity very low, resulted in low collection efficiencies. Since the unit is equipped with a secondary precipitator of modern design, additional tests were performed using this precipitator. The tests on the secondary precipitator indicated EPA compliance by a wide margin and show that an adequately designed precipitator will allow SRC to meet existing EPA particulate emission standards (Table C.26).

Table C.26. Particulate emissions from dual register burners

Values are in kg/10⁶ Btu

	Inlet	Outlet	
		Primary precipitator	Secondary precipitator ^a
Coal combustion	3.18	0.73	0.03
SRC combustion	0.45	0.41	0.02

^aPrimary precipitator deenergized during secondary precipitator tests.

Particle size distributions were determined at two locations. The results of the particle size distribution tests indicate that the flyash produced from the combustion of SRC contained a larger percentage of fine particles than the flyash produced from the combustion of normal coal. Fly ash resistivity measurements were attempted. The low resistivity of SRC flyash made it impossible to quantify this parameter. SRC flyash resistivity was clearly very low, however.

C.4.4.2 Solid products combustion emissions — conclusions

A number of conclusions regarding the combustion and emissions characteristics of SRC-I solid fuel products may be drawn based on the results of the Plant Mitchell burn test. Although these conclusions are based on a specific test in a specific boiler, it is felt that the comparisons and data trends will be generally valid when SRC is utilized in other boilers.

SO₂ and NO_x emissions were clearly within the December 1971 EPA Standards of Performance for New Utility Sources during these tests. SO₂ emissions were lower than for coal, due to the lower sulfur content of SRC. NO_x emissions were lower for SRC than for coal in spite of the higher fuel-nitrogen typically present in SRC solids. This may presumably be attributed to the design of the dual register burner which had been optimized for SRC and which employs staged combustion to reduce formation of NO_x.

Particulate emissions were considerably lower using SRC than coal, due to the low ash content of SRC solids. The fly ash formed was extremely high in carbon content, however, which led to a very low resistivity. The older design primary precipitator could not collect this SRC fly ash adequately, presumably because of the low ash resistivity. The secondary precipitator, which is of modern design, was able to reduce solid emissions to within the EPA New Source Standards. It is felt that a properly designed precipitator will be able to meet these standards in any future applications.

C.4.4.3 SRC liquids burn tests emissions

Large-scale burn tests have not been carried out using the liquid by-products from the SRC-I process. However, a large scale test has been conducted by Consolidated Edison of the

combustion characteristics of SRC-II liquids. These liquids are similar in chemical character to SRC-I liquids. Although the physical properties (such as density and viscosity) are expected to vary, this is not felt to be important to utilization of SRC liquids provided that appropriate minor modifications are made to the fuel storage and delivery system. The primary important difference is expected to be the nitrogen content of these liquids. Since the nitrogen content of SRC-I liquids is lower than for SRC-II, the results of the Con Ed burn test will be conservative if used to represent SRC-I liquids.

This section summarizes the Con Ed burn test and the major conclusions of that study. Complete detailed emissions data for that test are presented in the test report⁵ and summarized in the Draft EIS for the SRC-II project.⁶

The demonstration program was carried out by KVB, Inc.⁵ at the 74th Street Generating Station of Consolidated Edison. Approximately 4500 barrels of SRC liquids from the Fort Lewis pilot plant were fired in a test boiler with a nominal full-load capacity of 450,000 lb/h of steam. The SRC liquids burned contained 0.22% sulfur and 1.0% nitrogen.

Nitrogen oxide and particulate emissions are considered the most significant problems anticipated when burning SRC-II liquids. Therefore, the test was oriented toward combustion modifications to reduce these emissions. To obtain a baseline for comparison, data were also collected with a typical No. 6 fuel oil. Tests were carried out under a range of load, fuel/air, air distribution and other conditions, using the same range for both SRC-II liquids and fuel oil.

A variety of gaseous and particulate emissions were monitored including NO, NO₂, CO, O₂, SO₂, total hydrocarbons, polynuclear aromatic hydrocarbons, particulate mass, particulate size distribution, and particulate composition. In addition, boiler performance was evaluated for both fuels.

The results of the test program have been summarized and reported by KVB, Inc. The following gives the essence of that summary.

No major operational problems were encountered due to the combustion of SRC liquids. Visual inspections performed by Con Edison indicated no evidence of deleterious effects on the pump used to feed SRC-II liquids to the test boiler.

Boiler thermal efficiency levels with SRC-II liquids were comparable to those obtained with No. 6 fuel oil.

The combustion of SRC-II fuel oil resulted in nitrogen oxide emissions levels approximately 70% greater than those for No. 6 fuel oil under all test conditions. Higher NO_x emissions were anticipated for the SRC-II fuel oil due to its higher nitrogen content. Nitrogen oxide reductions achievable through combustion modifications were on the order of 35% for both SRC-II and No. 6 fuel oils.

Particulate mass emissions were lower for the SRC liquids than for the No. 6 fuel oil. The characteristics of the particulates were sufficiently different to suggest different formation mechanisms. At full load, the SRC-II combustion particulates exhibited a bi-modal particle size distribution, including very fine (0.05 microns diameter) individual particles and much larger (greater than 0.1 microns diameter) agglomerates. At reduced load, the number of agglomerates was small. In general, the particle sizes were smaller when burning SRC-II than when burning oil.

Total hydrocarbon emissions were less than 3 ppm under all operating conditions with both fuels. Carbon monoxide emissions were below 50 ppm under all operating conditions, with essentially equivalent excess air levels for both fuels. It was concluded that SRC-II did not have any greater tendency toward incomplete combustion than the No. 6 fuel oil.

The total polynuclear aromatic hydrocarbon emissions for both fuels were low; less than 6×10^{-6} lb/MM Btu. Although the emission levels with the SRC-II liquids were nominally higher than those exhibited by the No. 6 fuel oil, the measurement uncertainties are such that no significant trend can be assigned at this time. However, results of another study would indicate emission levels measured on these liquid fuels are substantially below those measured on direct coal-fired boilers.

C.4.4.4 Conclusions

Based on the results of the two large-scale burn tests, it is concluded that:

1. SRC fuel products, both solid and liquid, can be burned in existing utility boilers in compliance with the EPA Standards of Performance for New Utility Sources.
2. The use of solid SRC in a pulverized coal fired boiler requires modifications of pulverizers and burners. The technology necessary for these modifications exists and has been demonstrated.
3. Development programs may be required in order to determine equipment modifications required in order to use solid and liquid SRC fuels in other combustion applications.

C.4.5 Construction

C.4.5.1 Construction burning

Normal state air pollution control regulations generally prohibit open burning, with an exemption from the regulation allowed for open burning for disposal of natural growth for land clearing, provided that

1. no extraneous material such as tires or heavy oil, which tend to produce dense smoke, are used to cause ignition or aid combustion,
2. the burning is done on sunny days with mild winds,
3. the emissions from such fires shall not be equal to or greater than 40% opacity, and
4. open burning of construction debris is prohibited.

For the construction of this facility, the policy during land clearing will be that cleared vegetation will be sold or chipped; burning will be a last resort and used to dispose of cleared vegetation only.

C.4.5.2 Earth moving

During construction, it is estimated that about 3×10^6 yd³ of earth will be moved. Prevention of fugitive dust emissions is necessary. Normal construction practice includes minimizing exposed areas and keeping exposed areas, including non-hard-surfaced roads, sprinkled with water.

C.4.5.3 Water runoff

Earth disturbed by surface excavation is easily eroded by rain runoff. The mitigation measures described below will be detailed in the Construction Environmental Management Plan and will be one of the first activities to take place on the site. To prevent pollution of streams by sediment, a system of diversion ditches will be installed to prevent runoff from higher ground from entering the disturbed areas. Water will be retained in the ponds long enough so that the discharge to natural drainages will meet state and EPA requirements for suspended solids content. A National Pollutant Discharge Elimination System (NPDES) discharge permit will be obtained. This permit, issued by EPA, will specify the conditions of the discharge quality. The discharge will meet these specifications.

C.4.5.4 Paints and solvents

If water-based paints are used, only very small quantities of pollutant emissions will be released to the atmosphere. If oil-based paints are used, between 35 and 50% of the paints will be evaporated. Typically, about 45% of the paint is volatile hydrocarbons. Since a gallon of oil-based paint weighs about 12 pounds, about 5 pounds of hydrocarbons will be

released to the atmosphere per gallon of oil-based paint applied. An estimated 100,000 gallons of paint will be used, which will result in hydrocarbon emissions of about 250 tons. Probably, most of the painting will be done during the last year of construction.

C.4.5.5 Air emissions from construction equipment

From a list of required construction equipment, usage factors for each piece of equipment were estimated based on the equipment type, its probable utilization in each phase of construction, and the 38-month construction duration. The air emissions from the construction equipment, including construction vehicles, are shown in Table C.27.

Table C.27. Air emissions from construction equipment

Pollutant	Emissions ^a (tons/year)
CO	94.7
HC	11.1
NO _x	71.5
SO _x	4.48
TSP ^b	3.58

^a At peak of construction period.

^b Total suspended particulates.

Emission factors were provided from Sect. 3.2.7, pp. 3.2.7-1 through 3.2.7-5 of AP-42.⁷

C.4.5.6 Air emissions from highway vehicles

During construction, an estimated peak of 3500 persons will be employed at the site. Construction is planned for a five-day work week. The average round trip commuting distance is estimated to be 24 miles. The average carload is assumed to be 1.9 persons. This will result in 11,500,000 vehicle miles per year.

Emission factors for all highway vehicles are given by AP-42.⁷ These factors include a mix of vehicle types based on nationwide data. This mix includes 7.8% heavy-duty vehicles which would not be used by the construction workers for commuting. Deliveries of materials to the construction site would, however, be made by heavy-duty vehicles. Therefore, the construction worker vehicle miles traveled is increased by 7.8% to include truck deliveries to the site. Highway vehicular travel associated with construction is estimated to be 12,400,000 miles/year. Estimates of total emissions are shown in Table C.28. The traffic has been assumed to be heavily congested with a traveling speed of 10 mph throughout the entire trip length.

Table C.28. Air emissions from highway vehicles during construction of demonstration plants

Pollutant	Quantity		
	g/mile ^a	g/year	tons per year
CO	67.7	840 X 10 ⁶	920
HC	9.18	11 X 10 ⁶	120
NO _x	3.32	40 X 10 ⁶	45
SO ₂	0.20	3 X 10 ⁶	3
TSP ^b	0.44	5 X 10 ⁶	6

^a Data from AP-42.

^b Total suspended particulates.

It should be noted that only a small portion, perhaps 10% of the above emissions, would occur at the demonstration plant site. It should also be noted that these represent worst-case emissions, estimated before implementation of mitigation measures for traffic congestion problems. These mitigation measures should reduce emissions below these worst-case estimates. Section 4.2.3.1 contains the air quality impact analysis of traffic emissions.

C.5 EXPANDED COMMERCIAL PLANT

Commercial-scale SRC-I facilities may be built as a result of successful demonstration plant operation. Such facilities may be built at other sites, or an expanded plant may be built at the Newman site. One objective of demonstration plant operation and evaluation is to reduce the economic uncertainty for this type of synthetic fuel, including uncertainty about capital costs and operation and maintenance costs of required environmental controls.

The commercial plant's conceptual design adds four heater-dissolver trains in parallel to the one train in the demonstration plant, bringing the total plant feed rate up to 30,000 tons/d of coal. Other plant elements, in order to achieve economics of scale, would be larger versions of demonstration plant elements. These include conventional technologies such as coal storage and preparation, gasification, water and wastewater treatment, acid gas removal and sulfur plant, flares, cooling system, solid waste system, and product handling. Opportunities for increasing plant efficiency beyond the demonstration plant's economically justifiable level will also occur in the cooling and waste-heat recovery portions of the plant.

Pollution control facilities and techniques will be evolving and improving during the life of the demonstration plant. Experience at the demonstration plant will very likely lead to more advanced controls being designed into the commercial plant, but their nature cannot be specified at this time.

C.5.1 Air emissions

The emissions rates of the commercial plant will be less than five times those of the demonstration plant for all pollutants. The emission rates for SO₂ and particulates will be far less than directly proportional to plant capacity because the capacity of the coker/calcliner, which is the major source of these pollutants in the demonstration plant, is not expected to be greatly expanded in the commercial plant. Also, emerging process and control technologies, such as flash drying, which could greatly reduce emissions but are not commercially proven now, may be employed for the commercial plant. Extensive monitoring in the demonstration plant would reduce emissions in the commercial plant because it will provide more accurate emissions data that can be used for design improvement.

Ground-level concentrations of the pollutants will not be directly proportional to plant capacity, either. Because the commercial plant would occupy a larger area, most sources of emissions would be separated by hundreds of meters. The distances separating the sources reduce additive impact of each source.

The emission rates from the commercial plant will depend on many factors such as product slates and process design. Because planning for the commercial plant is still in an embryonic stage, the emission rates cannot be estimated with a high degree of certainty; many assumptions have to be made. The first key assumption is that the production rate of coke at the commercial plant will be about the same as that at the demonstration plant, and the production rates of the other products will be approximately five times those of the demonstration plant. Using these assumptions, the emission rates from point and fugitive sources in the commercial plant are estimated as follows:

	<u>Tons per year</u>
Sulfur dioxide	150
Particulates	615
Hydrocarbons	320
Nitrogen oxides	4150
Carbon monoxide	3600

Sulfur dioxide emissions from the commercial plant would be less than two times those of the demonstration plant. This relatively small increase is possible because the demonstration plant's largest SO₂ source (75 to 80%), the coker/calcliner, would not be greatly expanded for commercial operation.

Particulate emissions from point sources in the commercial plant are expected to be about 4.0 times the emissions of the demonstration plant (or 560 tons per year) because the coking and calcining processes are not expanded.

Accurate fugitive particulate emissions are difficult to determine; only monitoring during demonstration plant operation can give a reliable data base. Fugitive particulate emissions from the demonstration plant were estimated by using a variety of EPA publications and sources. The literature on fugitive particulate emissions is not very reliable because it does not take into account many important factors that can affect emissions, such as exposed surface area of coal piles and their orientation with respect to the prevailing wind or the effects of wind speed on pile loss. Only actual monitoring can accurately determine fugitive emission rates from the demonstration plant and provide a better basis for estimating fugitive emissions from the commercial plant. Fugitive particulate emissions from the commercial plant are expected to be less than five times those of the demonstration plant because the surface of coal piles in the commercial plant exposed to wind erosion would not be as much as five times those of the demonstration plant. For air quality impact analysis, the conservative assumption has been made that fugitive particulate emissions will increase by a factor of 5 over the demonstration emissions.

Hydrocarbon emissions from point sources at the demonstration plant as well as at the commercial plant will be small. The commercial plant will emit about 40 tons per year from point sources.

As for the demonstration plant, hydrocarbon emissions from the commercial facility will depend on control of the fugitive sources. Fugitive sources of hydrocarbons in the demonstration plant are estimated to contribute almost 90% of the plant's overall hydrocarbon emission rate. The estimates utilized for the demonstration plant emission inventory in Appendix C are based on the EPA guideline document *Assessment of Atmospheric Emissions from Petroleum Refining*, Vol. 3, Appendix B, April 1980. This document is based on emission measuring activities at 13 petroleum refineries throughout the United States. Overall fugitive emission rates from fittings such as valves, flanges, pumps, and compressors varied greatly among the refineries investigated, and none of the refineries studied employed maintenance or design consideration programs as stringent as those planned for the SRC-I plant. Consequently, the emissions inventory for the demonstration plant may be conservative. Operating experience at the demonstration plant would allow for more precise estimation of emissions for expansion to commercial capacity. If analysis before commercialization indicates the plant could be a major source of hydrocarbons, appropriate design considerations will be employed, or offsets will be obtained as necessary. As a worst-case assumption, the hydrocarbon emission rate from point and fugitive sources in the commercial plant can be assumed to be five times that of the demonstration plant, or less than 320 tons per year.

The nitrogen oxide emission rate of the commercial plant is estimated to be four to five times that of the demonstration plant, assuming the use of gaseous fuel. The commercial plant would emit a maximum of five times the CO of the demonstration plant. The plant commercialization may result in only 2.5 times the CO emissions of the demonstration plant. This low emission rate may be realized if the large CO₂ stream (which also contains 50% of the facility's CO emissions) can be pipelined to a tertiary oil recovery operation, rather than being vented to the atmosphere. This option appears feasible for a commercial-size plant.

Hydrogen sulfide. Modeling for H₂S concentrations carried out for the PSD permit application for the demonstration plant indicates that the odor threshold for the demonstration plant (10 ppb) will not be exceeded. If the H₂S emissions are conservatively estimated to scale upward by a factor of 5 for the commercial plant, the odor threshold for H₂S could be exceeded under certain meteorological conditions. Analysis during the demonstration phase will determine whether H₂S emissions must be lower than these conservatively estimated rates to meet odor standards for the commercial plant. Mitigation measures will be taken in the design of the commercial plant if required.

Lead. Lead concentrations for the demonstration plant were predicted using very conservative estimates of atmospheric lead emissions (i.e., all lead entering with the coal was assumed to be vented to the atmosphere at each of two locations, making for double accounting).

Actual lead emissions from the demonstration plant are expected to be much less than this conservative estimate, and emissions from the commercial plant are, therefore, expected to be much less than a 5 times' scale-up of this conservative estimate. The resulting lead concentrations will be lower than the ambient air quality standards. Monitoring during the demonstration phase will be done to confirm this analysis.

C.5.2 Water consumption and wastewater discharge

Current plans indicate a fivefold expansion of the demonstration-scale facility (6,000 tons/d) to commercial scale (30,000 tons/d). One of the major surface water hydrologic impacts accompanying expansion is increased water consumption. Impacts on flood flows are not expected to be significant, being primarily a small decrease in floodplain storage capacity as a result of additional site filling to raise the area above flood level. Current plans do not indicate that a further encroachment on or narrowing of the floodway will result from commercial expansion. Expansion of the barge slip will slightly alter flows of the Green River; however, with continued channel maintenance, no effect on channel navigability is anticipated (see Appendix Y).

Assuming zero liquid discharge (normal operation), water withdrawal from the Green River at commercial-scale operation is anticipated to be about 745 liters/s (11,822 gpm). This increased withdrawal constitutes up to a maximum of about 6.7% of the estimated 7-d, 10-year low flow. Because wastewater would not be returned to the river, net water consumption from the Green River at commercial-scale operation is anticipated to be about 745 liters/s (11,822 gpm) also, which is about 4.7 times that of the demonstration plant. This estimate was based on the following assumptions:

1. coking and calcining capacity will not greatly expand at the commercial plant;
2. other water requirements will be five times as much as the demonstration plant; and
3. treated wastewater quantity will remain the same as the demonstration plant for each additional 6000 tons/d processed.

Potential impacts to the water quality of the Green River are difficult to delineate at this time. Constraints due to water quality or quantity may require the use of zero wastewater discharge technology for all or part of the effluent. Experience and data gathered at the demonstration plant will serve as a basis for the decision of whether to continue discharge or to implement the zero-discharge alternative at the commercial plant. Extensive monitoring will also enlarge the data base regarding the treatability of SRC wastewaters at demonstration plant scale and enable an accurate projection of commercial plant wastewater characteristics. Treated wastewater will be discharged from the commercial plant only in compliance with operating permits and if the long-term data collected at the demonstration plant show that it will not cause significant impact on the environment.

C.5.3 Solid waste management

Alternatives for solid waste management for the commercial facility include, but are not limited to, onsite versus offsite disposal; landfill configurations for gasifier slag and flyash; waste stabilization versus hazardous landfilling; and disposal versus reutilization of materials. The ultimate decision on solid waste management at the commercial facility will be most effectively determined on the basis of studies and monitoring conducted at the demonstration plant.

The demonstration plant will have an extensive monitoring program to determine the long-term fate of contaminants in the solid waste materials. Runoff and leachate will be routinely analyzed. Such data will determine more definitively if a waste is hazardous or not.

Continued operation without commercial-scale expansion for 15 years further would require approximately 48.6 additional hectares (120 acres) of ash ponds. Sufficient land is available at the site for these ponds if no additional processing modules are constructed.

If additional SRC process modules are constructed to increase the plant capacity, insufficient onsite disposal land will be available to store all ash generated during the lifetime of the expanded plant. At that time disposal alternatives for ash which cannot be stored onsite will be evaluated. These alternatives include: fixation as a solid and sale as a commercial

commodity, fixation and utilization for land reclamation, acquisition of additional land offsite for disposal. Precise area requirements will depend on landfill or ash pond configuration. Alternative configurations to minimize land requirements are being evaluated, and the best alternative will be employed in the demonstration plant. Experience gained in the demonstration plant will facilitate the landfill design at the commercial plant.

In situ evaluation of several commercially available waste stabilization processes will be a part of the solid waste testing program at the demonstration plant. The evaluations will determine whether or not the processes can convert hazardous wastes to nonhazardous wastes or improve handling properties of solid wastes. Again the data will be used in the scale-up to the commercial plant.

Use of gasifier wastes as by-products will also be fully evaluated in the demonstration plant. A long-range program is required for the evaluation. One potential application would be using the materials as aggregates for road construction. Such use would help alleviate the solid waste management problems at the commercial facility.

C.6 FLOOD IMPACTS ON CONSTRUCTION AND OPERATION OF THE DEMONSTRATION PLANT

C.6.1 Construction

In the event of a 100- or 500-year flood during construction, access to the plant would be interrupted because U.S. Route 60 and the railroad would be under water; construction would therefore stop. Because most of the construction is taking place in the Green River floodplain (not a floodway) and only some temporary construction buildings would be located in the floodplain area, only minimal structural damage would be expected. Some cost would be incurred for cleaning up of materials and equipment that were left in low-lying areas. With reasonable notice (1 to 2 d) the majority of operating equipment and critical materials could be moved to high ground in the unlikely event of a flood occurrence. The USCOE flood control system and modern weather prediction methods are capable of providing such a notice of impending high water, which would allow sufficient time to secure plant operations or construction efforts. Assuming that the duration of a 100-year flood would be 12 d with an interval of 100 years and assuming a construction duration of 3 years, the average delay due to flood high water would be about one-third of a day (3% of 12 days). Significantly greater construction delays would be caused by the heavy rains which often precede flood conditions. Normal rainfall is taken into consideration in the productivity factors on construction man-hours.

C.6.2 Operation

All of the operating areas of the facility are either above the 500-year flood level or are diked to protect against a 500-year flood; consequently, minimal effects to equipment and facilities would be expected during a flood condition. Plant operation, however, would be curtailed by flood inundation of the public access roads and railroads, which would interrupt raw materials supply to the site and final product export from the site. As mentioned above in Sect. C.6.1, warning will be sufficient to allow plant operations to be secured before a 500- or 100-year flood. Some expense to clear roads and railroad tracks at the plant entrance of silt and debris deposits from the flood would be expected, but these costs are not expected to be excessive.

REFERENCES FOR APPENDIX C

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Appendix D

SRC-I FLOODPLAIN/WETLANDS REVIEW

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Appendix D

SRC-I FLOODPLAIN/WETLANDS REVIEW

The development of the proposed SRC-I demonstration plant at Newman, Kentucky, will necessitate encroachment of the Green River floodplain between river miles 18.5 and 19.8. Facilities to be located in the floodplain include the barge dock and water intake and wastewater discharge facilities as well as portions of the coal storage, ash ponds, and solid/liquid storage areas. Because portions of the site are in the 100- and 500-year floodplain, plant layout design studies attempted to minimize floodplain encroachment. This was in keeping with Executive Orders and Department of Energy guidelines regarding the placement of a Federal action in a floodplain, and to mitigate possible flood-related damage to the proposed plant. Consequently, all flood-prone areas that contain facilities of a sensitive nature will be filled and/or diked to or above the critical flood elevation. This floodplain encroachment will result in only minor flood-related impacts.

Based on current plant facility layout, several small farm ponds, which are considered wetlands habitat, and small acreages of riparian forest will likely be impacted during plant construction. These wetlands habitats are not unique or of major significance, and their elimination is not considered a major project impact. Alternatives to the proposed development have been evaluated. This analysis supports a tentative finding that there are no practicable alternatives to the projected floodplain/wetlands impacts that are capable of meeting the project requirements.

D.1 INTRODUCTION

Construction of the proposed SRC-I demonstration plant on the northern bank of the Green River at Newman, Kentucky, will necessitate floodplain encroachments. The site is located on a moderately high terrace between the confluence of the Green and Ohio rivers. Because of this location the site could conceivably be flooded by concurrent flood events in the Ohio River and the Green River. The site's general topography is sufficient to keep the major process area flood free in the projected 500-year flood event. However, other facilities necessary for the project, especially water transportation facilities, will have to be flood-proofed to maintain their security.

The construction of the SRC-I plant will require the elimination of five small farm ponds (0.6 ha) and several acres of riparian woodland (up to 10 ha) for the water transportation and water supply/discharge facilities.

To comply with Executive Order 11988, "Floodplain Management," and Executive Order 11990, "Protection of Wetlands," this report identifies, evaluates, and assesses the practicable alternatives to the floodplain and wetlands impacts associated with the proposed action. This report follows the regulations established by the Department of Energy (DOE) published in *Federal Reserve Regulations* (Title 10, Chap. X, Part 1022, Subparts A and B, Mar. 7, 1979).

D.2 PRELIMINARY FLOODPLAIN/WETLANDS DETERMINATION

The following is a preliminary floodplain/wetlands determination of the practicability of locating a Federal action outside of a floodplain. Pursuant to Executive Orders 11988 and 11990, floodplain/wetlands determination for the project are to be made by the Secretary of the DOE and will be included in the record of decision, following completion of the final EIS.

The proposed development of the Newman site for the SRC-I demonstration plant will encroach on an active floodplain and will have a minor impact on wetlands at the site. It is therefore necessary under Executive Orders 11988 and 11990 to determine if any other sites offer

practicable alternatives to reducing the floodplain/wetlands effects associated with the Newman site. Practicable alternative sites are defined as having no floodplain encroachment or wetlands impacts associated with the development of the proposed plant.

D.2.1 Siting criteria

In selecting the primary and alternative sites for the proposed SRC-I demonstration plant, several siting constraints were established to define minimum requirements for such resources as land, water, feed coal, etc. (see Appendix B.3). In all, 25 alternative sites were evaluated. Of primary siting importance were access to suitable feed coal; site area of 500 acres, which is large enough to accommodate construction of the demonstration plant and potential commercial expansion; a water supply sufficient to satisfy design criteria of 217 liters/s (3445 gpm) for the demonstration plant and as much as 1040 liters/s (16,500 gpm) for the future commercial plant; and access to barge and rail facilities for the delivery of construction materials and coal and the shipment of plant products.

The construction of the raw water intake facility, wastewater diffuser, and barge slip will be required for the demonstration plant. A barge docking facility is also required for the demonstration plant because of the nature of the equipment and materials required for construction. It is estimated that as much as 300,000 tons of construction equipment will be delivered to the site by barge. Because of limited capacities of railroads and highways for size and weight, much of the larger sized equipment, such as dissolvers, is not suitable for shipment by railroads or highways. Barge facilities are also necessary to maintain the flexibility of materials receipt and product shipping. After commercialization almost all of the feed coal would probably be shipped by barge, making the barge facility critical to the commercialization objective of the proposed action.

D.2.2 Practicability of alternative sites

As indicated in Appendix B.3, ten sites survived the initial screening of 25 potential sites. The ten sites included Ravenswood and Equality. Because of the design and site criteria necessary for construction and operation of the proposed plant, each of the ten sites would require barge facilities and intake and discharge structures.

Each of these facilities, located close or contiguous to a navigable river, are at least partially located in floodplains. Therefore, all ten sites would be expected to experience some degree of floodplain encroachment.

The extensive screening process produced no potential site that complies with the basic siting constraints, is environmentally acceptable, and does not require encroachment on a floodplain. The preliminary conclusion is that there are no practicable alternatives to locating in the base floodplain. This conclusion is not surprising in view of the requirements that are basic to the type of demonstration plant being proposed. In particular, the need for barge access for equipment delivery and feed coal delivery for the commercial facility necessitates some floodplain encroachment. Section 2.3.2.1 compares the floodplain/wetlands characteristics of the proposed and alternative sites.

D.3 FLOODPLAIN/WETLANDS ASSESSMENT

D.3.1 Project description

Flood elevations at the proposed site have been delineated by the U.S. Army Corps of Engineers as 385 and 388 ft (NGVD) for the 100-year "base" flood and 500-year "critical" flood, respectively (see Appendix G). These flood elevation determinations are considered to be best judgments in the absence of definitive studies in the area. Defining the base and critical flood elevations at the site is difficult due to the confluence of the Green and Ohio rivers, existing topographical features separating the two floodplains, and assumptions made regarding the timing and backwater effects of flood-crest passages down the Green and Ohio rivers. In the absence of these definitive studies, the U.S. Army Corps of Engineers' recommended flood elevations presented above are used as the basis of this floodplain determination. The natural areas of the site above these two flood datums are illustrated in Figs. D.1 and D.2.

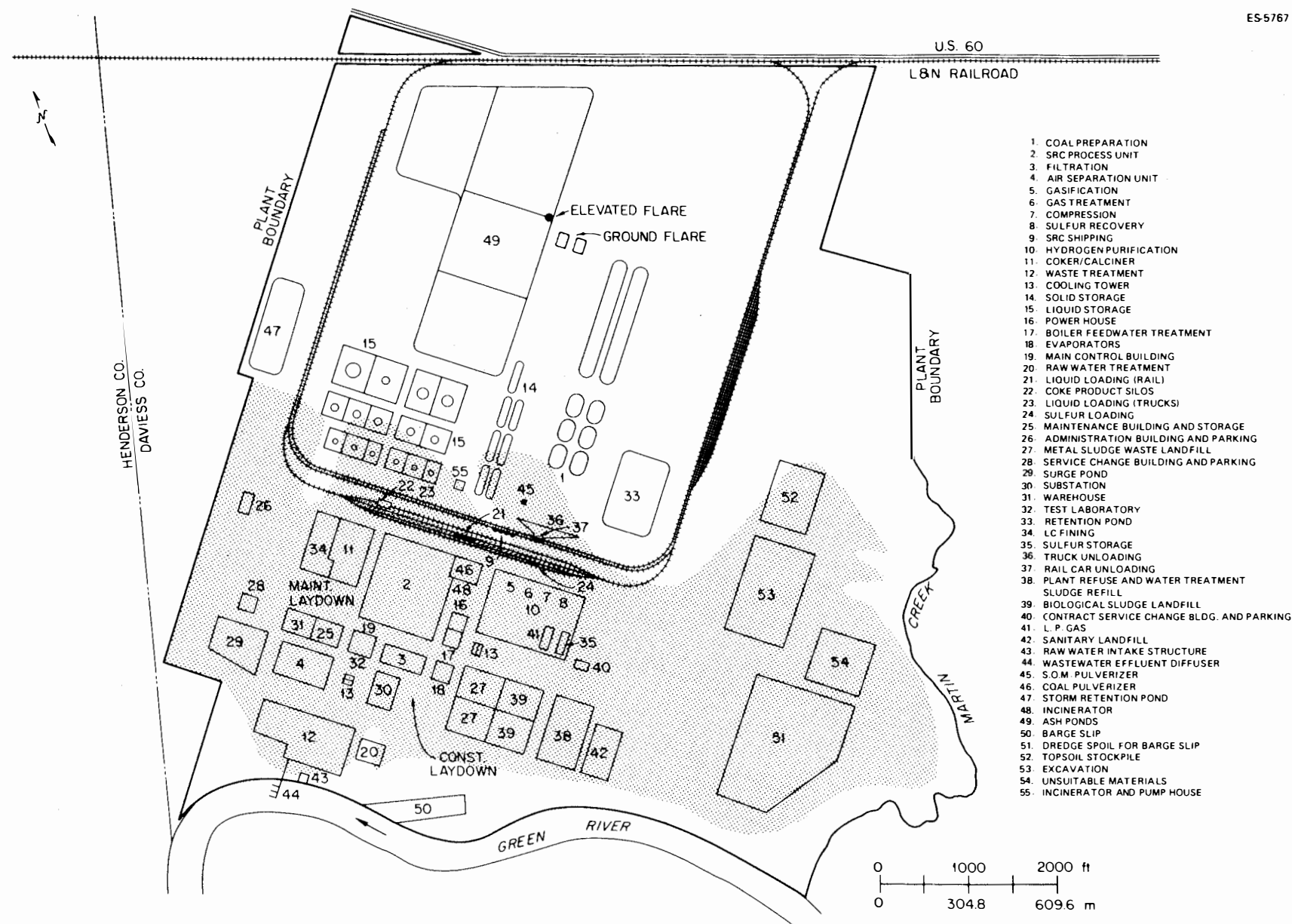


Fig. D.1. SRC-I plot plan (shading shows areas above the 100-year flood elevation).

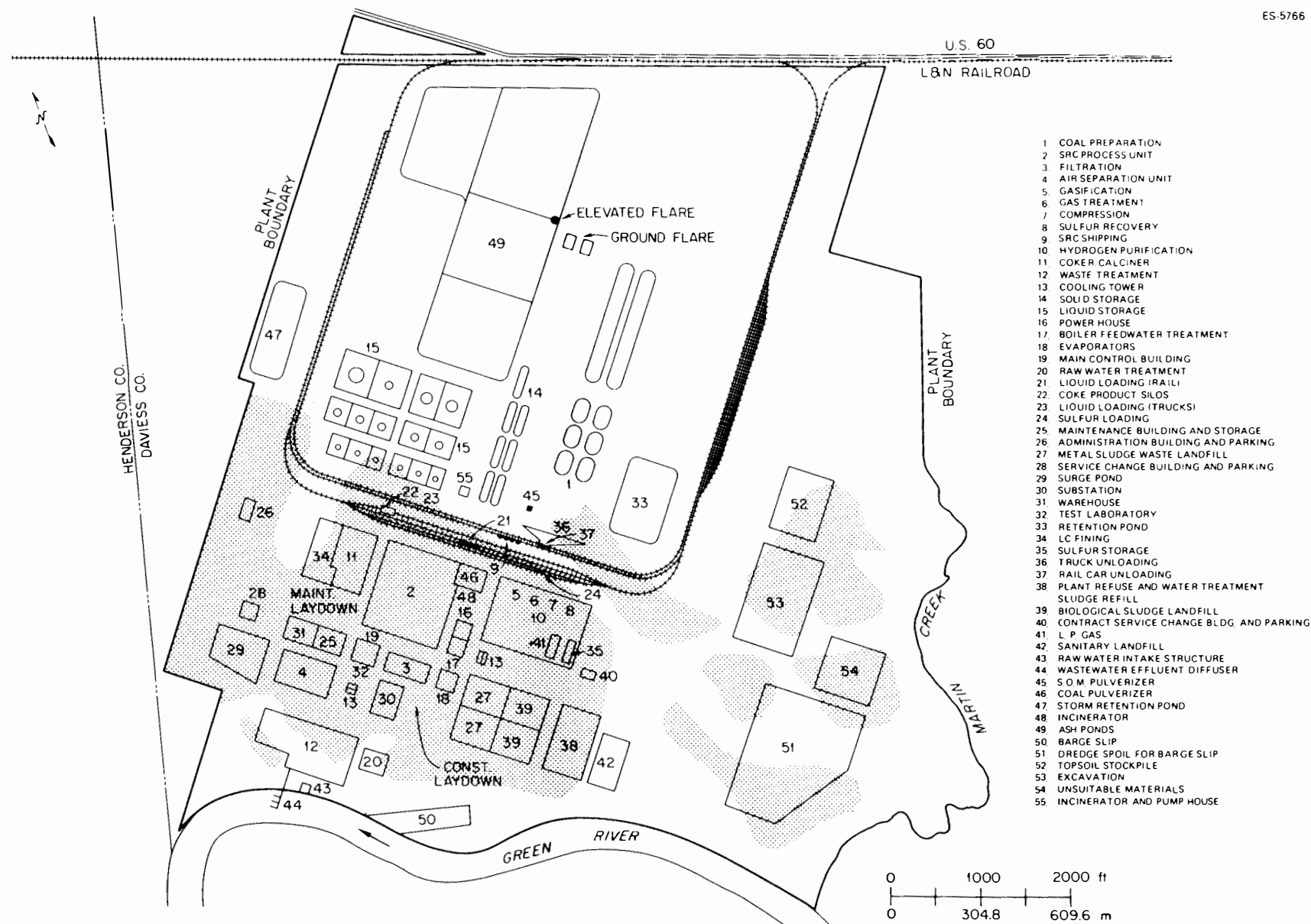


Fig. D.2. SRC-I plot plan (shading shows areas above the 500-year flood elevation).

The layout of the SRC-I facilities at the Newman site are constrained by project and site requirements that require the elevation of the process and storage areas to be out of the 100- and 500-year floodplains. Primary among these constraints is the project's requirement for the barge delivery of process feed coal for the commercial plant, almost 100%, and the delivery of large, heavy equipment during the construction phase of the demonstration plant. As illustrated in Figs. D.1 and D.2, various permanent and temporary structures and utilities have to be constructed within the bounds of the 100- and 500-year floodplains. The layout of the site has been carefully developed to utilize as much of the higher ground as possible for the demonstration plant and to retain sufficient high ground in the southeastern quadrant for the potential commercial expansion phase.

The facility components can be divided into the following general classification in relation to floodplain encroachment:

1. river-dependent facilities (floodplain encroachment and flood proofing inevitable),
2. process areas and warehousing (nonfloodplain areas utilized),
3. coal, product, and waste storage (flood-secure designs required),
4. permanent utilities (some flood proofing required), and
5. temporary construction facilities (major flood proofing not required).

The development of the site will generally not require floodplain encroachments in the northern third of the site. With the exception of roadways through this area, no recontouring will be necessary to prevent floodwaters from flowing over this area. The middle third of the site will require flood proofing and runoff water control for the liquid storage, ash ponds, SRC product storage, coal storage, and the administration building, which will result in floodplain encroachment and impacts. The southern third of the site, adjacent to the river, will not entail floodplain encroachments, aside from the small encroachments necessary for the construction of the river-dependent facilities. This sector of the site will contain the major process facilities and will also contain sufficient acreage for commercial expansion. The temporary construction facilities are in flood-secure areas that should provide ample protection during the short construction period. The major facilities to be constructed within the 100-year floodplain are discussed below. The site grading plan is shown in Fig. D.3.

From the initiation of studies for the SRC-I siting analysis, the avoidance of wetlands and other natural wildlife habitats has been a policy objective. The absence of major wetlands and woodlands at the site is due to the extensive clearing and drainage of the sites for agricultural development. These prior changes have resulted in the site containing five or six small farm ponds that could be considered wetland habitat. In addition, there is a fringe of bottomland and riparian forest along Martin Creek and the Green River. Biological (field reconnaissance) surveys and evaluation of these habitats were conducted during the environmental report phase of the project. Several of these farm ponds and small acreages of the riparian forest will be lost during plant construction.

Barge docking facility

The barge docking facility (illustrated in Figs. D.4 and D.5 and described in Appendix Y) is designed to provide for the water transportation of construction materials to and from the site and for coal supply transference during the demonstration phase. The barge docking facilities will be expandable to facilitate similar uses should commercial expansion occur. It is estimated that almost 100% of the commercial plant's feed coal will be supplied by barge. The expandable barge dock option was chosen because of the long-term savings that would occur during construction of the commercial facility. The barge slip site has been carefully chosen to take advantage of lower ground along the base of the bluff, thereby reducing the volume and the area of excavation. The dock decking and the access ramps will be designed for inundation under larger flood events. Construction of the demonstration barge slip, docks, and access ramps will necessitate the removal of 700 ft of riparian habitat equaling 0.8 ha (2 acres) of habitat. The area of dredging is estimated to be 3300 m² (3946 yd²). The dredged material will be excavated by conventional dragline clamshell and scraper in the inland areas and by hydraulic dredge for the final cut and the riverine sectors. Dredged material will be used for fill or disposed of in upland fill sites. Riprap will be provided to reduce shoreline erosion and to secure the cut banks. Currently, coal unloading facilities have not been designed, but they are expected to be conventional, commercial designs that will utilize the best available control technology to reduce air pollution fugitive emissions.

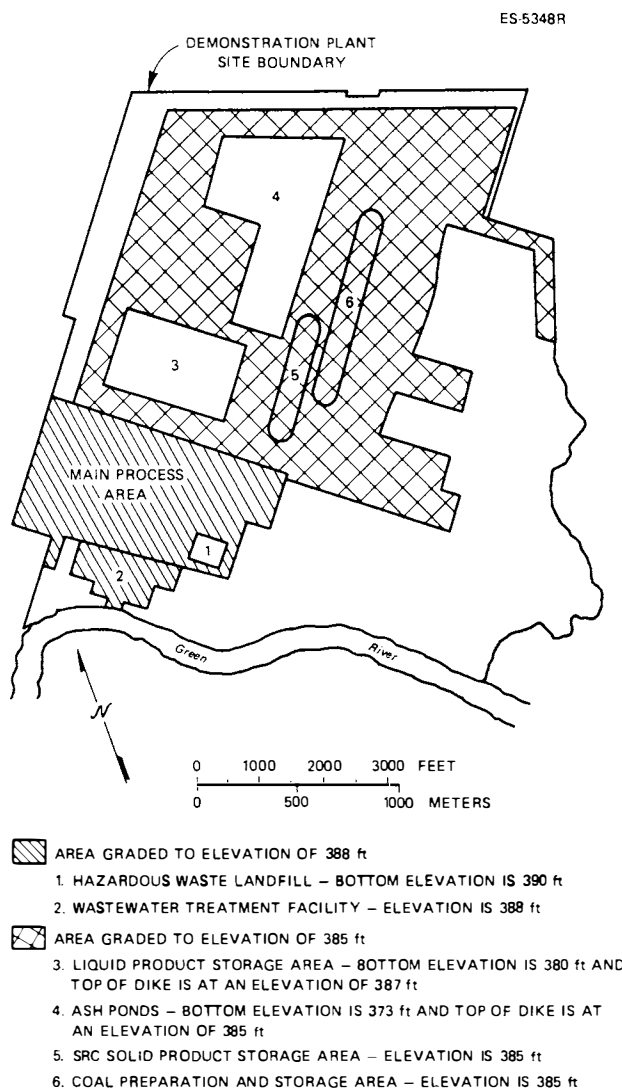


Fig. D.3. Site development plans for the proposed SRC-I facility at Newman, Kentucky.

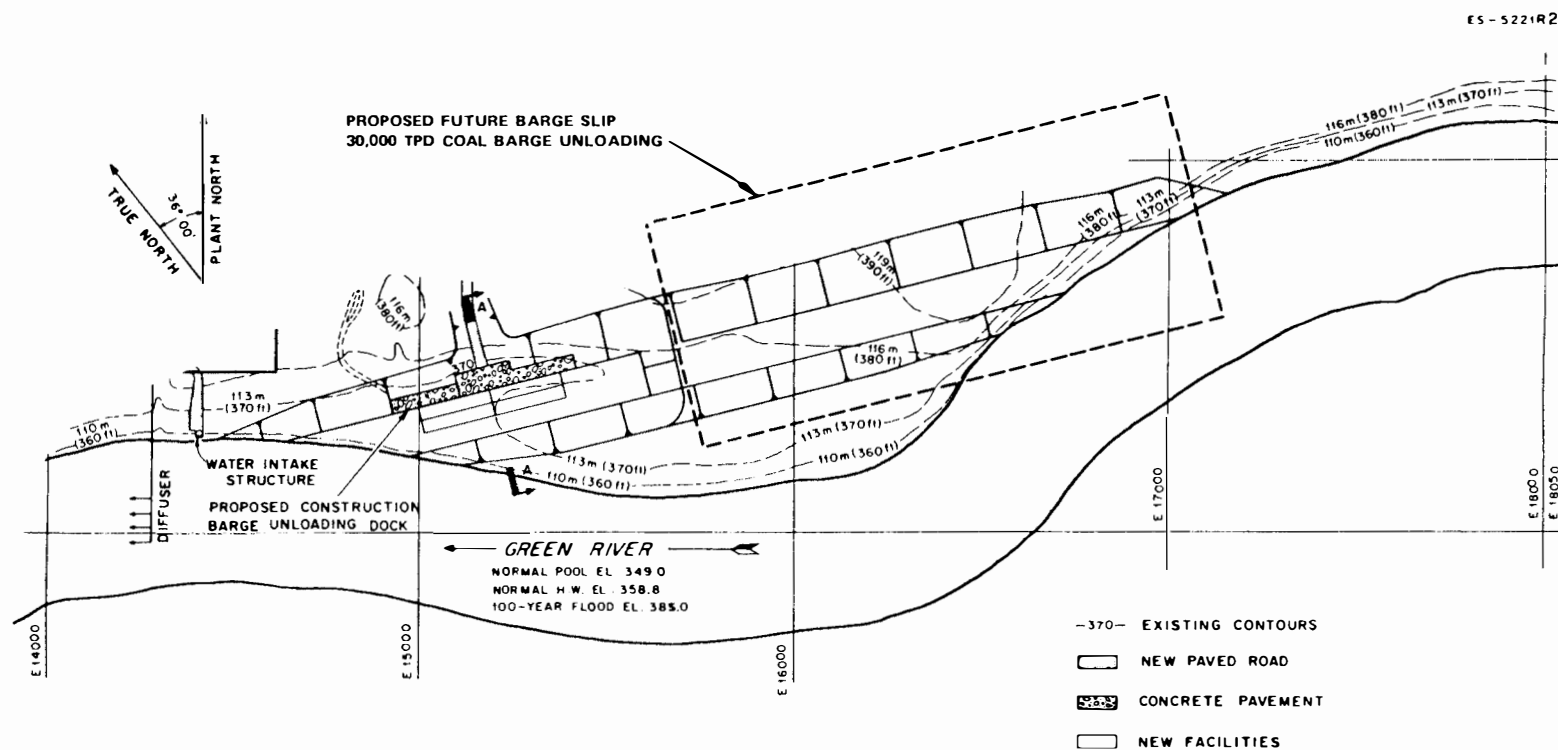


Fig. D.4. Planned location of barge dock facility for the proposed SRC-I site.

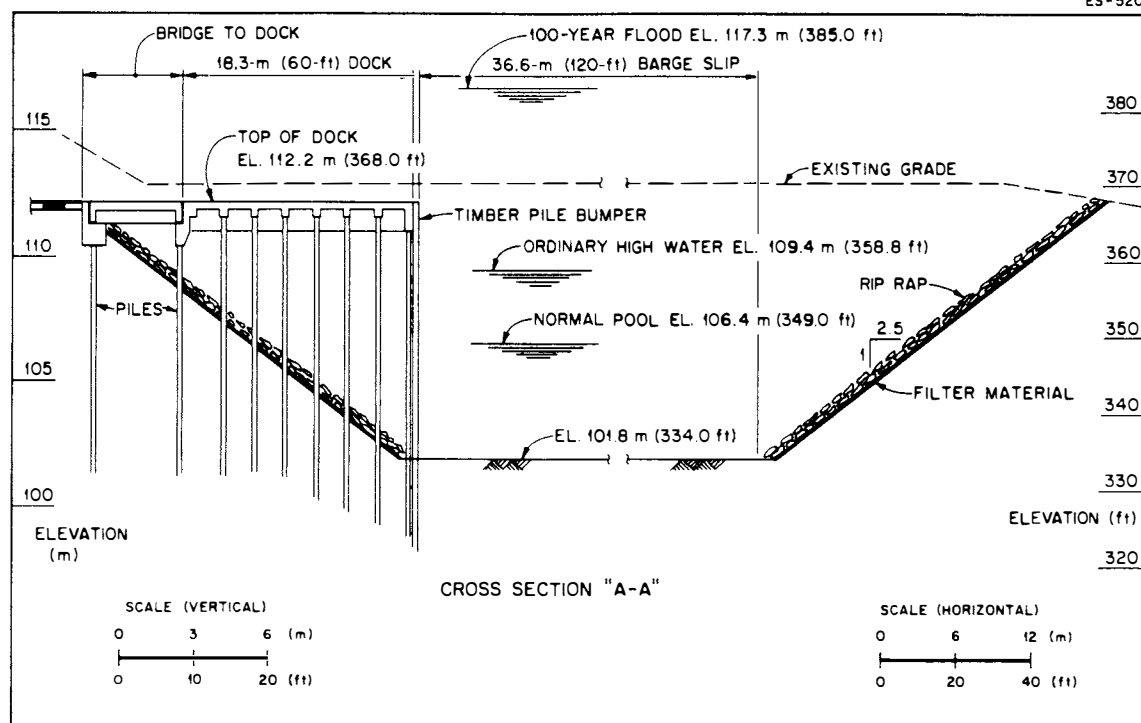


Fig. D.5 Preliminary design showing cross section of the barge dock facility planned for the proposed SRC-I site.

Raw water intake facility

The raw water intake facility will be located immediately downstream of the barge facility. Two alternative intake devices are under consideration: conventional and submerged (illustrated in Figs. D.6 and D.7). Appendix C, Sect. C.1.2.6, discusses these devices. Normal water withdrawals will be 2520 gpm. Short-term and fire-protection water requirements would be added to this volume. The structure will be flood-proofed to above the 500-year flood elevation.

The channel will require about 2000 yd³ of dredging and will probably require maintenance dredging. Dredge spoil will be stored in upland sites (Fig. 2.3). Construction will result in the elimination of 120 m² of riparian habitat and 192 m² of river bottom habitat.

Wastewater diffusion system

The wastewater diffuser system is illustrated in Figs. D.1 and D.8. The weighted diffuser line will be designed to provide the necessary wastewater dispersion characteristics, avoid impacts on the river's water commerce, and ensure flood-scour security. The effluent line will require the disturbance of 120 m² of riparian habitat and 192 m² of river bottom habitat. Data are as follows:

Plant size (tpd)	Operating mode	Assumed flow rate		Pipe diam. (in.)	Orifice diam. (in.)	No. of orifices	Jet velocity (fps)	Temp. (°F)	
		Mgd	Cfs					Summer	Winter
6,000	Normal	1.56	2.41	20	2	40	4.7	105	55
6,000	Maximum	2 x 1.56	4.82	20	2	80	5.1	105	35
30,000	Normal	5 x 1.56	12.07	20	2	100	10.8	105	55

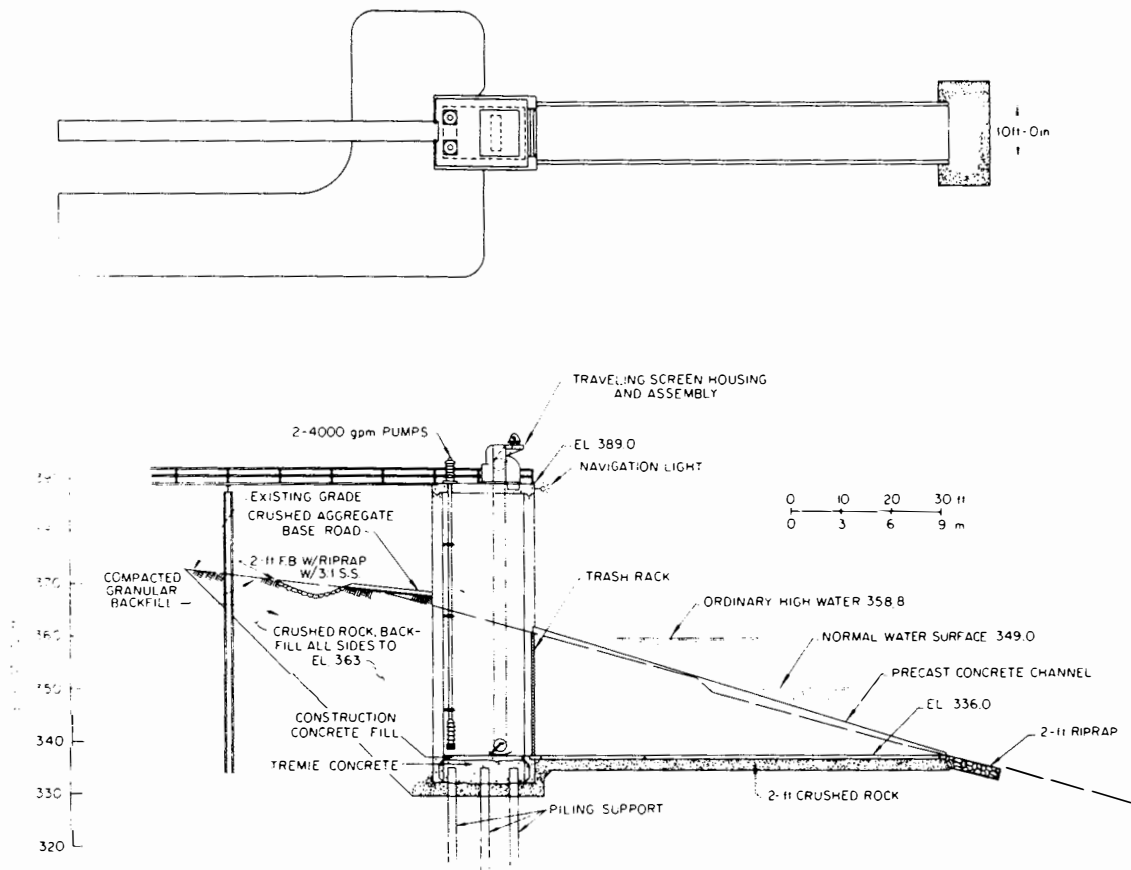


Fig. D.6. Conventional raw water intake device.

Ash pond landfills

The location of the ash ponds (Fig. D.1), necessitates the rerouting of Bryant Ditch and an encroachment on the Green River floodplain. The landfills will incorporate a clay and other liners to prevent leaching. The base of the landfills will be below the 100-year flood level, and the top of the embankment will be above the 500-year flood elevation. Leachate collection removal, followed by treatment, will be provided above and below the impervious liners. The amount of encroachment is about 5 acres.

Liquid storage area

The liquid product storage and associated spill containment reservoirs are located immediately west of the ash pond lagoons (Fig. D.1). The product tankage will be surrounded by a dike system raised above the 500-year flood elevation. Rainwater runoff collection and reuse will be designed into the facility. The necessity of providing dike protection from flooding ensures that reservoir capacities are also adequate for containment of product spillage and rainfall runoff. To avoid groundwater contamination by product liquids in the event of tank rupture or spills, the diked area will be lined with appropriate impermeable materials.

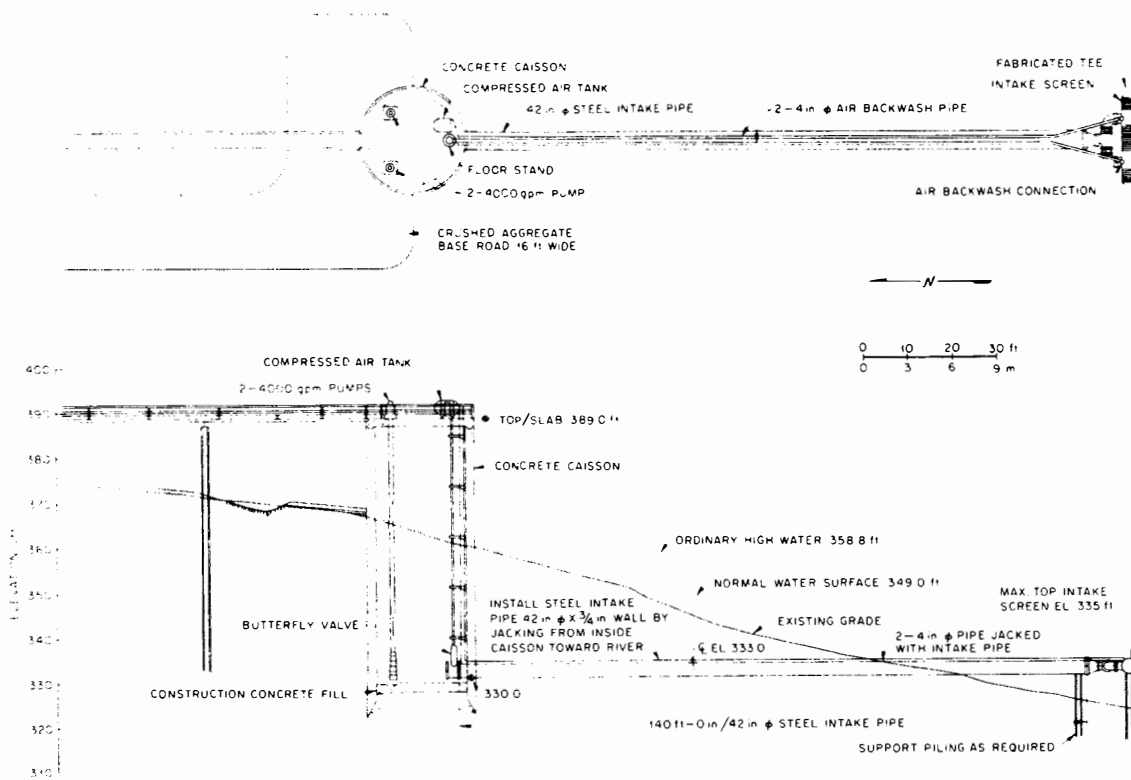


Fig. D.7. Submerged raw water intake device.

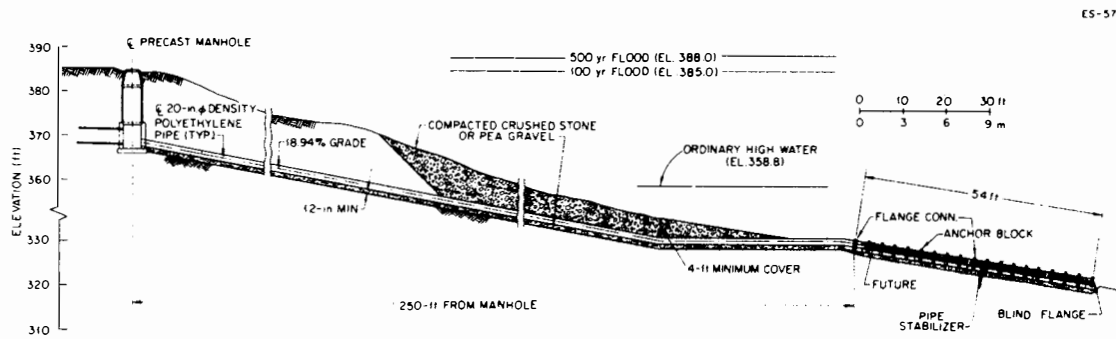


Fig. D.8. Proposed wastewater effluent river diffuser.

SRC solid product storage

The SRC solid product will be stored in an open-diked area before it is shipped. The area (illustrated in Fig. D.1) will be filled to above the 100-year flood level and will be equipped with an impermeable liner and rainwater collection and treatment system capable of handling major rainfall events.

Coal storage area

The open coal storage area (Fig. D.1), will necessitate encroachment in the 100-year floodplain. The open storage area will be filled to above the 100-year floodplain. The coal storage piles will have an internal surface water collection system. Collected water from the storage areas will be drained into the water reclamation system.

Temporary construction facilities

Construction of the demonstration facility will require many temporary storage and layout areas, roads, utility corridors, parking lots, and temporary shops and offices. As shown in Fig. D.1, many of these areas will be located in areas below the 100-year flood elevation, but at elevations above the most frequent flood events. These areas would not be used after the construction of the demonstration plant until the commercial expansion phase. The temporary areas will not be flood proofed from major flood events but will be graded to provide normal drainage and erosion control.

D.3.2 Floodplain effects

The construction of certain facilities within the 100- and 500-year floodplain of the overlapping Green River and Ohio River floodplains is unavoidable. The floodplain impacts of increased flood elevations due to site development and the concomitant loss of overbank flood storage are minimal. A floodwater profile impact determination was conducted by modeling the 100-year storm flood profiles before and after construction by using the U.S. Army Corps of Engineers standard HEC-2 computer program (Appendix E). Operation of the computer analysis was conducted by altering programmed variables and matching the Corps of Engineers 100-year flood profile along this study reach and then deleting the floodplain used for the SRC-I project. The analysis indicated that the construction of the facility would result in an increase of the height of the flood profile of about 0.25 in. immediately upstream of the facility. Based on these findings the increased flooding impacts resulting from constructing the SRC-I facility are considered to be negligible. The development of the river-dependent facilities will require encroachment in the floodplain of lesser flood events. The design of these facilities has included flood proofing the structures, with allowance for certain areas to be inundated. The development of the facility would not be expected to increase flooding of any upstream or downstream residences.

The loss of a small amount of floodplain storage is considered insignificant compared with the magnitude of floods that could affect the site. Surface drainage at the site will be carefully controlled to prevent ponding. Drainage from potentially contaminated areas will be collected, treated, and reused by the facility. Based on these design parameters, impacts from uncontrolled water runoff are not expected to reduce floodplain values in the Green River, Martin Creek, or the Richland Slough.

Secondary impacts due to the eventual commercialization at the site are not expected to materially change the levels of impacts as presented for the demonstration plant. The site has sufficient elevated areas above the 100-year floodplain to build the expanded facilities. The largest floodplain encroachment from the commercial development would be the expansion of the barge slip and product feed and waste storage areas.

D.3.3 Wetland effects

Wetlands in the United States have been classified by Shaw and Fredine.¹ Habitats (other than the Green River) on the site that may be considered wetlands under their classification include the bottomland forest along Martin Creek, Bryant Ditch, the Green River shoreline, and six

small ponds. Bryant Ditch and the Green River shoreline are low-quality wetlands. Bryant Ditch was originally an agricultural drainage ditch; it flows only intermittently and is not an important habitat for biota. The Green River shoreline is steep in most places on the site. This steep shoreline does not form any wetlands that are flooded or wet for periods of time long enough to be important to many species or to perform significant amounts of services usually associated with floodplains (i.e., groundwater recharge, sediment entrapment, and reduced flood levels). Because of the low quality of these two wetland habitats, their modification because of the SRC-I project will not have significant impacts.

The Martin Creek bottomland forest and the ponds are higher-quality wetland areas. The Martin Creek forest will not be affected by the SRC-I project. Five of the six small ponds will be eliminated. The total area of ponds to be eliminated is 0.6 ha (1.5 acres). About 0.1 to 0.2 ha of pond area will remain. Although these ponds support a wide variety of species, including aquatic biota, amphibious biota, and a few waterfowl, no information indicates that these ponds are in any way unique in comparison with ponds in general. Because of their small size, their importance as a regional resource is minimal. Considering all wetlands found on the site, the loss of wetlands and wetland values caused by the SRC-I project is minimal.

The change in land use at the site (from intensive agriculture to industrial development) would be expected to yield some wildlife and wetland benefits if the site is replanted for wildlife habitat improvement or allowed to go fallow and proceed through the stages of secondary succession with the creation of wetlands occurring as necessary surface drainage rearrangements are made. Minor site wetland and wildlife enhancement programs will provide some improvement in the site's habitat value. However, the net effect will be a loss of wildlife habitat and of potential for the area to support significant wildlife populations.

D.4 ALTERNATIVE ACTIONS AT THE PROPOSED SITE

Alternative actions at the proposed site include alternative layouts for plant facilities and alternative designs for plant facilities. These alternatives constitute environmental impact mitigation measures when they result in reduced impacts. This section describes facility layout and design alternatives, along with other potential environmental impact mitigation measures, which have been evaluated during the various phases of development of the proposed SRC-I demonstration plant.

D.4.1 Alternative site layout and design

The alternative layout designs considered that would possibly reduce floodplain/wetlands impacts are

1. locate the demonstration facility above the 100-year floodplain elevation,
2. raise the site to above the 500-year flood elevation,
3. raise the base of the ash and liquid storage areas above the 100-year flood elevation,
4. utilize adjacent land with higher elevations in Henderson County,
5. use an alternative docking arrangement, and
6. delete barge transportation from the project.

Locate the demonstration plant above the 100-year floodplain elevation

With the exception of the river-dependent facilities (i.e., intake and dock structures), it is feasible to utilize areas above the 100-year floodplain for the construction of the SRC-I demonstration plant. This alternative would necessitate locating all process and storage facilities for a future commercial plant within floodplain areas. Thus, this alternative represents only a short-term deferral of floodplain encroachment and is not considered to offer any long-range benefits relative to the proposed design. In addition, unsuitable load-bearing characteristics of the soil in certain areas above the 100-year floodplain make this alternative undesirable from an engineering standpoint.

Raise the site above the 500-year flood elevation

Although this alternative is feasible, it would cause a substantial delay in the project's completion and would result in substantial cost increases. To raise the base of the ash and liquid storage tanks alone would require the acquisition of 11 million yd³ of soil from an offsite location and would delay the project for about two years. Importing the soil would cost about \$33 million, and delay would escalate equipment costs.

With respect to floodplain encroachment, this alternative would have the same impacts as the proposed action, which includes diking to prevent inundation of plant facilities.

Raise the base of the ash and liquid storage areas above the 100-year flood elevation

This alternative would require less fill than for raising facilities above the 500-year flood elevation but would result in encroachment similar to the proposed diked design. The elevation of the ash and liquid tank bases might provide added flood security and environmental benefits. Consequently, this design alternative is being considered.

Utilize adjacent land with higher elevation in Henderson County

About 90 acres of flood-free agricultural land exists in Henderson County adjacent to the site. The feasibility of using this land is recognized for the commercial expansion phase. However, for the present, it has been concluded that the inclusion of this small area would result in program delays and would not materially change the floodplain/wetlands impacts of the proposed action. Based on these factors, this alternative has not been pursued. Adoption of this alternative would necessitate additional environmental monitoring work for groundwater and surface water hydrology, archaeology, terrestrial and aquatic ecology, noise, and land use. At a minimum, the monitoring work would require eight months. Additionally, this alternative would require a major plot plan rearrangement, which would cause a delay of up to 11 months.

Use an alternative docking arrangement

During the initial design, several possible dock arrangements were considered, including locating the dock at different locations along the shoreline in lieu of the proposed slip arrangement. The shoreline arrangements were rejected primarily because of navigational hazards and problems with the security of facilities. Because of the sharpness and narrowness of the river bends adjacent to the site, a shoreline arrangement would be likely to increase accidents that could result in spills of hazardous materials. The proposed barge slip facility utilizes the location that minimizes the amount of excavation; therefore, the environmental impacts associated with construction are minimized. Based on these factors, the proposed barge slip design is considered the most acceptable environmental design.

Delete barge transportation from the project

Because of limited capacities of railroads and highways, it would be impossible to ship bulky and heavy equipment to the site if this alternative is adopted. Although it is possible to fabricate the equipment on site, it would be extremely costly.

This alternative would also dramatically limit the flexibility of materials receipt and product shipping. After commercialization almost all the feed coal would probably be shipped by barge; thus, deleting the barge option would reduce the feasibility of commercialization at this site.

Furthermore, deletion of the barge facility would not significantly alter the impacts associated with floodplain encroachment. For the above reasons, this alternative was rejected.

D.4.2 Mitigation measures

The primary mitigation measures to reduce floodplain/wetlands impacts have been careful plant layout and alternative design analyses as previously discussed. The results of these analyses have been to minimize floodplain encroachments, to avoid significant offsite flooding impacts, and to reduce the amount of wetlands utilized to almost zero.

The management and construction of the facilities will be conducted in accordance with permit stipulations and sound engineering practices. Throughout the construction and operation phases, drainage and erosion control procedures will be followed to reduce ponding and sedimentation. Spoil from the dredging of Green River will be either utilized for fill (if the material is acceptable) or leveled and resealed at an upland site. There are sufficient buffers from the main construction area to preclude offsite sedimentation in excess of that which would be expected from normal agricultural practices.

Bryant Ditch will be rerouted around the liquid product and ash storage area and will maintain its function of providing site surface drainage. Spill collection, control, and treatment will be designed into the process, handling, and storage areas, and these facilities should preclude any potential spill impacts to Bryant Ditch, Green River, or to groundwater resources.

Flood protection will be designed into all floodplain structures to protect the facilities from flood waters and to protect the environment from facility failure and possible spill and leakage. Process areas will be raised to above the 500-year flood elevation by site grading and filling. The bases of the slag disposal and liquid tankage areas will be below the 100-year flood level and will be protected from flooding by normal diking procedures and other filled areas. During the wet season (late winter and spring) when groundwater levels naturally rise, high water table conditions accompanying flood events could cause flooding within the tankage area, and exert uplifting forces beneath the slag ponds. This could breach liners in the slag disposal landfills, providing a route for potentially hazardous substances to enter the groundwater. However, the likelihood of such an impact will be minimized by liner stabilization measures including a hold-down system to prevent failure under high groundwater conditions. Hazardous wastes will be stored as shown in Fig. D.9 in an area of the site naturally above the 500-year flood elevation (Fig. D.3). The transfer and storage of coal, products, and wastes will be conducted utilizing best control technology to avoid spillage, fugitive losses, drainage and leaching from the site. A surface water collection and control system will be designed to preclude discharge of untreated runoff from potentially contaminated areas. It is believed that these mitigation measures can provide the environmental security that a project of this nature and magnitude requires.

ES-5192

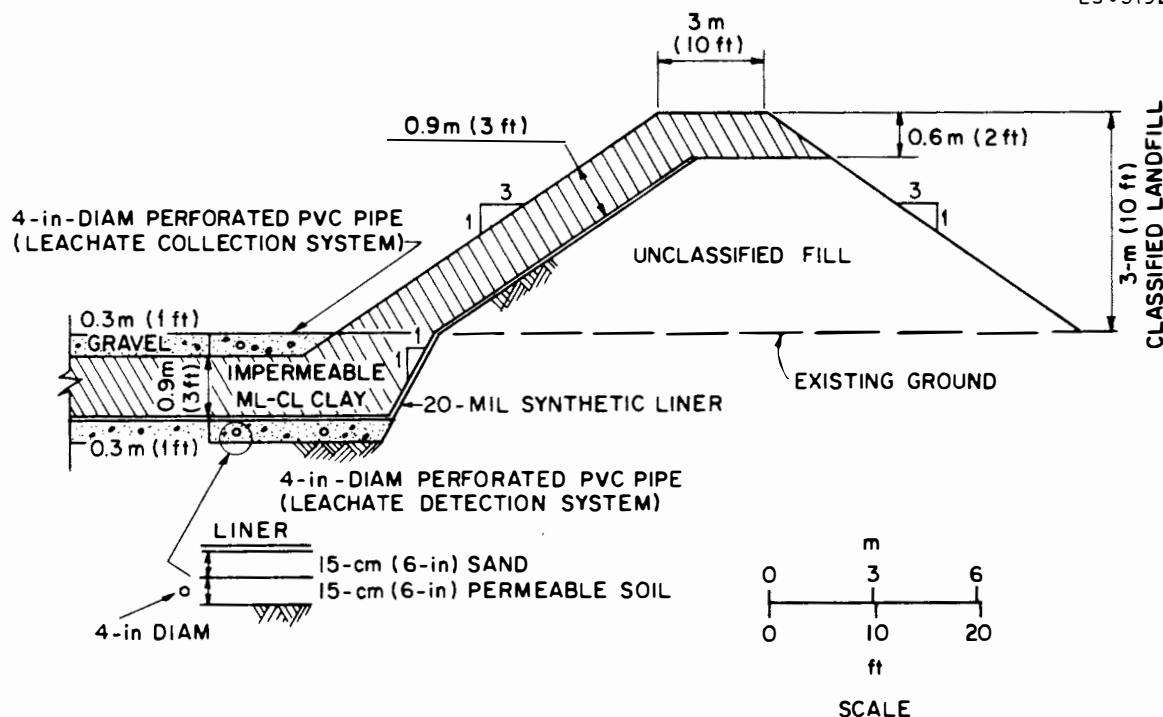


Fig. D.9. Cross-sectional diagram of the proposed hazardous waste landfill.

D.4.3 No action – no floodplain/wetlands encroachment

Encroachment on floodplain/wetlands areas at the Newman site cannot be avoided if the proposed SRC-I demonstration plant is constructed and operated there. The project's requirement for barge transportation, rail access of coal, and water withdrawals for plant use necessitate some degree of floodplain encroachment. The minor impacts expected at the Newman site can be eliminated only if the plant is not constructed and operated. The use of an alternative site would avoid impacts at the Newman site but would result in floodplain/wetlands encroachment at the alternative, as has been described previously in Sect. D.2.2. The only way to avoid floodplain/wetlands encroachment is to terminate the contract for this demonstration program – the no-action alternative.

If the decision is made to terminate the demonstration project, the opportunity to obtain the intended environmental, technical, and economic data on the SRC-I process at near-commercial scale would be greatly reduced. The proposed SRC-II demonstration program would provide information of a generic nature, such as hydrogen production via gasification; ash and slag disposal; pressure letdown; large-scale oxygen production; wastewater treatment; solid-liquid separation; and high-temperature and -pressure handling of hydrocarbon, hydrogen, and oxygen mixtures. However, the conceptual designs for each of the two SRC demonstration plants have unique features. Demonstration of both technologies would provide a valuable diversity of information and operating experience about alternative designs.

Demonstration plants are considered by DOE to be a factor in reducing scale-up risks (technical, financial, and environmental) from pilot plant to commercial facilities to a reasonable level. Since the SRC process is nearer to commercial readiness than any other direct coal liquefaction process, decisions that restrict or inhibit its path to commercial development may delay DOE's response to meeting national energy goals through the use of direct coal liquefaction technology. Also, in the absence of a synfuel industry producing clean-burning fuels, conventional coal utilization and its associated environmental impacts would likely continue.

On the other hand, commercial synfuel development may take place in the private sector, when economic conditions make it attractive. If commercialization takes place without the benefits of a demonstration program, it is likely that development would proceed in a less controlled manner, with large-scale technical and environmental problems solved during the operation of the plant rather than during the design of the plant.

REFERENCE FOR APPENDIX D

1. S. P. Shaw and C. G. Fredine, *Wetlands of the United States: Their Extent and Their Value to Waterfowl and Other Wildlife*, United States Fish and Wildlife Service, Circular 39, 1971.

Appendix E
IMPACTS ON FLOOD ELEVATION

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Appendix E

IMPACTS ON FLOOD ELEVATION

Newman site floodplain encroachment study

Flooding at the site could result from three different scenarios: (1) Green River flooding only, (2) backwater from the Ohio River at the mouth of the Green River causing increased water levels of the Green River at the site, and (3) Ohio River flooding at River Mile 769 encompassing the site area. For the first case, the 100-year flood of the Green River at the site has been calculated to be 382.5 ft. For the second case, review of flood elevations in the Ohio and Lower Green rivers has indicated that because simultaneous 100-year floods are unlikely, the Green River flood level of 382.5 ft would be reached. The third scenario would appear to be the worst case, or more conservative case, because the 100-year flood level on the Ohio River at River Mile 769 has been estimated to be 385 ft by the Corps of Engineers. Because the two rivers share a common four-mile wide floodplain at the site, the potential exists for the greatest flooding to result from overflow from the Ohio River.

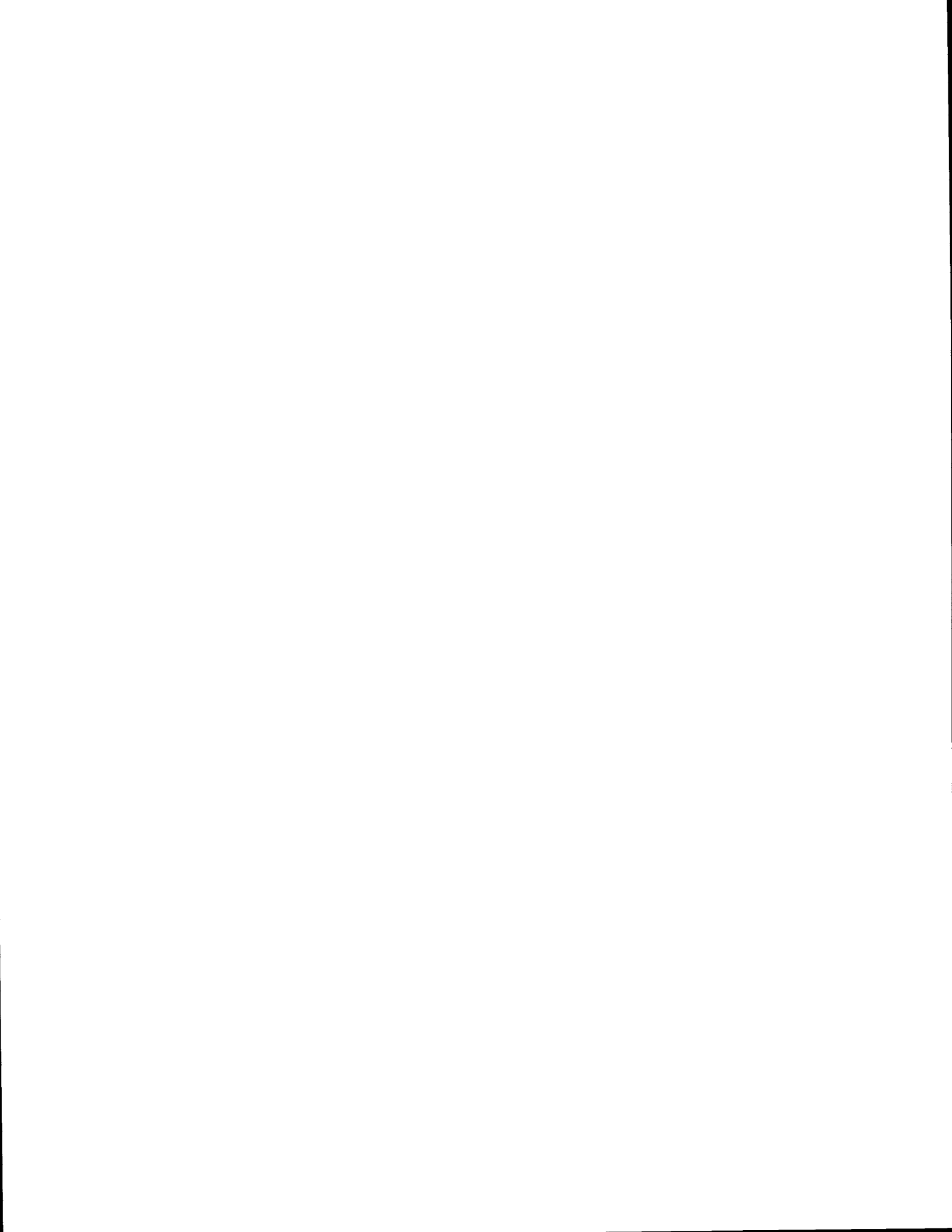
Assuming the latter scenario, an investigation was conducted to determine the increase in the 100-year flood elevation resulting from the proposed site development. The basic approach consisted of first developing and calibrating a backwater model for the 100-year flood under existing conditions and then modifying the model to reflect the presence of plant structures in the floodplain to determine their effect on the 100-year flood elevation.

The backwater model was developed by using the Corps of Engineer's HEC-2 computer program. In the vicinity of the site, the Ohio and Green rivers share a common floodplain. Cross sections were therefore developed across the common floodplain by using available USGS 7.5-minute topographic maps having a contour interval of 10 ft. Backwater computations were begun at River Mile 776, near Newburgh Dam, and were performed a distance of 8.4 miles upstream of the site. A total flow of 920,000 cfs, corresponding to the 100-year flood discharge on the Ohio River downstream of the Green River confluence, was used in the analysis.

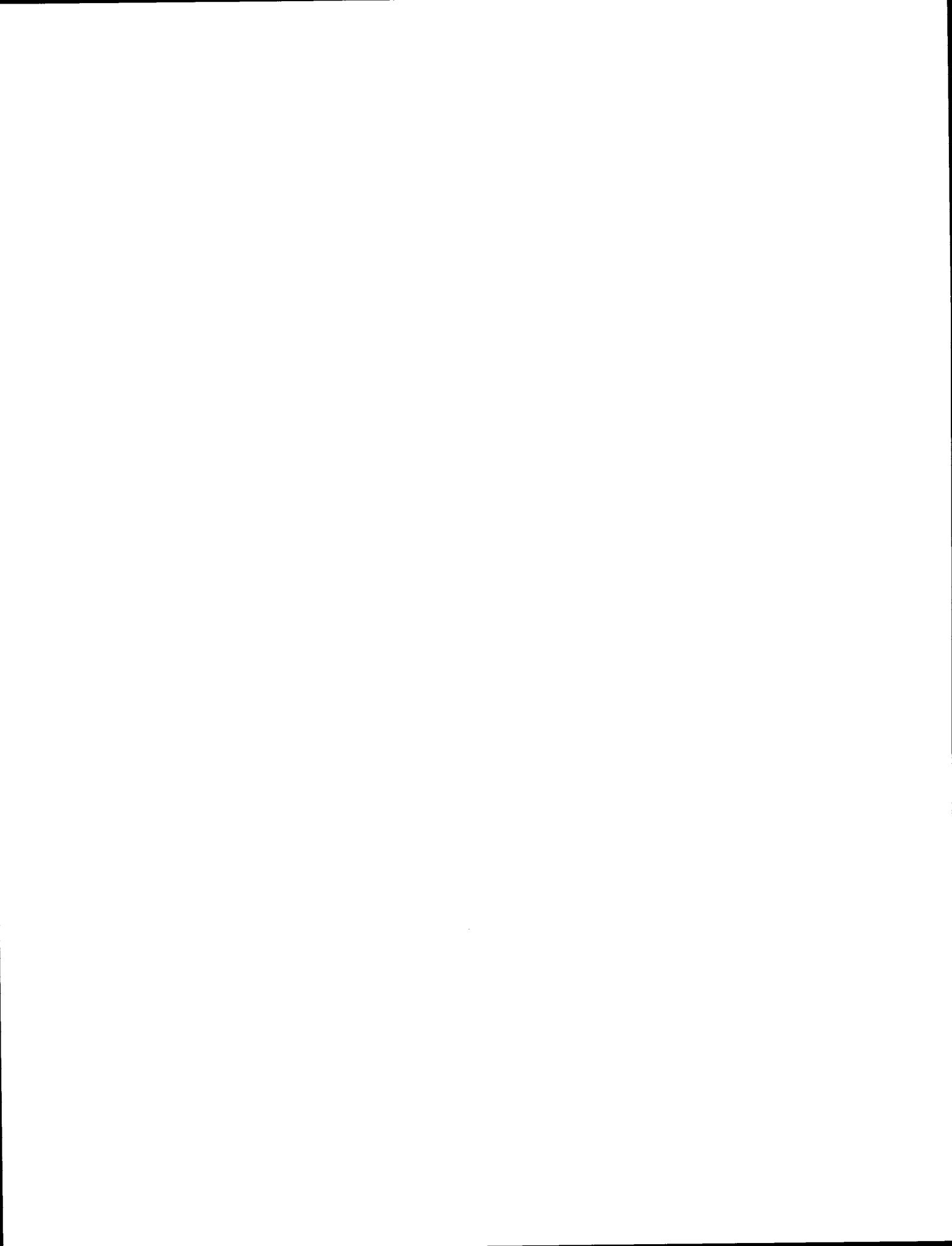
The backwater model for existing conditions was calibrated by the adjustment of Manning's n to reconstitute the Corps of Engineers' 100-year flood profile along the study reach. Calibration was achieved using values of Manning's n as equal to 0.03 for the channel and 0.07 for the overbank, which resulted in a computed 100-year flood elevation of 117 m (384.93 ft) at the site. This value agrees favorably with the Corp's 100-year flood elevation of approximately 117 m (385 ft).

The calibrated model was then used to determine the increase in the 100-year flood elevation resulting from plant development. Cross sections passing through the plant area were modified to reflect the presence of the proposed railroad embankment, dikes, and other plant structures. Backwater computations were then performed again, which resulted in a computed 100-year flood elevation of 384.95 ft at the site.

Based on this analysis, it was concluded that, because of the presence of plant structures, the 100-year flood elevation would be increased an average of 0.02 ft, or about 0.25 in., along the floodplain cross section immediately upstream of the plant area.



Appendix F
SURFACE WATER HYDROLOGY



Appendix F

SURFACE WATER HYDROLOGY

F.1 HYDROLOGY

The site is located near the confluence of the Green and Ohio Rivers at about river mile 19 of the Green River. The Green River watershed includes 23,040 sq km (8896 sq miles) of West-central Kentucky and 976 sq km (377 sq miles) of north central Tennessee. Major tributaries are the Barren, Nolin, Pond, and Rough rivers (Fig. F.1).

Figure F.2 shows the area inundated by the historical flood, the area inundated by a 5-year flood, and the Green River's floodway boundary. The floodway was determined by Dames & Moore using National Flood Insurance Agency methods from information provided by the U.S. Army Corps of Engineers (COE). As shown in Fig. F.1, the 100-year floodway of the Ohio River would not come anywhere near the proposed site on the Green River. The floodway boundary represents that F-3 point in the floodplain at which the water level is increased by 1 ft above the initial flood elevation as storage capacity in the floodplain is reduced. These boundaries are set by the National Flood Insurance Agency in conjunction with local communities to restrict development along waterways. If no floodway boundary map exists, as is the case for this area of the Green River, the floodway has not been legally defined. Appendix D has additional information about floodplains and wetlands.

The following sections provide specific descriptions of the surface water systems in the vicinity of the site (Fig. F.3).

F.1.1 Green River

The Green River, which forms the site's southern boundary from river mile (RM) 18.5 to 19.8, converges with the Ohio River about 21 km (13 miles) northwest of the site. The main stem of the Green River is navigable, with a pool maintained by a series of four locks and dams operated by the COE.

The Green River flows northwest past the site and then bends sharply to the south just past the site's western boundary. At the site, the Green River's navigable channel reaches a depth of about 3 m (9 ft); the river is approximately 61 m (200 ft) wide, with a pool normally maintained at elevation 106.4 m (349 ft) above mean sea level National Geodetic Vertical Datum, 1929 general adjustment (NGVD). This pool elevation is maintained by Lock and Dam No. 1, located 16 km (10 miles) downstream from the site.

In addition to the four locks and dams on the Green River, four reservoirs, one each on the Barren, Nolin, and Rough Rivers and one on the Green River main stem (Fig. F.1), help regulate flow in the basin.

The Green River gaging station closest to the site is near Lock 2, at Calhoun, Kentucky (RM 63.3). Flow data are available from 1930 to the present.

The regulated flow of the river below Lock 2 at Calhoun is 22.3 m³/s (400 cfs) (ref. 1). The predicted 7-d, 10-year low flow of the Green River at its confluence with the Ohio River is approximately 11.2 m³/s (394 cfs) (ref. 2). The lowest flow on record at Calhoun was 7.9 m³/s (280 cfs) in October 1930.

The maximum recorded discharge at Calhoun, 5890.6 m³/s (208,000 cfs), occurred on January 27, 1937, during the greatest flood recorded on the Green River (ref. 3). The flood of 1898 may have been greater, but no accurate records are available.

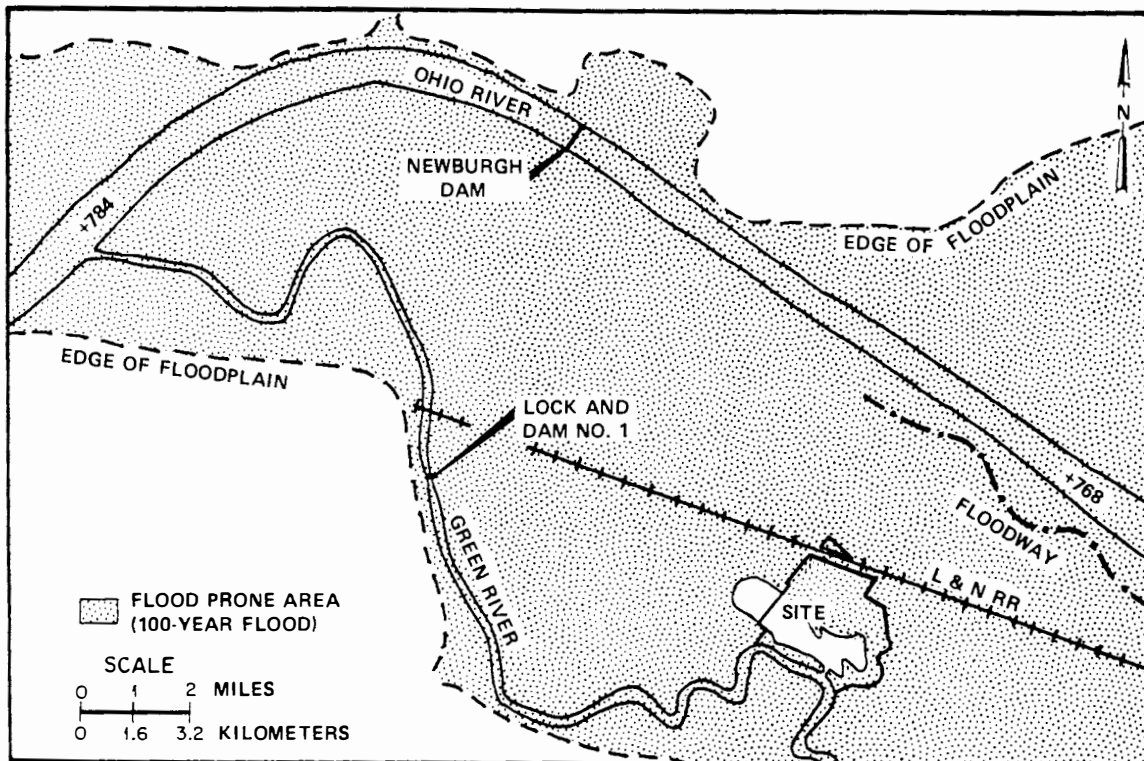
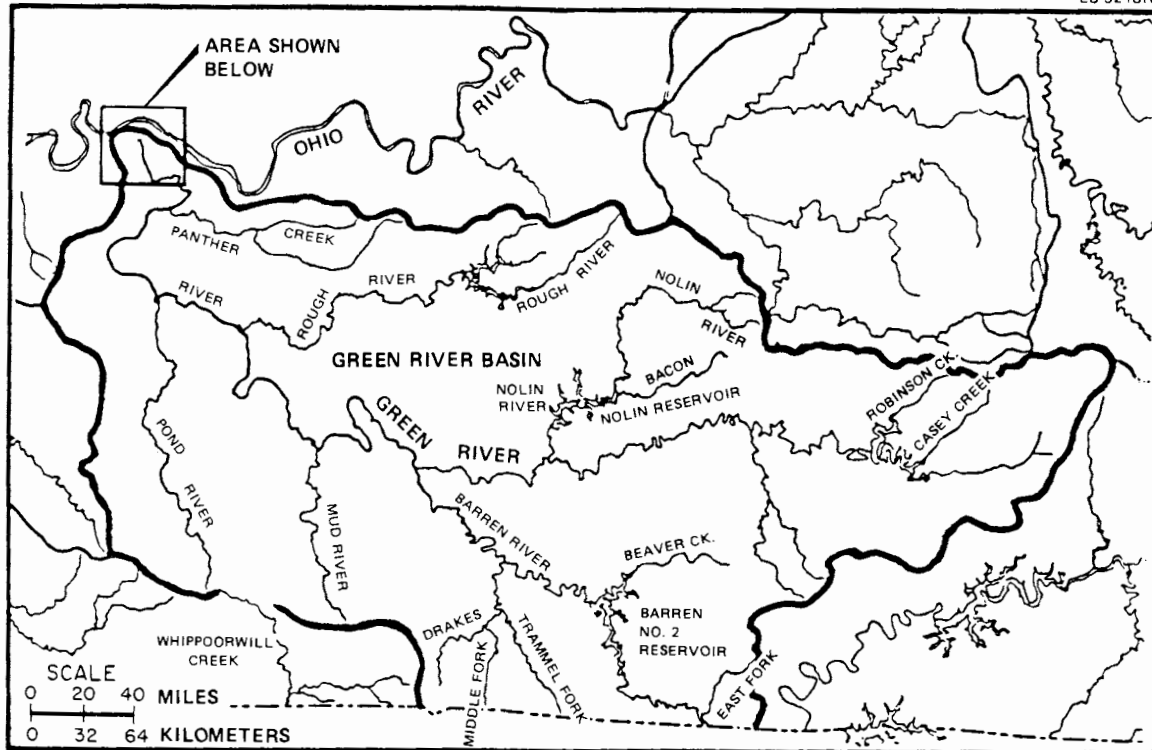


Fig. F.1. Major tributaries of the Green River (above) and the common floodplain of the Green River and the Ohio River.

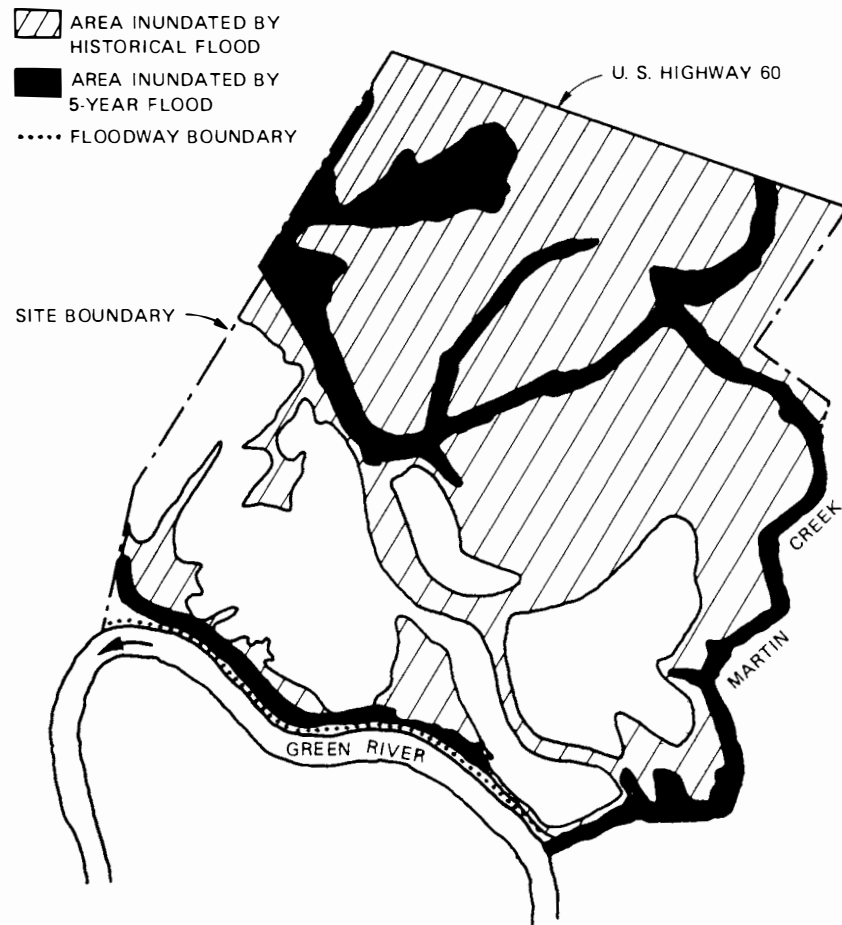


Fig. F.2. Areas of the site inundated by historical and 5-year floods.

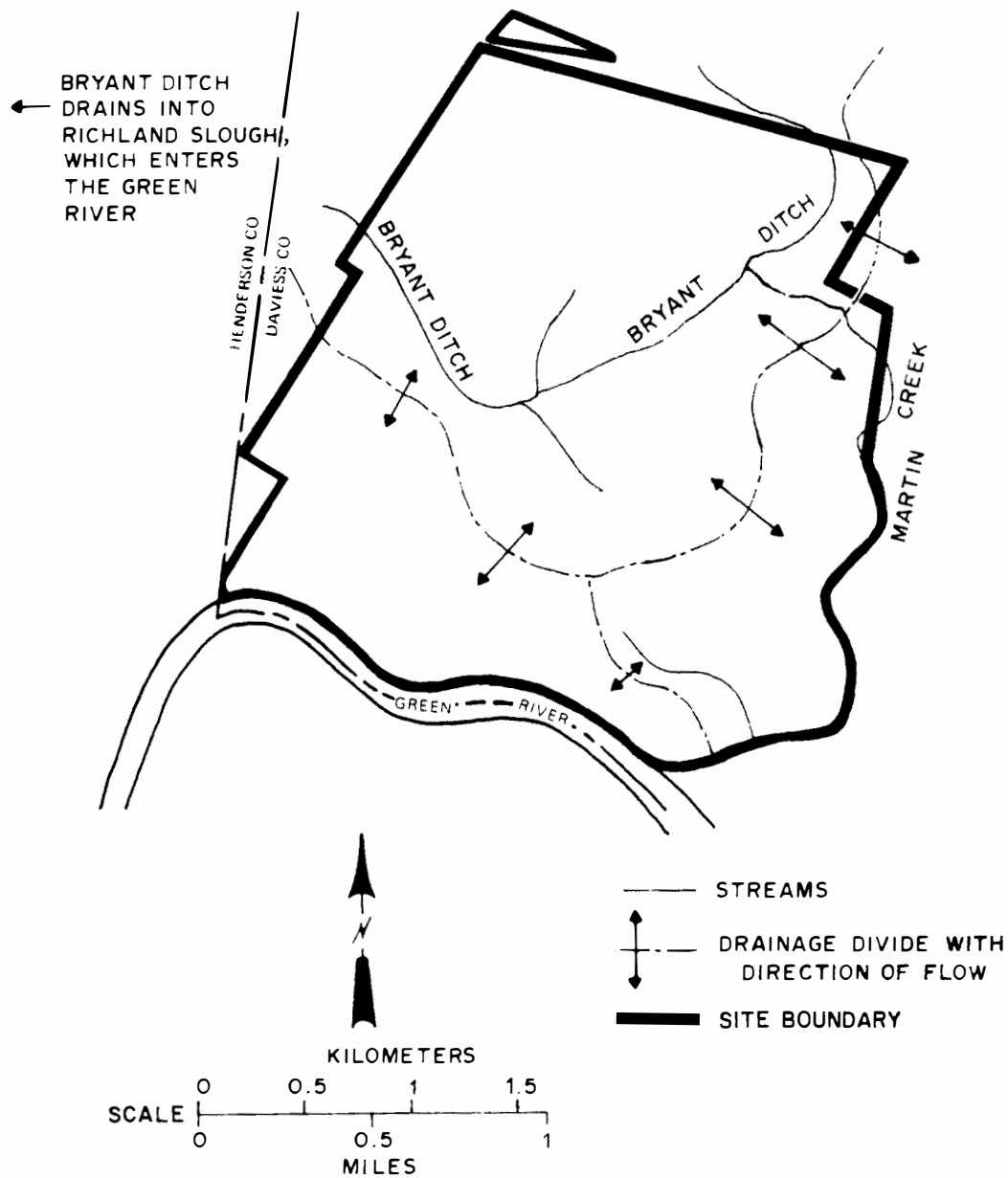


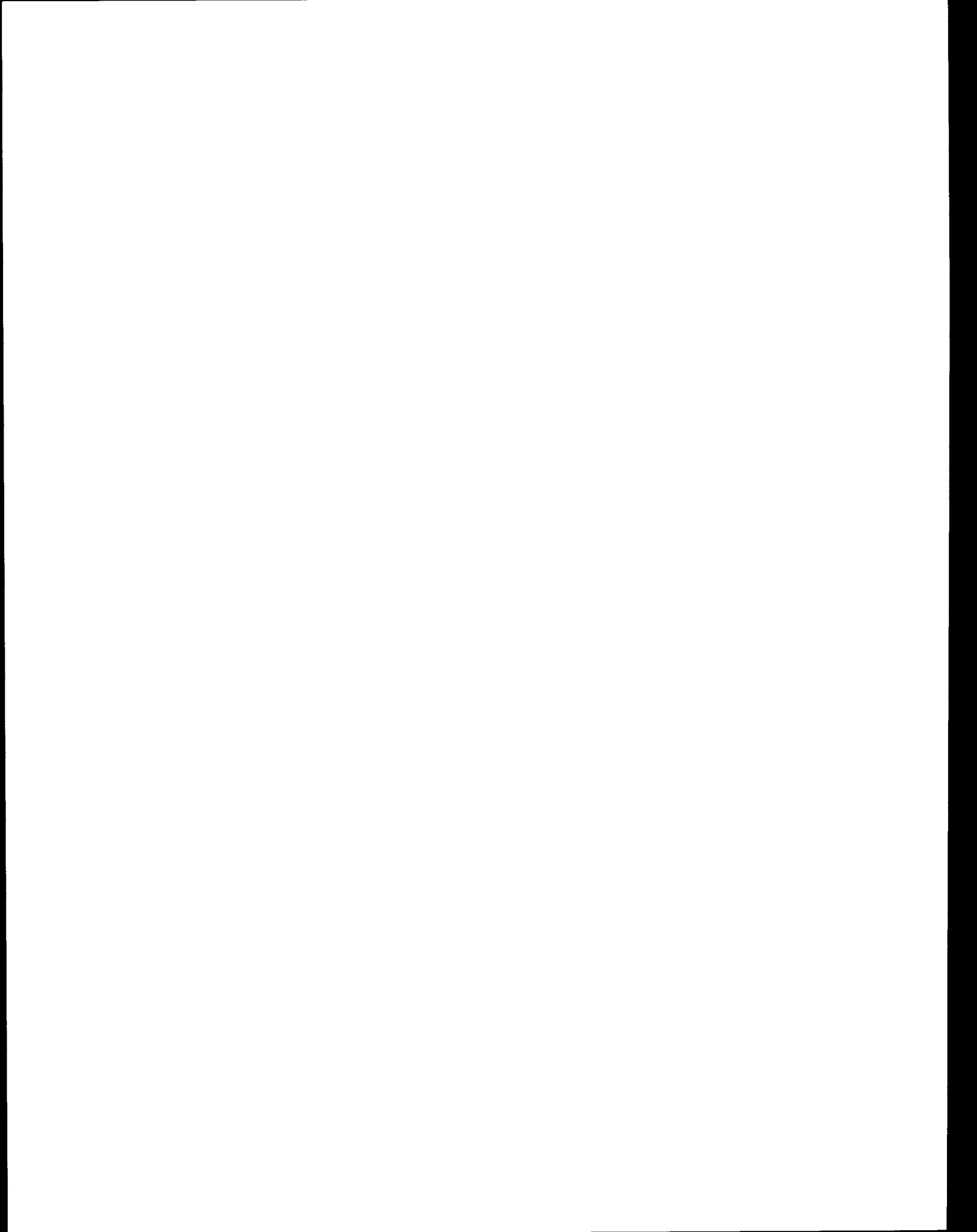
Fig. F.3. Surface water systems in the vicinity of the site.

The site is drained primarily by two shallow, intermittent streams (Fig. F.3). Martin Creek, which comprises the site's eastern boundary, drains surface water from the eastern half of the site. It flows directly to the Green River at RM 19.8. The western portion of the site is drained by Bryant Ditch, a man-made channel maintained by draglining. Except for an occasional pool, both creeks are usually dry during summer and fall. Bryant Ditch flows into Richland Slough about 2.5 km (3.1 miles) west of the site. The oxbow slough then flows about 5.8 km (3.6 miles) before emptying into the Green River at RM 15.4.

The six farm ponds onsite, 0.3 ha (1 acre) or less each, are probably recharged from precipitation via surface drainage (Fig. F.2). Pond P-1 is also periodically recharged by flooding of the Green River. The majority of water loss may result from seepage to the groundwater and from evaporation; however, no quantitative data are available on the site's recharge or water loss characteristics.

REFERENCES FOR APPENDIX F

1. B. Layman, U.S. Army Corps of Engineers, Louisville District, personal communication, 1977.
2. Department of Natural Resources and Environmental Protection, Division of Water Quality, *River Basin Water Quality Management Plan for Kentucky, vol. 3, Green River Basin*, Frankfort, Ky., 1975.
3. U.S. Geological Survey, *Water Resources Data for Kentucky*, annual reports for 1975-1979.



Appendix G

LETTER FROM THE CORPS OF ENGINEERS ON FLOOD ELEVATIONS



ORLED-HB

11

DEPARTMENT OF THE ARMY
LOUISVILLE DISTRICT CORPS OF ENGINEERS
P O BOX 59
LOUISVILLE KENTUCKY 40201

RECEIVED
APR 28 1980

Mr. Kap Sharma
SRC-1 Joint Venture
P.O. Box 538
Allentown, PA 18101

Dear Mr. Sharma:

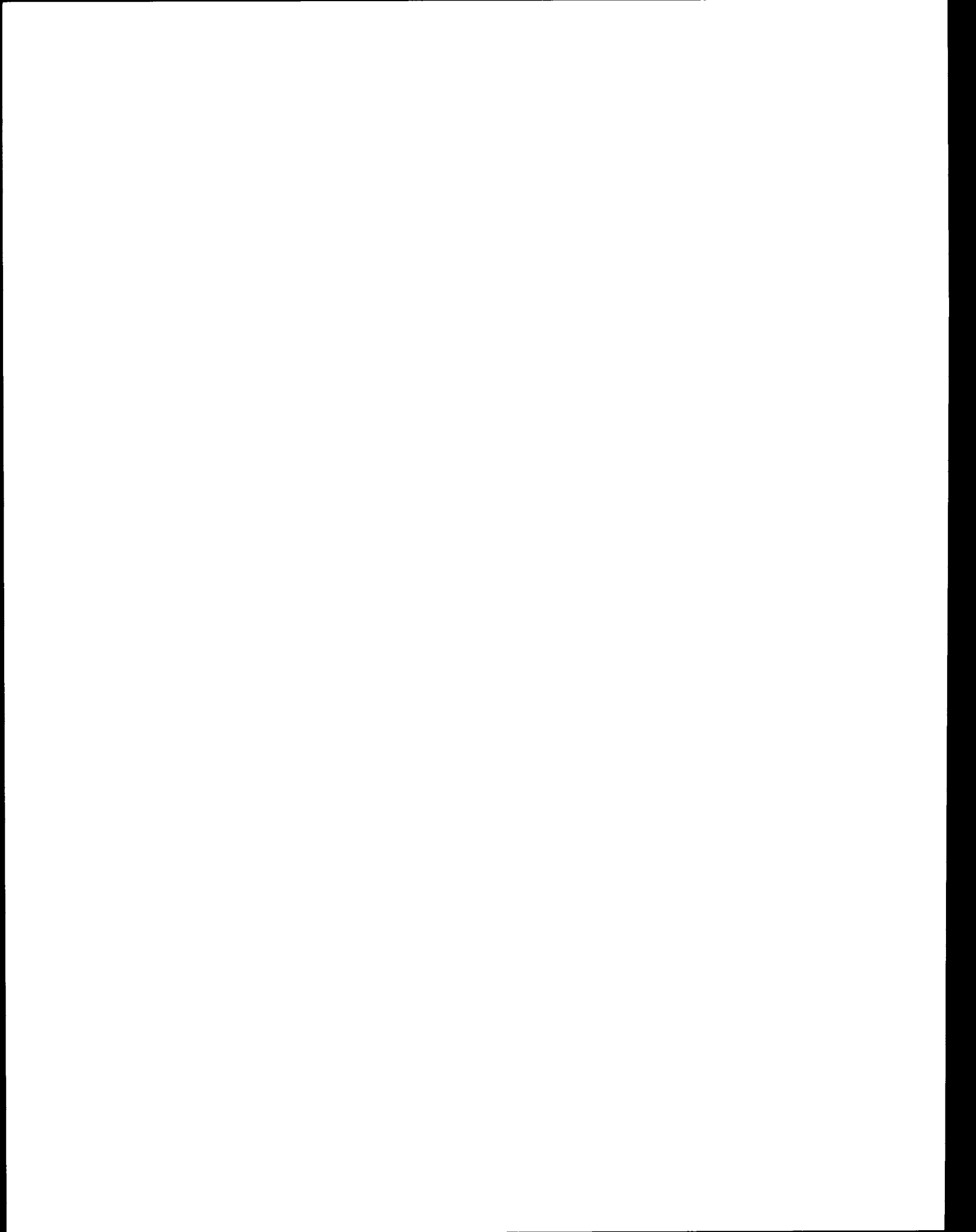
Mr. Mullins of this office discussed with Mr. Knauss the impact of the Ohio River floods of 100 and 500-year frequency of occurrence on the Green River at Mile 19. It is our judgment that the land between the rivers is low enough in elevation to be ineffective in separating the flooding between the two rivers. In the absence of any definitive study in the area, the Ohio River flood elevations of 385 and 388 (NGVD) at Mile 768 are recommended for use at Green River Mile 19.

The above information is believed commensurate with your request of 17 April 1980.

Sincerely,

A handwritten signature in dark ink, appearing to read "Noah M. Whittle", is written over the typed name.

NOAH M. WHITTLE
Chief, Engineering Division



Appendix H
SURFACE WATER QUALITY

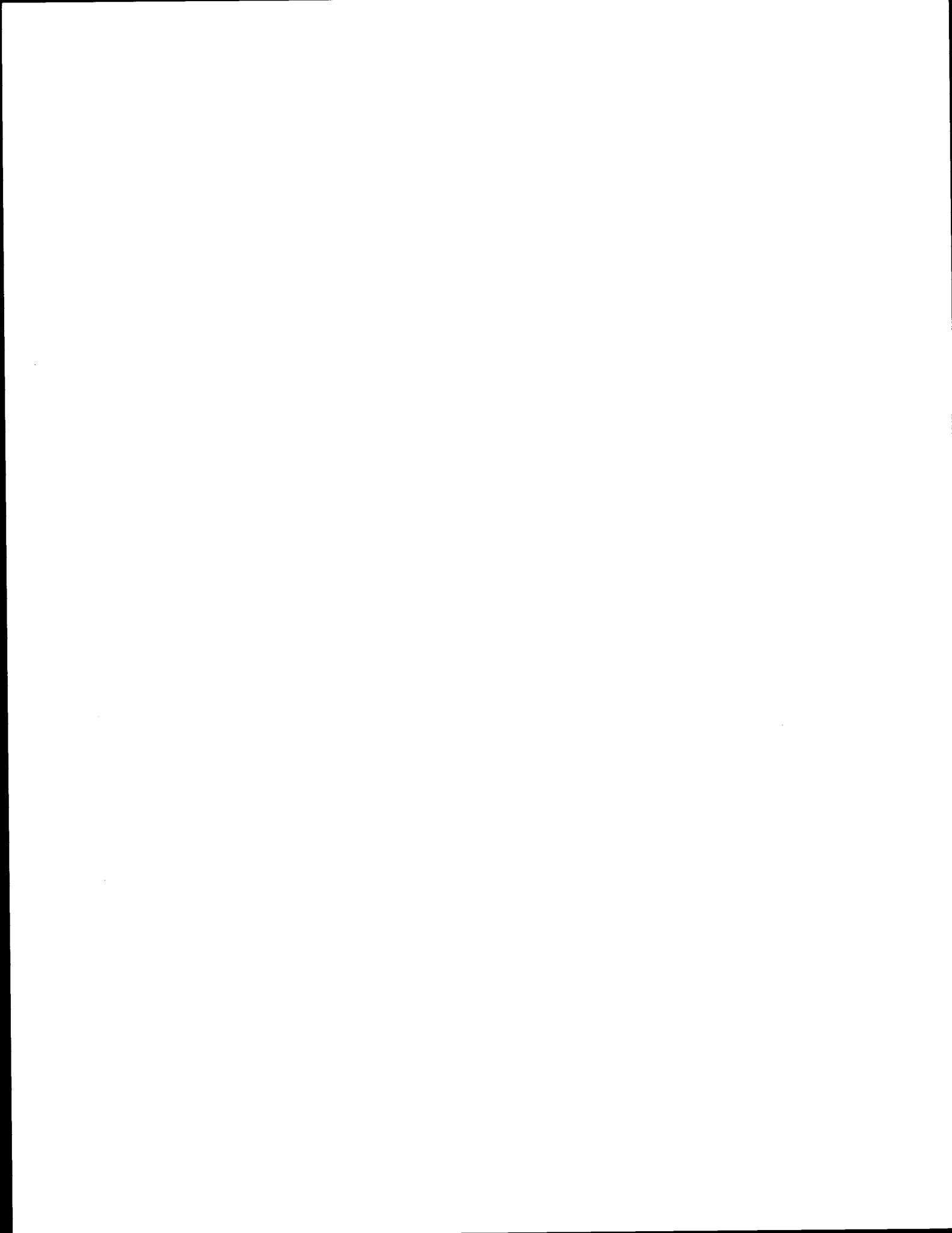


Table H.1. Water quality standards and criteria applicable to the Green River^a

Constituent	Kentucky water quality standard	Criterion ^b	Agency	Value protected ^c
Alkalinity	Greater than 20 mg/L	<i>d</i>	EPA	B
Ammonia, un-ionized	0.05 mg/L	0.02 mg/L	EPA	B
Arsenic	0.05 mg/L	<i>d</i>	EPA	B,D
Bacteria	Fecal coliform content during the recreation season shall not exceed 200 colonies per 100 mL as a monthly geometric mean, based on not less than five samples per month or 400 colonies 100 mL in more than 10% of sample taken during the month			R
Barium	1 mg/L	<i>d</i>	EPA	D
Beryllium	1.1 mg/L (hard water)	<i>d</i>	EPA	B
Cadmium	0.012 mg/L (hard water)	24-h average $\exp(1.05[\ln h] - 8.53)$, maximum $\exp(1.05[\ln h] - 3.73)$	EPA-T	B
Chloride	250 mg/L	<i>d</i>	ORSANCO	D
Chlorine, total residual	0.01 mg/L	<i>d</i>	EPA	B
Chromium, hexavalent	0.368 mg/L (B)	24-h average 0.29 $\mu\text{g/L}$, maximum 21 $\mu\text{g/L}$	EPA-T	B
Chromium, total	0.05 mg/L			
Copper, total	1 mg/L (D), 0.0034 mg/L (B)	24-h average 5.8 $\mu\text{g/L}$, maximum $\exp(0.94[\ln h] + 3.48)$	EPA-T	D,B
Cyanide, free	0.005 mg/L	24-h average 5.8 $\mu\text{g/L}$, maximum 52 $\mu\text{g/L}$		B
Fluoride	1 mg/L	<i>d</i>	ORSANCO	D
Hydrogen sulfide undissociated	0.002 mg/L	<i>d</i>	EPA	B
Iron, total	1 mg/L	0.3 mg/L	EPA	B,D
Lead, total	0.05 mg/L (D), 0.046 mg/L (B)	24-h average $\exp(2.35[\ln h] - 9.48)$, maximum $\exp(1.22[\ln h] - 0.47)$	EPA-T	D,B
Manganese	0.05 mg/L (D), 0.082 mg/L (B)	<i>d</i>	EPA	D,B
Mercury	0.002 mg/L (D), 0.0016 mg/L (B)	24-h average 0.00057 $\mu\text{g/L}$, maximum 0.0017 $\mu\text{g/L}$	EPA-T	D,B
Mixing zones	Defined on a case-by-case basis ^e			
Nickel	0.183 mg/L (B)	24-h average $\exp(0.76[\ln h] + 1.06)$, maximum $\exp(0.76[\ln h] + 4.02)$	EPA-T	D,B
Nitrate	10 mg/L	<i>d</i>	ORSANCO	D
Oil and grease	Virtually free from all oil and grease, particularly from associated tastes and odors	<i>d</i>	EPA	D
Oxygen, dissolved	Daily average of 5.0 mg/L; not to be less than 4.0 mg/L at any time	<i>d</i>	ORSANCO	B

Table H.1. Water quality standards and criteria applicable to the Green River^a
(Continued)

Constituent	Kentucky water quality standard	Criterion ^b	Agency	Value protected ^c
pH	6-9 units	6.5-9 units	EPA	B
Phenol	0.005 mg/L	0.001 mg/L	EPA	B
Selenium	0.01 mg/L (D), 0.031 mg/L (B)	24-h average 35 µg/L, maximum 260 µg/L	EPA-T	D,B
Silver	0.05 mg/L (D), 0.00044 mg/L (B)	<i>d</i>	EPA	D
Solids, total dissolved	750 mg/L	Daily 500 mg/L, maximum 750 mg/L	ORSANCO	D
Solids, total suspended	Shall not be changed to the extent that indigenous aquatic community is adversely affected			B
Sulfate	250 mg/L	<i>d</i>	EPA	D
Temperature	Not to exceed 31.7°C at any time ^f			B
Toxics, noncumulative and nonpersistent materials	Instream concentration shall not exceed 0.1 of the 96-h median lethal concentration (LC50) of a representative indigenous aquatic organism			B
Other substances	Instream concentration shall not exceed 0.1 of the 96-h median lethal concentration (LC50) of a representative indigenous aquatic organism			
Vanadium	0.046 mg/L (B)	0.1 mg/L (A)		B,A
Zinc	5 mg/L (D), 0.134 mg/L (B)	24-h average 47 µg/L, maximum exp(0.83 [ln h] + 1.95)	EPA-T	D,B

^aUnless otherwise specified, standards and criteria are expressed as concentrations not to be exceeded.

^bCriteria may be indicated as a function of hardness (h).

^c"B" denotes water quality criteria for the protection of freshwater biota; "D" denotes criteria for the protection of domestic water supplies; "R" denotes criteria for the protection of recreational waters; and "A" denotes criteria for the protection of agricultural supplies. These same letters are used to denote the same meaning in other columns of this table.

^dSame.

^eThe mixing zones (1) shall be free of all pollutants that are in excess of median lethal concentration (LC50) for a representative indigenous aquatic organism; (2) shall not interfere with spawning areas, nursery areas, fish migration routes, public water supply intakes, or bathing areas, or preclude the free passage of fish or other aquatic life; (3) whenever possible, shall not exceed one-third of the width or cross-sectional area of the receiving stream, and, in no case, shall exceed one-half of this volume; and (4) in all cases, must be limited to an area or volume that will not adversely alter the legitimate uses of the receiving water, or adversely affect an established community of aquatic organisms.

^fAlso, (1) the normal daily and seasonal temperature fluctuations that existed before the addition of heat from other than natural causes shall be maintained; (2) the maximum temperature rise other than the effects of a mixing zone shall not exceed the natural temperature by 2.8°C, with a maximum rate of change not to exceed 1°C per h; and (3) water temperature for all surface waters should not exceed these maximum limits: January and February, 10°C; March, 15.6°C; April, 21.1°C; May, 26.7°C; June, 30.6°C; July and August, 21.7°C; September, 30.6°C; October, 25.6°C; November, 21.1°C; and December, 13.9°C.

Sources: Kentucky Department of Natural Resources and Environmental Protection, *Surface Water Standards*, Report 401 KAR 5:031, Frankfort, Ky., December 1979; Ohio River Valley Water Sanitation Commission, *Ohio River Main Stem, Assessment of 1977 and Future Water Quality Conditions*, Cincinnati, March 1978, pp. 145-148; U.S. Environmental Protection Agency, *Quality Criteria for Water*, Report 440/9-76-023, Washington, D.C., July 1976; and U.S. Environmental Protection Agency, "Water Quality Criteria Documents, Available (Criteria for Toxic Substances)," *Fed. Regist.*, November 28, 1980, pp. 79318-79379.

Table H.2. Water quality data for the Green River Lock and Dam No. 1, at RM 9.1

Period of record—October 1956 to August 1974

Parameter	Values ^a			No. of samples
	Mean	Maximum	Minimum	
Alkalinity, total, as CaCO ₃	79	119	44	39
Aluminum, total, µg/liter	0.1	0.1	0.1	2
Bicarbonate	97	170	54	143
Calcium, dissolved	36	62	18	127
Chloride, dissolved	24	254	2.5	143
Color, PCV	7	50	1	119
Fluoride, dissolved	0.1	0.5	0.0	122
Hardness, total, as CaCO ₃	124	225	58	143
Iron, total, µg/liter	370	1300	0	71
Magnesium, dissolved	7.7	18	3.0	127
Manganese, total, µg/liter	180	550	0	81
Nitrate, total	1.4	2.0	1.0	3
pH, units	7.3	8.1	6.8	106
Phosphate	0.14	0.48	0.01	42
Potassium, dissolved	1.6	4.1	0.3	125
Silica, dissolved	9.0	17	4.9	132
Sodium, dissolved	16	132	2.0	127
Sulfate, dissolved	40	107	10	143
Temperature, °C	16.7	31.0	4.0	38
Total dissolved solids	190	572	88	140

^a Values expressed in mg/liter unless otherwise noted.

Source: U.S. Department of the Interior, Geological Survey, 1956–1974 (ER, Appendix E, Table E.3).

Table H.3. Water quality data for the Green River near Sebree, Kentucky, at RM 41.3

Period of record—November 1975 to June 1979

Parameter	Values ^a			No. of samples	Sampling Period	
	Mean ^b	Maximum	Minimum		Start	End
Acidity, total	0	0	0	11	11/5/75	6/6/79
Alkalinity	75.9	103	45	11	11/5/75	2/24/76
Ammonia, N	0.15	<10	0.01	91	11/5/75	6/6/79
Arsenic, total, µg/liter		47		12	12/3/75	10/19/78
Bacteria						
Fecal coliform per 100 ml	375.7	3,900	0	78	11/14/75	10/19/78
Total coliform per 100 ml	1,815.5	20,000	0	71	11/14/75	10/19/78
Barium, total, µg/liter		300	0	34	11/5/75	10/19/78
Biochemical oxygen demand (BOD)	2.0	4.4	0.1	37	11/14/75	10/19/78
Cadmium, total, µg/liter		7	0	39	11/14/75	6/6/79
Calcium, total	43.28	125.0	24.0	77	11/5/75	11/13/78
Chemical oxygen demand (COD)	11.33	22.00	<4.00	6	1/18/79	6/6/79
Chloride, total	5.6	9	2.8	11	11/5/75	2/24/76
Chromium, total, µg/liter		30	0	33	11/5/75	10/19/78
Cobalt, total, µg/liter		30	3	19	11/5/75	2/24/76
Copper, total, µg/liter		80	2	22	7/11/77	6/6/79
Cyanide, total		<10	0	86	11/5/75	6/6/79
Flow, ft ³ /s	30,850	42,400	9,800	6	1/18/79	6/6/79
Fluoride, total	0.27	0.9	0	11	11/5/75	2/24/79
Hardness, total	113.6	270	8	35	11/5/75	6/6/79
Iron, total, µg/liter	3,254.6	3,280	90	41	11/5/75	6/6/79
Lead, total, µg/liter		75	0	44	11/5/75	6/6/79
Magnesium, total	9.8	17	4.9	78	11/5/75	4/2/79
Manganese, total, µg/liter	381.7	1,700	110	35	11/5/75	4/2/79
Mercury, total, µg/liter		22.5	0	45	11/5/75	6/6/79
Nickel, total, µg/liter		<100	6	33	11/5/75	10/19/78
Nitrate, total ^c	0.82	1.24	0.33	78	11/5/75	6/6/79
Nitrogen, Kjeldahl	0.50	2.9	<0.1	89	11/5/75	6/6/79
Oxygen, dissolved	9.9	15.0	6.4	50	11/5/75	6/6/79
pH, units	7.4	8.3	6.6	31	6/28/76	6/6/79
Phenol, µg/liter		17	0	88	11/5/75	6/6/79
Phosphate, dissolved	0.013	0.03	0	11	11/5/75	5/26/77
Phosphorus, total	0.19	1.48	0.02	87	11/5/75	6/6/79
Potassium, total	1.9	2.9	1.5	11	11/5/75	5/26/77
Selenium, total, µg/liter		<10	0	12	12/3/75	10/19/78
Silica, dissolved	5.93	6.7	5	11	12/3/75	4/6/77
Silver, total, µg/liter		<30	0	21	11/5/75	10/19/78
Sodium, total	7.6	17	4	39	11/5/75	11/13/78
Specific conductance, µmhos	286.1	513	149	52	11/5/75	6/6/79
Sulfate, total	58.8	260	26	84	11/5/75	6/6/79
Solids, total dissolved	195.4	476	118	80	11/5/75	6/6/79
Solids, total suspended	77.3	492	10	87	11/5/75	6/6/79
Temperature, °C	15.3	26.1	0	52	11/5/79	6/6/79
Total organic carbon	4.73	11	2.6	11	11/5/75	5/26/77
Un-ionized ammonia	0.0017	0.003	0.001	6	1/18/79	6/6/79
Zinc, total, µg/liter	39.6	260	<10	46	11/5/75	6/6/79

^a Measurements are given in milligrams per liter (mg/liter) unless otherwise noted.^b Data reported in "less than" figures prevented computation of mean values.^c All values starting with 1/10/78 are based on Nitrate and Nitrite.

Source: Ohio River Valley Water Sanitation Commission, "Water Quality Data from Sebree, Kentucky," ORSANCO Quality Monitor, 1975–1979 (ER, Appendix E, Table E.4).

Table H.4. Water quality data for the Green River near Beech Grove, Kentucky, at RM 49.1

Period of record—October 1974 to July 1979

Parameter	Values ^a			No. of samples
	Mean	Maximum	Minimum	
Alkalinity, as CaCO ₃	78	110	45	53
Ammonia, N	0.04	0.15		19
Arsenic, total, µg/liter	1.00	6.00	0.0	18
Barium, total, µg/liter	6.00	100.00	0.0	6
Bicarbonate, HCO ₃	97	130	61	41
Cadmium, total, µg/liter	1.00	8.00	0.0	17
Calcium, dissolved	39	60	24	53
Chloride, dissolved	6.3	14	2.9	54
Chromium, total, µg/liter	15.00	40.00	0.0	19
Cobalt, total	0.001	0.011	0.0	19
Coliform bacteria, fecal, per 100 ml	300	2,500	22	28
Copper, total	0.009	0.035	0.003	19
Fluoride, dissolved	0.1	0.4	0.0	54
Hardness as CaCO ₃	136	220	80	53
Iron, total, µg/liter	3,322	12,000	100	19
Kjeldahl nitrogen	0.43	1.2	0.16	54
Lead, total, µg/liter	18.00	41.00	5.00	18
Magnesium, dissolved	9.0	17	4.2	53
Manganese, total, µg/liter	326.00	840.00	70.00	19
Mercury, total, µg/liter	0.20	0.50	0.0	18
Oxygen, dissolved	7.1	8.2	0.0	8
pH, units	7.2	8.5	6.0	51
Phosphate	0.14	0.15	0.12	3
Potassium, dissolved	2.4	11	1.4	53
Selenium, total, µg/liter	0.0	1.00	0.0	18
Silica, dissolved	5.5	7.4	3.4	54
Silver, total, µg/liter	0.0	1.00	0.0	6
Sodium, dissolved	6.5	15	2.4	53
Sulfate, dissolved	55	120	16	54
Temperature, °C	17.4	30.0	2.0	56
Total dissolved solids	192	319	104	54
Total organic carbon	4.9	11	0.0	24
Turbidity, JTU ^b	35	270	2	52
Zinc, total	0.038	0.07	0.01	19

^a Values expressed in milligrams per liter (mg/l) unless otherwise indicated.^b JTU — Jackson Turbidity Units.

Source: U.S. Department of the Interior, Geological Survey, 1975–1979, (ER, Appendix E, Table E.5).

Table H.5. Average trace element concentrations^a in geologic formations

Element	Shale ^b	Limestone ^b	Western Ky. ^c Coal	Ky. No. 9 Coal ^d
Arsenic	13	1	7	9.05
Beryllium	3	<1	1.4	
Boron	100	20	70	
Cadmium	0.3	0.035		0.166
Chromium	90	11	18	0.724
Copper	45	4	8.8	
Iron				9,850
Lead	20	9	6.4	0.012
Manganese	850	1,100	19	
Mercury	0.4	0.04		0.0002
Nickel	68	20	16	
Selenium	0.6	0.08	3.1	0.829
Vanadium	130	20	32	
Zinc	95	20	48	

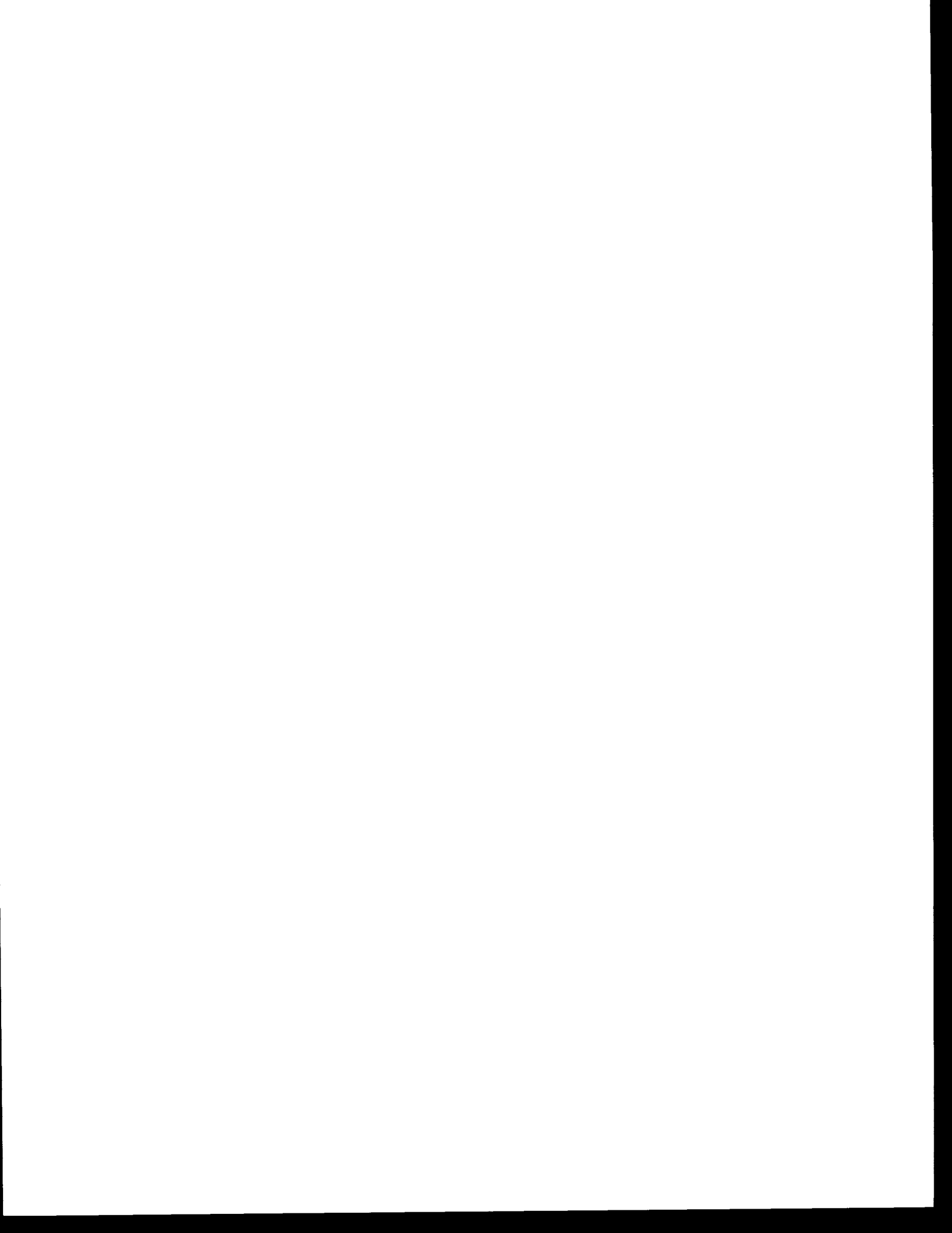
^aConcentrations given as parts per million (ppm).^bShale and limestone values are national mean composites.^cAverage values for western Kentucky coal.^dLeachate concentrations taken from ER, Table Q.3, Appendix Q.

Source: Data from U.S. Department of the Interior, Fish and Wildlife Service, March 1978 (ER, Appendix E, Table E. 16).

**Table H.6. Estimated area disturbed by construction
in and near the Green River**

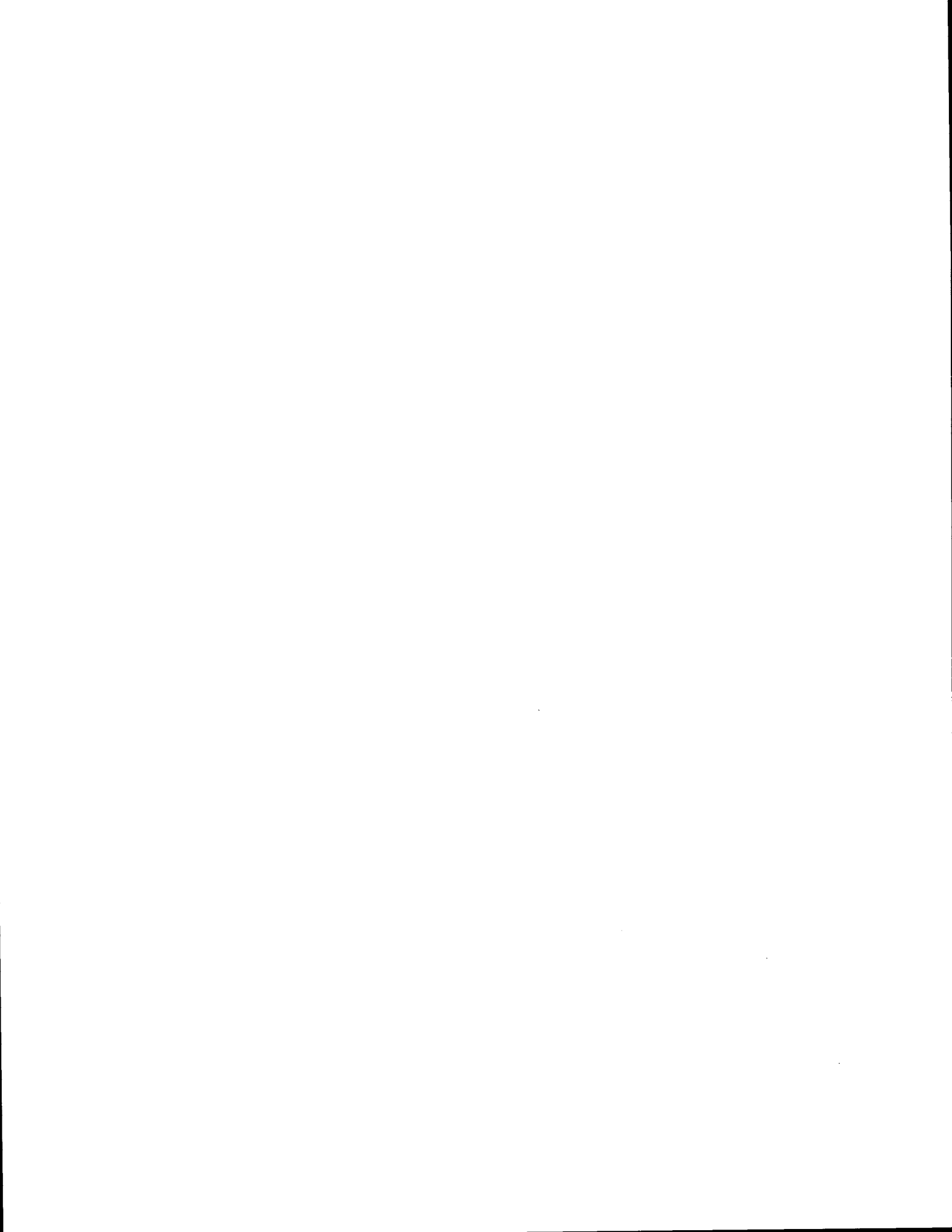
Facility	Area disturbed (m ²)	
	River bottom	Riparian habitat
Water intake structure	192	120
Effluent diffuser	120	60
First stage barge slip (demo plant)	3300	16000
Expanded barge slip (commercial plant)	3300	17000

Source: Appendixes C and Y.



Appendix I

U.S. DEPARTMENT OF ENERGY-U.S. FISH AND
WILDLIFE SERVICE CORRESPONDENCE





Department of Energy
Oak Ridge Operations
P.O. Box E
Oak Ridge, Tennessee 37830

April 9, 1980

Mr. Kenneth E. Black
Regional Director
U. S. Fish & Wildlife Service,
Southeast Region
Federal Building
75 Spring Street, S.W.
Atlanta, GA 30303

Dear Mr. Black:

SRC-I - ENVIRONMENTAL IMPACT STATEMENT

The U. S. Department of Energy (DOE) is preparing an Environmental Impact Statement on the proposed construction and operation of a Solvent Refined Coal (SRC-I) Demonstration Plant near Newman, KY. During the preparation of the Environmental Report, the industrial partner of DOE, Southern Company Services, has contacted the U. S. Fish & Wildlife Service and other agencies, and has made an assessment of the potential impact the proposed facility would have on endangered or threatened species and on critical habitat for such species.

In compliance with Section 7(c) of the Endangered Species Act, Amendments of 1978 (P.L. 95-362, November 10, 1978), the Department of Energy requests that you provide any information available to the Fish and Wildlife Service regarding: 1) the presence of any listed or proposed to be listed endangered or threatened species in the area of the proposed project, 2) the presence of any critical habitat for a listed or proposed species, or 3) any potential impact of the proposed project on such species. To assist in your review, copies of appropriate sections of the Environmental Report and a map showing the location of the proposed site are enclosed.

Preparation of the Environmental Impact Statement is critical to the project schedule and receipt of your response by May 15, 1980, would be greatly appreciated. If you cannot respond by this date, please advise me as soon as possible of the expected date of your response.

If you or your staff have questions regarding this matter, please contact me or James Reafsnnyder at (615) 576-1055.

Sincerely,


John F. Pearson, Jr.
Assistant Manager for Solvent
Refined Coal Projects

MS:331:RCM

Enclosures:
As stated

cc: L. M. Joseph, DOE/FE-40, w/o encl.



United States Department of the Interior

FISH AND WILDLIFE SERVICE

ROOM 279, FEDERAL BUILDING
ASHEVILLE, NORTH CAROLINA 28801

June 17, 1980

Mr. John F. Pearson, Jr.
Department of Energy
Oak Ridge Operations
P.O. Box E
Oak Ridge, Tennessee 37830

Re: 4-2-80-A-192

Dear Mr. Pearson:

We have reviewed the proposed construction of a solvent refined coal demonstration plant in Daviess County, Kentucky, as requested by letter of April 9, 1980, received April 10, 1980. It appears that the endangered Indiana bat (*Myotis sodalis*) may occur in the area of influence of this action during the summer months. Our records indicate that no other proposed or listed endangered or threatened species are known to occur within the project area.

Section 7(c) of the Endangered Species Act of 1973, as amended 1978, requires agencies to provide a biological assessment for the listed species and/or the species proposed for listing which are likely to be affected. The biological assessment shall be completed within 180 days after the date on which initiated, or a mutually agreed time frame, before any contracts for construction are entered into, and before construction is begun. We do not feel that we can adequately assess the effects of the proposed action on listed species, species proposed for listing or Critical Habitat without a complete assessment. At a minimum the following information is requested:

1. Identification of the listed species, species proposed for listing and Critical Habitat determined to be present within the area affected by the proposal.
2. Description of the survey methods used to determine presence of listed species or species proposed for listing within the area.
3. The results of a comprehensive survey of the area. It is appropriate to:
 - a. Survey the suitable habitat available at the project site for trees which could potentially be used as maternity roosts for the Indiana bat.

405050

- b. If suitable habitat is present, you should then determine if the habitat does in fact support the Indiana bat by appropriate field surveys.

If the results of these investigations are negative, this would complete your responsibilities in conducting a biological assessment.

- 4. Description of any difficulties encountered in obtaining data and completing proposed studies.
- 5. Description of the proposed construction project and associated activities.
- 6. Description of methods and results of studies made to determine the actual and potential impacts of project or associated activities on listed species, species proposed for listing, or Critical Habitat. In addition to the direct (site related) impacts of project construction the biological assessments should include, when applicable, descriptions of:
 - A. Impacts associated with project operation.
 - B. Secondary impacts from activities, such as development, which will be generated by the proposed project.
 - C. The cumulative effects of the proposal on the species and/or its Critical Habitat. Cumulative effects are defined as the direct and indirect impacts of the Federal action under consideration coupled with the identifiable effects of other reasonably foreseeable actions of the Federal agency; other Federal, State, and local agencies; corporations; and individuals upon a species or its Critical Habitat.
- 7. Where impacts to listed species, species proposed for listing, or Critical Habitat are identified, the assessment should include a discussion of the efforts that will be taken to eliminate, reduce, or mitigate any adverse effects.
- 8. Conclusions of the agency including recommendations regarding further studies.
- 9. Any other relevant information.

Should you require additional information on this subject, please contact Mr. Gary Henry, Mr. Robert Currie, or Ms. Nora Murdock in the Asheville Area Office, FTS 672-0321, commercial 704/258-2850, ext. 321.

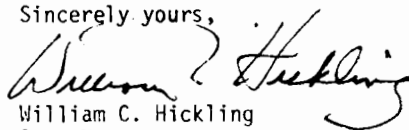
After your agency has completed and reviewed the assessment, it is your responsibility to determine if the proposed action "may affect" any of the listed species or Critical Habitat. If the determination is "may

affect," you are required to initiate consultation by a written request to the Regional Director (SE/T), U.S. Fish and Wildlife Service, Richard B. Russell Federal Building, 75 Spring Street, S.W., Atlanta, Georgia 30303. At this time you should provide a copy of the biological assessment and any other relevant information that assisted you in reaching your conclusion. If the determination is "no effect," consultation is not necessary, unless requested by the Fish and Wildlife Service. If the species proposed for listing have not been listed in the period of time during which a biological assessment was conducted, consultation is not required. However, at any point in time that the species is listed, you are required to reinitiate consultation, if you determined that the proposed action "may affect" the species.

Your attention is also directed to Section 7(d) of the Endangered Species Act, as amended, which underscores the requirement that the Federal agency and the permit or license applicant shall not make any irreversible or irretrievable commitment of resources during the consultation period which in effect would deny the formulation or implementation of reasonable alternatives regarding their actions on any endangered or threatened species.

If we can be of further assistance, please advise.

Sincerely yours,



William C. Hickling
Area Manager



Department of Energy
Oak Ridge Operations
P.O. Box E
Oak Ridge, Tennessee 37830

OCT 3 1980

United States Department of the Interior
Room 279, Federal Building
Fish and Wildlife Service
Asheville, NC 28801

Gentlemen:

INDIANA BAT (MYOTIS SODALIS) AT DOE'S PROPOSED SRC I SITE

In response to your June 17, 1980 letter on the above subject, you will find attached two relevant documents:

1. "Biological Assessment of Impacts of the Proposed SRC I Facility on the Indiana Bat (Myotis Sodalis)" prepared by the Oak Ridge National Laboratory in conjunction with Indiana Bat experts from Memphis State University. (Enclosure 1.)
2. "Preliminary Draft Environmental Impact Statement for SRC I", scheduled for release as a public draft in a few weeks. (Enclosure 2.)

These two documents respond to most of the concerns directed to DOE in the June 17 letter.

Briefly, the results of two trapping surveys confirm that at least a few individuals of this endangered species can be expected to be present on a seasonal basis in the 17 ha riparian forest along Martin Creek, the eastern boundary of the SRC I plantsite. It is unfortunate that survey efforts could not be initiated earlier in the summer to confirm whether or not a maternity roost is present. It was somewhat fortuitous that the current plans for plant layout concentrate the heavy process areas fairly remote from the Martin Creek forest, and consideration is being given to other plant layout and design measures that might benefit bats living along the creek. Further surveys are tentatively planned for the 1981 season to try to determine more about Indiana Bats on the plantsite.

U.S. DOI/Fish & Wildlife

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OCT 3 1980

Notwithstanding any efforts on our part, taken in genuine good faith to reduce any conceivable adverse impacts of the SRC I Plant on the Martin Creek forest area or to further consider the susceptibility of any individuals that live on or near the plantsite, it is DOE's considered opinion based on available information that, even in the worst case, where all ecological features important to the bat's habitation on the plantsite might be destroyed, there would not result any discernible impact to the species or to a critical habitat of the species. We are, therefore, reasonably confident with a "no effect" determination and do not plan to enter into formal consultation with the Fish and Wildlife Service.

Independent of the Fish and Wildlife Service determination on any need for further formal consultation on this matter, DOE-ORO requests guidance on the proper course of action relative to protection of the Martin Creek forest area in the short term. Kentucky Department of Energy, one of U.S. DOE's partners for the SRC I project, currently holds a purchase option for the forest property on the west side of Martin Creek, but this option does not include timber rights. No options are held, nor are any planned, for the forest property on the east side of the creek. DOE-ORO is not aware of any imminent plans of the current property owners to harvest the Martin Creek forest timber; however, there are currently no legal impediments to such action and the eventual harvest of the west side timber, prior to the exercise of the purchase option, would not be an unrealistic expectation. Subject to Fish and Wildlife's advice, DOE-ORO would be willing to request that the Kentucky Department of Energy pursue the addition of timber rights to the west side forest property purchase option and, if necessary to seek timber rights or other legal arrangements to prevent destruction of the east side forest as well.

In addition to the requirements of Section 7.(c) of the Endangered Species Act, DOE-ORO also acknowledges its responsibility to confer with the Fish and Wildlife Service relative to Section 622(a) of the Fish and Wildlife Coordination Act. Toward this end, we have attached copies of two of the SRC I EIS Environmental Report appendices, "Appendix D - Wildlife" and "Appendix G - Aquatic Ecology". We believe that the SRC I DEIS and reference materials will substantially document that the project, as conceived, does not pose a significant threat to wildlife resources. We would welcome your thoughts on this subject.

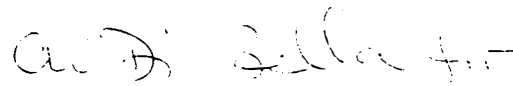
U.S. DOI/Fish & Wildlife

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OCT 3 1980

Please contact James A. Reafsnnyder, Research and Development Manager for the SRC projects, at FTS 626-2429, or Jake Alexander, Environmental Engineer assigned to SRC 1, FTS 626-0849, if you have questions or need additional information.

Sincerely,



John F. Pearson, Jr.
Assistant Manager for
Solvent Refined Coal Projects

MS-331:JKA

Enclosures

CC w/encl. 1:
U.S. DOI F&WS
75 Spring St. SW
Atlanta, GA 30303

Mr. James Roth, Asst. to Secy.
U.S. Department of Interior
Office of the Secretary
Washington, D.C. 20240



United States Department of the Interior

FISH AND WILDLIFE SERVICE

ROOM 279, FEDERAL BUILDING
ASHEVILLE, NORTH CAROLINA 28801

November 4, 1980

Mr. John F. Pearson, Jr.
Assistant Manager
Solvent Refined Coal Projects
Department of Energy
P.O. Box E
Oak Ridge, Tennessee 37830

Re: 4-2-80-A-192

Dear Mr. Pearson:

This is in response to your letter of October 3, 1980, received October 10, 1980, requesting endangered species review of your Biological Assessment for the Department of Energy's (DOE) proposed SRC I site at Newman, Kentucky. This letter will confirm the information provided to Mr. Gabriel Marciante of your office by Mr. Robert Currie of this office on November 4, 1980.

Based upon the information provided in your assessment, it is clear that construction of the proposed project definitely "may affect" the endangered Indiana bat (*Myotis sodalis*). The final regulations developed by the Service to implement the provisions of Section 7 state in Section 402.04(a)(3) (copy enclosed) that: "when a Federal agency identifies activities or programs that may affect listed species or their habitat, the agency shall convey a written request for consultation with available information to: the Regional Director . . ." Your request for formal consultation should be directed to Mr. Kenneth Black, Regional Director, U.S. Fish and Wildlife Service, Richard B. Russell Federal Building, 75 Spring Street, S.W., Atlanta, Georgia 30303. The consultation will be handled by the Asheville Area Office and we would appreciate receiving a copy of your request for consultation. Available information concerning the effects of the project on the Indiana bat should accompany your request for consultation. If you have previously provided any of this information to us, it is appropriate to refer to it rather than supply an additional copy. We have not received a copy of Dr. Harvey's report to you on the results of his survey. A copy of Dr. Harvey's report should accompany your request for consultation.

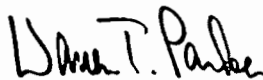
The Endangered Species Act of 1973 has been amended several times since the regulations referred to above were issued. The Service is currently developing revised regulations to incorporate the changes required by these amendments. However, the circumstances under which formal consultation is required have not been altered by these amendments nor will the revised regulations change them. Formal consultation will still be required any time a Federal agency determines that their actions "may affect" a federally listed endangered or threatened species. Formal consultation is also required when requested by the Service.

Additionally you requested guidance concerning the protection of the vegetation along Martin's Creek. We believe that purchase of the timber rights for the property along the west side of the creek and purchase of an easement for the timber rights on the east side of the creek would constitute a positive conservation measure by DOE.

Review of this project under the Fish and Wildlife Coordination Act is the responsibility of the Service's Land and Water Resources Development Field Office in Cookeville. In order to expedite Coordination Act review of your Draft Environmental Impact Statement when it is issued, you should (in addition to the copies sent through other channels) send a copy directly to Mr. Thomas S. Talley, Field Supervisor, U.S. Fish and Wildlife Service, P.O. Box 845, Cookeville, Tennessee 38501.

We appreciate your interest in the Endangered Species program and look forward to continued cooperation in meeting our mutual responsibilities under the Endangered Species Act. If you have any questions concerning this letter, please contact Mr. Robert R. Currie, Mr. Gary Henry, or Ms. Nora Murdock, FTS 672-0321 or commercial telephone number 704/258-2850 ext. 321.

Sincerely yours,

A handwritten signature in dark ink, appearing to read "Warren T. Parker". The signature is fluid and cursive, with the first name "Warren" and last name "Parker" being the most legible parts.

Warren T. Parker
Acting Area Manager

WEDNESDAY, JANUARY 4, 1978

PART IV



DEPARTMENT OF COMMERCE

National Oceanic and
Atmospheric Administration

DEPARTMENT OF THE INTERIOR

Fish and Wildlife Service



ENDANGERED SPECIES ACT OF 1973

Interagency Cooperation Regulations

Department of
Commerce
National Oceanic and
Atmospheric Administration
Department of
the Interior
Fish and Wildlife Service
Endangered Species
Act of 1973
Interagency Cooperation Regulations



Department of Energy
Oak Ridge Operations
P.O. Box E
Oak Ridge, Tennessee 37830

November 20, 1980

Mr. Kenneth Black
Regional Director
U.S. Fish and Wildlife Service
Richard B. Russell Federal Building
75 Spring Street, SW
Atlanta, Georgia 30303

Dear Mr. Black:

REQUEST FOR CONSULTATION SRC I, 4-2-80-A-192

In accordance with the guidance presented in Warren T. Parker's letter to me on November 4, 1980 on the subject, on behalf of the U.S. Department of Energy, I would like to request consultation with the Fish and Wildlife Service pursuant to 509 CFR 402.04(a)(3), with respect to impacts on the Indiana bat (Myotis sodalis) by our proposed Solvent Refined Coal I Plant at Newman, Kentucky. Since our biological assessment for the site indicated that the project "may affect" the endangered Indiana bat the consultation process is warranted.

Enclosed with this request is a copy of our biological assessment and a copy of Dr. Michael Harvey's report to us on the results of his survey for the Indiana bat at the Newman site.

It is our belief and that of our expert consultants that the SRC I project will not jeopardize the continued existence of the Indiana bat nor result in the destruction or adverse modification of a critical habitat for that species. I hope you will concur.

If you require any further information or would like to arrange for a meeting on the subject, please contact James A. Reafsnyder at FTS 626-2429, or Gabriel J. Marciano at 626-0850.

Sincerely,

John P. Pearson, Jr.
Assistant Manager for
Solvent Refined Coal Projects

MS-331:GJM

Enclosure

CC w/encl:
W. T. Parker, F&WS/Asheville



Department of Energy
Oak Ridge Operations
P.O. Box E
Oak Ridge, Tennessee 37830

November 21, 1980

Mr. Thomas J. Talley, Field Supervisor
U. S. Fish and Wildlife Service
Post Office Box 845
Cookeville, TN 38501

Dear Mr. Talley:

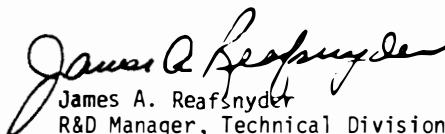
COORDINATION WITH THE FISH AND WILDLIFE SERVICE FOR DOE'S PROPOSED
SRC-I COAL LIQUEFACTION PLANT AT NEWMAN, KENTUCKY

Reference is made to John F. Pearson's letter of October 3, 1980, to the Asheville Area Office of the U. S. Fish and Wildlife Service (copy attached), which acknowledged DOE's responsibility to confer with the Fish and Wildlife Service relative to Section 622(a) of the Fish and Wildlife Coordination Act.

Attached for your review is an updated version of the Preliminary Draft EIS previously submitted to the Asheville Area Office. Also, attached is a copy of the SRC-I Environmental Report, which contains pertinent data on wildlife and aquatic ecology for the proposed Newman, Kentucky site. We believe the information in the attached documents substantiates that the proposed SRC-I plant does not pose a significant threat to wildlife resources. Your review of the attached documents and any comments you may have would be appreciated. Representatives of DOE's industrial partner (International Coal Refining Company), preparers of the Environmental Report, the Oak Ridge National Laboratory, which is currently preparing the draft EIS, and DOE are available to meet at your convenience and discuss any concerns you may have.

If you require additional information or wish to arrange a meeting on this subject, please call me at FTS 626-1055 or contact Gabriel Marciante at FTS 626-0850.

Sincerely,


James A. Reafsnnyder
R&D Manager, Technical Division
Solvent Refined Coal Projects

SR-74:JAR:tfk

Enclosures:
As stated

Thomas J. Talley
U. S. Fish & Wildlife Service -2-

cc: Dan Harker, Director (w/enclosures)
Nature Preserves Commission
Commonwealth of Kentucky

U. S. Fish & Wildlife Service, Asheville, N. C.
U. S. Fish & Wildlife Service, Atlanta, GA
Mr. James Roth, Asst. to Secretary, S, DOE



United States Department of the Interior

FISH AND WILDLIFE SERVICE

75 SPRING STREET, S.W.
ATLANTA, GEORGIA 30303

Copied for J. L. Morris, 12-12-80

G. J. Marcianite
J. A. Reafsnider
C. R. Boston

DEC 9 1980

Mr. John F. Pearson, Jr.
Department of Energy
Oak Ridge Operations
Post Office Box E
Oak Ridge, Tennessee 37830

Dear Mr. Pearson:

Re: Log Number 4-2-80-A-192

This acknowledges your letter of November 20, 1980, received November 26, 1980, requesting consultation as required under Section 7 of the Endangered Species Act. In your letter you referred to potential effects from the proposed Solvent Refined Coal I Plant at Newman, Kentucky, on the following Endangered or Threatened species: Indiana bat (Myotis sodalis).

The Fish and Wildlife Service representatives who will assist you with this consultation are Mr. Gary Henry and Mr. Bob Currie at the Asheville Area Office, Room A-5, Plateau Building, 50 South French Broad Avenue, Asheville, North Carolina 28801, telephone FTS 672-0382, commercial 704/258-2850, extension 321.

The information which you provided has been forwarded to the Asheville Area Office for review. If you have additional information in your files that could assist us in this consultation, we would appreciate your forwarding it directly to the Asheville Area Office.

We appreciate your interest and concern in the preservation of listed species and feel confident that our cooperative effort will contribute toward minimizing potential adverse effects to these species.

Sincerely yours,

Walter D. Stigitz

Acting Regional Director

108246

Copied for G. Marciante
3/4/81



United States Department of the Interior

FISH AND WILDLIFE SERVICE
PLATEAU BUILDING, ROOM A-5
50 SOUTH FRENCH BROAD AVENUE
ASHEVILLE, NORTH CAROLINA 28801

March 2, 1981

Mr. John F. Pearson, Jr.
Department of Energy
Oak Ridge Operations
Post Office Box E
Oak Ridge, TN 37830

Re: 4-2-80-192

Dear Mr. Pearson:

This is in response to your letter of November 20, 1980, received November 26, 1980, requesting formal Section 7 consultation under the Endangered Species Act of 1973, as amended, for the proposed construction of the Solvent Refined Coal-I Demonstration project in Daviess County, Kentucky. This Biological Opinion addresses the impacts of construction and operation of the demonstration facility on the endangered Indiana bat (Myotis sodalis). Our analysis does not address the impacts of the expansion of the demonstration facility to a commercial operation, nor does it address the construction impacts of the power transmission line which will be required for the project. This letter presents the Biological Opinion of the U.S. Fish and Wildlife Service and was prepared in accordance with the Section 7 Interagency Cooperative Regulations (50 C.F.R. 402, 43 FR 870).

We have reviewed the biological information provided by you, the survey report prepared by Dr. M. Harvey, and other information in our files which is applicable to this project. The Indiana/Gray Bat Recovery Team reviewed and commented on the adequacy of your biological assessment. Copies of or references to pertinent documents are contained in the Administrative Record for this consultation which is maintained in this office.

It is the Biological Opinion of the Fish and Wildlife Service that the construction and operation of the SRC-I demonstration plant and its cumulative impacts will not jeopardize the continued existence of the endangered Indiana bat.

This consultation concerns the construction of a demonstration solvent refined coal project in Newman, Daviess County, Kentucky, by the Department of Energy in cooperation with the International Coal and Refining Company. During the demonstration phase of the project's operation, the proposed plant will process 6,000 tons of coal per day. Should the process be commercially feasible, the plant may be expanded to a 30,000 ton per day

1.22

plant in the future. Current project plans call for the construction of coal barge unloading facilities on the Green River and plant processing units in the upland portions of the 1,484 acre site. None of the construction activities planned for the demonstration project will directly effect the bottomland hardwood forest found along the west side of Martin Creek. Indirect impacts on this area from site preparation will be minimized by carefully controlling erosion from the disturbed soil surfaces.

The biological assessment submitted for this project adequately reviews the biology of the Indiana bat both in general terms and in relation to the proposed project. The presence of a maternity colony of Indiana bats in the area adjacent to Martin Creek has not been documented. However, this area contains habitat which is suitable for summer use by the Indiana bat and during the survey performed in July and August, 1980, several mature female Indiana bats were captured on the site. In order to complete Endangered Species review in a timely manner, the Department of Energy made the assumption that the Martin Creek forest does support a maternity colony of Indiana bats. The analysis of project impacts is performed from this perspective in the biological assessment. The Department of Energy plans to continue their studies of Indiana bat use of the site during the spring and summer of 1981.

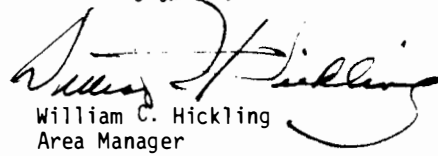
The Department of Energy has made a commitment to preserve the character and biological integrity of the Martin Creek bottomland hardwood forest located within the site boundaries. This will provide protection for the suitable Indiana bat habitat found on the west side of Martin Creek. We recommend as a conservation enhancement measure that the Department of Energy, through acquisition of the timber rights, provide for the protection of the suitable habitat found on the east side of Martin Creek. Based upon the information currently available, protection of this area would constitute an action on the part of the Department of Energy which would enhance the status of the Indiana bat. Such action would be in keeping with the directive in Section 7(a) of the Endangered Species Act, as amended, to Federal agencies to "utilize their authorities in furtherance of the purposes of this Act by carrying out programs for the conservation of endangered species . . ."

The Department of Energy is reminded of its continuing responsibility to review its activities and programs in light of Section 7 and to reinstate this consultation if:

1. New information becomes available which indicates that the proposed action may have additional impacts on listed species;
2. The action as described is modified; or,
3. Additional species are listed which may be affected by the proposed action.

We appreciate the conscientious manner in which the Department of Energy has met its endangered species responsibilities on this project and look forward to continued cooperation in meeting our mutual responsibilities under this Act.

Sincerely yours,



William C. Hickling
Area Manager

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Appendix J
AQUATIC ECOLOGY



Table J.1. Fish species collected during baseline monitoring

Green River ^a	
Longnose gar	Blue catfish
Gizzard shad	Channel catfish
Skipjack herring	Flathead catfish
Goldeye	White bass
Carp	Black crappie
Emerald shiner	Bluegill
Spotfin shiner	Spotted bass
Bigmouth buffalo	White crappie
Smallmouth buffalo	Sauger
River carpsucker	Freshwater drum
Quilback	
Martin Creek ^b	
Gizzard shad	Mosquitofish
Carp	Bluegill
Emerald shiner	White crappie
Ghost shiner	Sauger
Spotfin shiner	Blackspotted topminnow
Bryant Ditch ^c	
Green sunfish and other sunfishes	Golden shiner
Emerald shiner	Mosquito fish
Richland Slough ^d	
Bowfin	Bluegill
Gizzard shad	Flier
Golden shiner	Largemouth bass
Suckermouth minnow	Longear sunfish
Black bullhead	Warmouth
Yellow bullhead	White crappie
Black crappie	
Ponds ^e	
Bluntnose minnow	Green sunfish
Golden shiner	Bluegill
Black bullhead	

^aER, Appendix G, Part I, Tables G.11, G.12, and G.13.^bER, Appendix G, Part I, Table G.14.^cER, Appendix G, Part I.^dER, Appendix G, Table G.15.^eER, Appendix G, Table G.16.

Table J.2. Fish species collected in Green River
lock and dam chambers, 1960–1963^a

Silver lamprey	River redhorse
Paddlefish	Golden redhorse
Spotted gar	Blue catfish
Longnose gar	Black bullhead
Shortnose gar	Yellow bullhead
Bowfin	Channel catfish
Skipjack herring	Brindled madtom
Gizzard shad	Freckled madtom
Threadfin shad	Flathead catfish
Goldeye	American eel
Mooneye	Rock bass
Grass pickerel	Warmouth
Stoneroller	Green sunfish
Carp	Orangespotted sunfish
Silvery minnow	Bluegill
Speckled chub	Longear sunfish
Streamline chub	Redear sunfish
Silver chub	Hybrid sunfish
Golden shiner	Spotted bass
Emerald shiner	Largemouth bass
Ghost shiner	White crappie
Common shiner	Black crappie
Rosyface shiner	Greenside darter
Spotfin shiner	Logperch
Mimic shiner	Blackside darter
Steelcolor shiner	Dusky darter
Pugnose minnow	Sauger
Bluntnose minnow	Walleye
Bullhead minnow	Freshwater drum
River carpsucker	Brook silverside
Quillback	
Highfin carpsucker	
Smallmouth buffalo	
Bigmouth buffalo	
Black buffalo	
Spotted sucker	
Silver redhorse	
Shorthead redhorse	

^aJ. R. Charles, "Effects of Oilfield Brines," Reprinted from *Proceedings of the 18th Annual Conference, Southeastern Association of Game and Fish Commissioners*, pp. 16–18, October 18–21, 1964.

Table J.3. Ichthyoplankton species collected in the Green River during baseline monitoring^a

Ichthyoplankton identified to the level of species	
Carp	Pirate perch
Emerald shiner	Bluegill
Steelcolor shiner	Rock bass
Ghost shiner	Freshwater drum
Bullhead minnow	Paddlefish
Channel catfish	Gizzard shad
Blue catfish	Goldeye
Flathead catfish	Mooneye
Ichthyoplankton identified to the level of genus or family	
Shiner	Carp sucker
Crappie	Sucker
Sunfish	Buffalo
Pikeperch	Gar
Rock bass	Topminnow or studfish
White bass	Catfish or bullhead
Shad or herring	Darter

^aInformation from ER, Appendix G, Part I, Tables G.18 to G.30B.

Table J.4. Peripheral fish species (considered rare or threatened in Kentucky, but more abundant in other parts of their range)^a

Troutperch
Mud darter
Harlequin darter
Tippecanoe darter
Longhead darter

^aC. H. Stephens and J. S. Durrell, *Endangered and Rare Species in Kentucky*, p. 7, Publication of the Department of Natural Resources and Environmental Protection, Frankfort, Ky, March 1979.

Table J.5. Average daily densities (No./100 m³) of ichthyoplankton
collected at Green River sampling stations during 1979

Date	Station ^a												
	11(S)	12(S)	12(M)	13(S)	21(S)	22(S)	22(M)	22(B)	23(S)	31(S)	32(S)	32(M)	33(S)
3/22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4/5	1.3	1.0	0.7	0.5	0.2	0.0	1.8	0.4	1.1	2.5	0.6	0.5	2.0
4/19	58.3	34.2	65.5	49.5	50.1	50.0	62.2	76.5	49.3	30.5	52.6	45.7	45.7
5/3	747.3	112.0	50.0	127.9	149.7	152.9	122.6	138.1	359.7	683.6	91.3	69.7	227.1
5/17	1135.8	402.9	274.8	297.8	565.6	542.0	264.0	48.2	349.6	2003.6	267.8	172.0	256.5
5/31	239.5	44.5	74.7	120.7	193.1	131.0	58.7	126.4	451.0	431.3	265.3	70.3	259.9
6/18	1825.3	411.9	693.9	758.1	697.1	565.7	768.5	680.3	793.3	670.5	586.4	385.0	1347.2
7/2	245.0	131.1	593.7	1031.0	656.7	467.5	190.6	165.2	1237.6	546.7	578.6	223.6	1844.6
7/24	33.7	49.7	26.1	143.1	33.4	32.1	35.7	29.2	59.9	78.2	51.8	79.5	52.0
8/7	5.9	5.2	2.4	8.1	5.6	7.4	2.7	2.3	11.5	13.4	4.3	2.6	12.2
8/21	2.1	9.4	61.4	26.4	10.3	14.3	40.6	29.4	24.9	49.3	16.9	37.1	13.6
9/6	0.4	0.6	0.2	0.3	0.9	1.7	0.0	0.2	1.4	1.0	0.2	0.0	0.4
10/11	0.7	0.2	0.0	0.0	0.2	0.7	0.2	0.0	0.0	2.1	0.0	0.0	3.4

^aS—surface; M—middle; and B—bottom.

Source: ER, Appendix G, Table G.17.

Table J.6. Ichthyoplankton densities (No/100 m³) at the site of the proposed SRC-I water intake during 1979
(mean density $\pm$ standard error, n = 4)

Date	Station		
	21 S North channel (intake site)	22 S Mid-channel	23 South channel
3/22	0.0	0.0	0.0
4/5	0.2 $\pm$ 0.15	0.0	1.1 $\pm$ 0.4
4/19	50.1 $\pm$ 7.1	50.0 $\pm$ 10.7	49.3 $\pm$ 10.8
5/3	149.7 $\pm$ 22.6	152.9 $\pm$ 14.2	369.7 $\pm$ 47.6
5/17	565.6 $\pm$ 36.8	542.0 $\pm$ 93.1	349.6 $\pm$ 101.1
5/31	193.1 $\pm$ 73.2	131.0 $\pm$ 34.0	451.0 $\pm$ 337.8
6/18	697.1 $\pm$ 165.6	565.7 $\pm$ 165.9	688.2 $\pm$ 100.8
7/2	656.7 $\pm$ 264.6	467.5 $\pm$ 173.7	1237.6 $\pm$ 316.2
7/24	33.4 $\pm$ 8.4	32.1 $\pm$ 3.0	59.9 $\pm$ 12.2
8/7	5.6 $\pm$ 1.5	7.4 $\pm$ 1.4	11.5 $\pm$ 4.8
8/21	10.3 $\pm$ 1.6	14.3 $\pm$ 1.2	24.9 $\pm$ 2.0
9/6	0.9 $\pm$ 0.6	1.7 $\pm$ 0.4	1.4 $\pm$ 1.2
10/11	0.2 $\pm$ 0.3	0.7 $\pm$ 0.4	0.0

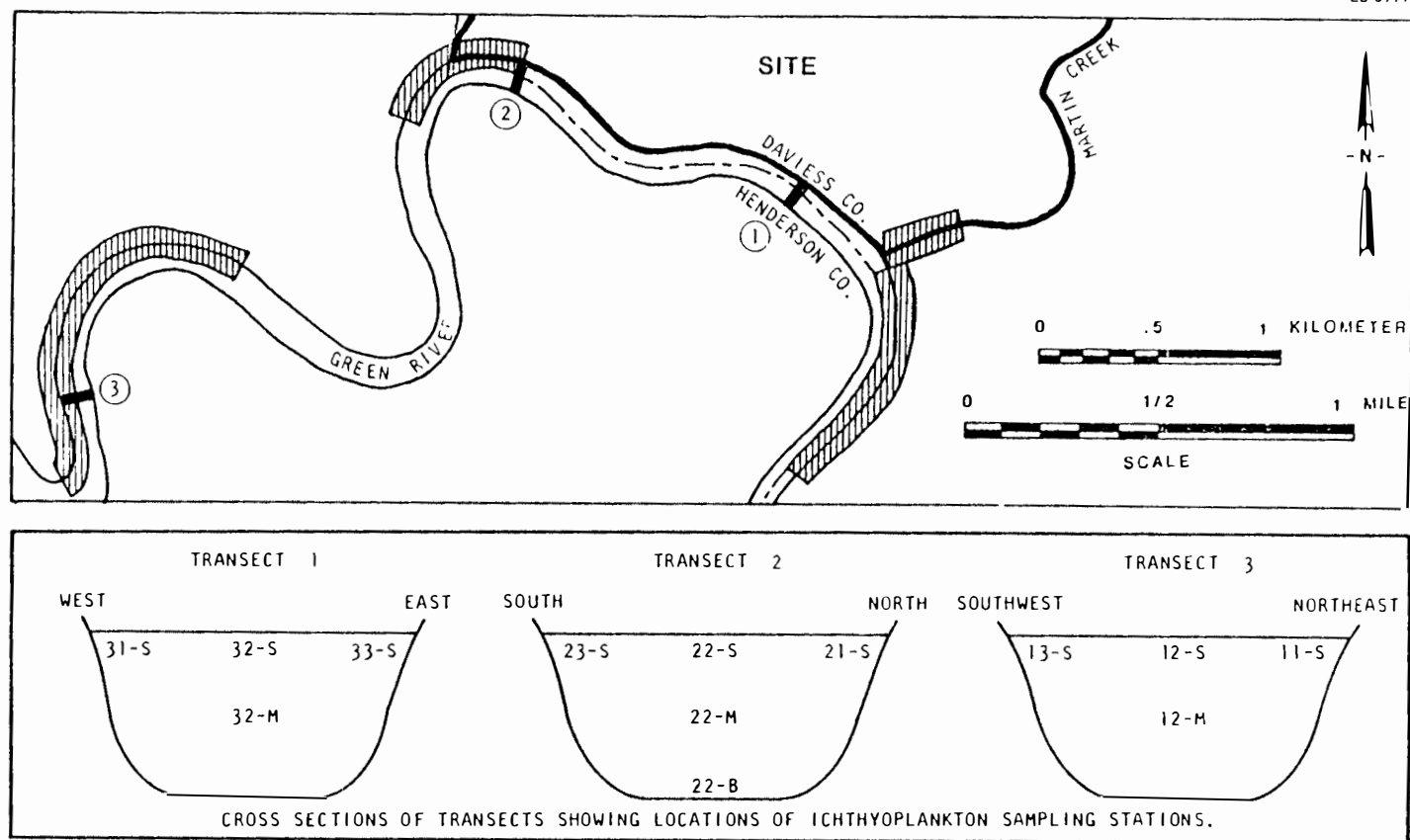
Source: ER, Tables G-19-G-30.

Table J.7. Derivation of Kentucky toxicity-based standards

Parameter	96-h LC ₅₀ (µg/liter)	Source of data ^a
Arsenic	19,485	Bluegill, geometric mean of five values
Beryllium	3,250	Fathead minnow, hardness = 140 mg/liter
Cadmium	6,435	Fathead minnow, regression of 96 h LC ₅₀ vs hardness, exp [1.25(ln h) 2.67]
Chromium		
Trivalent	22,700	Fathead minnow, exp [0.83(ln h) + 5.98]
Hexavalent	36,860	Geometric mean of flow-through measured tests at hardness equal to 209 mg/liter
Copper	345	Fathead minnow, exp [1.12(ln h) + 0.38]
Cyanide	284	Fathead minnow, geometric mean of two tests at 230 and 250 mg/liter hardness (the only two values for adult fathead minnows)
Lead	4,612	Fathead minnow, geometric mean of three values at 20 mg/liter hardness
Mercury	164	Fathead minnow, geometric mean of two values, 150 and 180 µg/liter hardness
Nickel	18,260	Fathead minnow, exp [0.83(ln h) + 5.76]
Selenium	3,060	Fathead minnow, geometric mean of all values except fry and juvenile
Silver	44	Fathead minnow, exp [0.83(ln h) - 3.52]
Zinc	13,400	Fathead minnow, geometric mean of all values at 100 mg/liter hardness

^aAll 96-h LC₅₀ values were taken from the 1980 Water Quality Criteria Documents.

Source: J. O'Connor, EPA Region 4, Atlanta, Georgia, personal communication to R. D. Roop, Oak Ridge National Laboratory, Oak Ridge, TN.



EXPLANATION

- ③ ICHTHYOPLANKTON SAMPLING TRANSECT
- 31-S ICHTHYOPLANKTON SAMPLING STATION
- ||||| OTHER SAMPLING AREA (FOR REFERENCE)

Fig. J.1. Ichthyoplankton sampling locations by transect and station. Source: ER, Fig. G.3.

Appendix K
TERRESTRIAL ECOLOGY

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Appendix K

TERRESTRIAL ECOLOGY

This appendix provides supportive discussion for Sects. 3.2.1.3 and 4.2.1.3, description of and impacts on terrestrial ecology. Correspondence with the U.S. Fish and Wildlife Service (USFWS), including their assessment of impacts on the Indiana Bat, is presented in Appendix I.

K.1 BIOLOGICAL ASSESSMENT FOR THE INDIANA BAT*

The Indiana bat (*Myotis sodalis*) is listed by the U.S. Fish and Wildlife Service (USFWS) as an endangered species.¹ In compliance with Sect. 7(a) of the Endangered Species Act of 1973, as amended, the U.S. Department of Energy (DOE) supplied the USFWS with biological and physical information on the SRC-I Project in April 1980 (Appendix I) and requested information on the potential presence of endangered plant and animal species on the SRC-I site. The response from the USFWS indicated that Indiana bats may occur on the site and requested that DOE perform a survey for the bat (Appendix I). Therefore, an onsite survey was arranged by DOE and its industrial partners and conducted by authorized bat experts, M. J. Harvey and M. L. Kennedy, from Memphis State University, and J. S. Kessler, from the U.S. Corps of Engineers, Louisville District, from July 25-31 and August 10-15, 1980.

The purpose of this document is to present the methods, results, and implications of the survey, and to assess the significance of potential impacts of the SRC-I project on the Indiana bat.

The present document, the July-August 1980 onsite survey for the Indiana bat, and supporting information in the Draft Environmental Impact Statement (DEIS) and the Environmental Report (ER) prepared by the industrial partner, constitute the official Biological Assessment required of DOE for compliance with Sect. 7(c) of the Endangered Species Act of 1973 as amended in 1976, 1977, and 1978. These Biological Assessment documents will be submitted to the USFWS.

This report was prepared by DOE staff. Although information obtained during the survey by the bat experts was freely used in this document, any errors and inadequacies in this document are the sole responsibility of the DOE staff. The bat experts will file with the USFWS their own report of their survey activities.

K.1.1 Description of the SRC-I project

The environment of the SRC-I site and project design, layout, and processes are described in Sects. 2.2 and 3.2. Impacts are described in Sect. 4.2. To briefly summarize, about 85% of the 600-ha site consists of active agricultural fields and pasture. Approximately 15 ha of riparian forest occur on the site along Martin Creek, which bounds the site to the southeast, and 15 ha occur along the Green River, which bounds the site on the south. Additional riparian forest is located along the southeastern bank of Martin Creek, which is off the site (Martin Creek is the SRC-I site property line). Riparian forest is the preferred habitat for Indiana bats in the spring, summer, and early fall;^{2,3} agricultural fields and pasture are not important to the species. A portion of the Green River forest would be cleared for SRC-I facilities, but none of the Martin Creek forest where Indiana bats have been found.

*This is the assessment that was presented in the DEIS and submitted to the USFWS. Subsequent to issuance of the DEIS, the USFWS concurred with DOE's assessment that the proposed project will not jeopardize the existence of the Indiana Bat (Appendix I).

K.1.2 Indiana bat ecology

The Indiana bat ranges from eastern Oklahoma and southeastern Alabama to extreme southern Wisconsin and Vermont.^{4,5} During the winter, the bat hibernates in caves. Tens of thousands of these hibernating bats occur in single caves, during which time the species is most vulnerable to human disturbance. In the spring, most of the bats disperse from the caves. Females disperse to riparian forests, where they form small colonies (e.g., 25 to 30 adult females) and raise their young.^{2,4} Each female gives birth to a single young. The colonies are located under the loose bark of dead and living trees and in cavities in trees, from which the bats fly nightly to feed, primarily within the forest. Small groups of males spend the spring and summer around the caves, but most males leave the cave areas in the spring and remain away for the summer. During the summer, the species is much less vulnerable to localized human disturbance because much lower numbers of bats occur in any one area. In the fall, males and females return to the caves, where copulation occurs. The number of Indiana bats using caves known to be hibernacula has been estimated at 509,000 individuals.⁶

The major threat to the existence of the Indiana bat species appears to be disturbance at caves, where the high aggregation "makes the species extraordinarily vulnerable to natural catastrophes and losses caused by humans" (ref. 7). The serious human hazards to which bats in general are subjected while hibernating in caves are clearly shown by Tuttle.⁸ Widespread application of pesticides and large-scale clearing of riparian and bottomland forests for agriculture and urbanization may also be major threats to existence of the Indiana bat.^{4,9,10} The total population of Indiana bats has declined rapidly during recent years, and the species is now virtually gone from the northeastern United States.¹¹

Although no caves exist in the immediate area of the site, the largest extant hibernating population of Indiana bats (numbering about 150,000) is located in three caves approximately 97 km northeast of the site.⁶ In addition, the Mammoth Cave region, where several thousand Indiana bats hibernate, is about 130 km ESE of the site, although this is not expected.

Studies of the summer distribution of Indiana bats hibernating at Mammoth Cave and at Bat Cave in northeastern Kentucky show that males and females move almost exclusively northward in the spring and occupy rather distinct summer geographic ranges (Fig. K.1). The SRC-I site lies outside of these ranges, which indicates that Indiana bats may be less abundant in the SRC-I site area than within these summer geographic ranges.

The following habitats, all caves or mines, have been designated as Critical Habitat for the Indiana bat (50 CFR Part 1.1:109, Revised October 1979):

1. Illinois, the Blackball Mine, La Salle County.
2. Indiana, Big Wyandotte Cave, Crawford County; Ray's Cave, Greene County.
3. Kentucky, Bat Cave, Carter County; Coach Cave, Edmonson County (Mammoth Cave area).
4. Missouri, Cave 021, Crawford County; Cave 009, Franklin County; Cave 017, Franklin County; Pilot Knob Mine, Iron County; Bat Cave, Shannon County; Cave 029, Washington County.
5. Tennessee, White Oak Blowhole Cave, Blount County.
6. West Virginia, Hellhole Cave, Pendleton County.

Of these, the following lie within 161 km (100 miles) of the SRC-I site:

1. Big Wyandotte Cave, 97 km (60 miles) NE of the site.
2. Ray's Cave, 145 km (90 miles) NNE of the site.
3. Coach Cave (Mammoth Cave area), 130 km (80 miles) ESE of the site.

K.1.3 Methods of surveying for Indiana bats

Before initiating trapping, the survey team inspected the onsite riparian habitats that might be suitable for Indiana bats. The trees along the Green River formed a very narrow strip of woods, in many places only a few trees wide. The forest along Martin Creek was much wider, having many

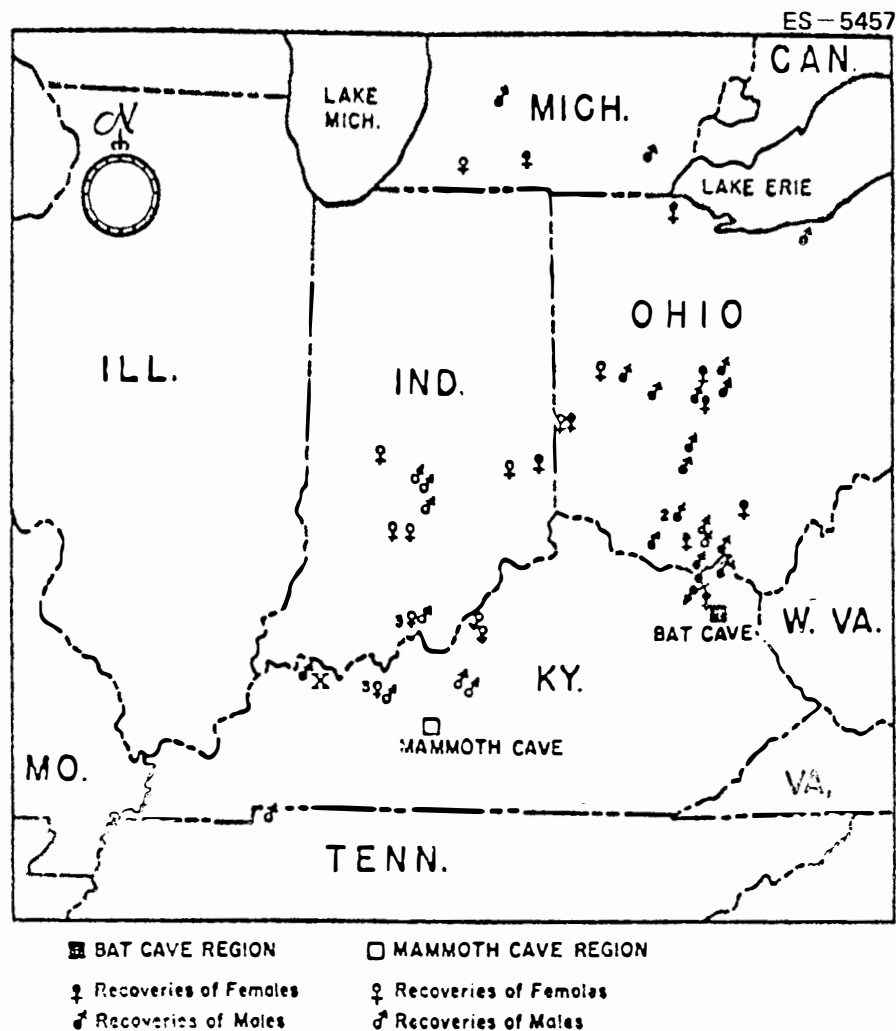


Fig. K.1. Summer distribution of *Myotis sodalis* that winters in two of Kentucky's cave regions; this distribution is based on recoveries of banded individuals. Numbers indicate multiple recoveries from the same locality. The "x" shows the location of the SRC-I site. Source: Reprinted by permission of R. W. Barbour and W. H. Davis, *Bats of America*, University Press of Kentucky, Lexington, 1969.

large, tall trees, large dead trees with loose bark, and trees with cavities. The forest canopy was not dense and was broken in many places by openings 15 to 30 m in diameter. This forest appeared to be better habitat for Indiana bats than the woods along the Green River, based on the description by Humphrey et al. of suitable Indiana bat habitat.² No flow of water was visible in Martin Creek at the time of the survey, although pools of standing water occurred in several places.

To identify the several species of bats expected to occur on the site, individual bats were captured with mist nets. Three Indiana bats were marked temporarily with red fingernail polish on a toenail so that recaptured bats could be distinguished from those captured for the first time. A fourth could be identified by an existing distinctive hole in one wing. The bats were released unharmed as soon as possible after capture.

Trapping was done on six nights in July (July 25-31) and five nights in August (August 10-15). During the July sampling period, 45 mist nets were erected in wooded areas along Martin Creek

and the Green River, or nearby (two over ponds; one in an empty barn). Nets measuring 7 ft high with widths of 18 ft, 30 ft, 42 ft, and 60 ft, respectively, were used. Most nets were placed on 8 to 10 ft poles, except that two multiple, high nets (30 ft and 24 ft) were also employed, both in the Martin Creek area.

By night one (before dark) of netting, 16 nets had been erected: 10 in the Martin Creek area and 6 near the Green River. Before night two, 14 additional nets were placed along Martin Creek, bringing the total number of nets on the site to 30. Six more nets were added to the Martin Creek area before night three (total, 36 nets). That number remained the same on night four. Four additional nets were placed in the Martin Creek area before night five (total, 40 nets). Several nets were also moved before night five. Before night six, 5 more nets were placed near the Green River. The total netting effort in July consisted of 203 net nights.

During the August sampling period, additional nets were erected along the Green River. Total approximate netting effort was 219 net nights (counting multiple nets erected together as single nets), including 146 net nights along Martin Creek (and a few at ponds) and 73 net nights along the Green River. A night vision scope and a bat detector (ultrasonic sound detector) were used to search for flying bats.

In both sampling periods, nets were opened at dusk and closed (bundled and tied) at dawn. They were checked periodically between dusk and midnight, the period of greatest bat activity. During daylight hours, the site was searched for signs of bat habitation. Many dead and living trees with loose bark or cavities were examined in an attempt to locate a nursery colony.

K.1.4 Results of surveys for Indiana bats

In the July sampling period, three Indiana bats were captured along Martin Creek, while none was captured along the Green River. All three bats were adult females (one or more years old) that showed no indication of lactation, although they appeared to be reproductive females that had had young at some time (M. J. Harvey, Memphis State University, personal communication, Sept. 30, 1980). All were captured in nets set at conventional height (on 8 to 10 ft poles) across Martin Creek. One was caught during each of the first three nights. None was recaptured. Sixteen additional bats of other species were also captured. They consisted of nine red bats (*Lasiurus borealis*), five big brown bats (*Eptesicus fuscus*), one Keen's bat (*Myotis keenii*), and one evening bat (*Nycticeius humeralis*).

In the August sampling period, one additional Indiana bat, a nonlactating adult female, was captured along Martin Creek. Again none was captured along the Green River. Fifteen red bats were also caught.

Inspection of the Martin Creek forest indicated that there were sufficient numbers of large living and dead trees with loose bark and cavities to support nursery colonies. No evidence of a nursery colony was found, although only a small fraction of the many potentially suitable nursery trees could be adequately examined to determine the presence or absence of a colony.

Searches for bats conducted with the night vision scope and the bat detector indicated that bat populations were relatively low on the site and at Richland Slough west of the site, and that the mist nets were capturing as many of the bats as could be reasonably expected.

K.1.5 Discussion of results

Although adult female Indiana bats were captured on the SRC-I site, the existence of a nursery colony was not conclusively shown. Two results indicated that there may have been no nursery colony on the site: (1) the females were not lactating and (2) no immature bats were captured. However, it is possible that females were not lactating because the young may have already been weaned by the time of the July survey. Extrapolating from the results of Humphrey et al.,² any young at the SRC-I site could have become volant by July 13 and could have been weaned before initiation of the survey on July 25. Thus, any females that had young may not have shown signs of lactation at the time of the survey. This extrapolation is based on the assumption that the raising of young at the SRC-I site, because of its more southern location, was a week advanced over that studied by Humphrey et al.² in 1975 in east-central Indiana, where young became volant by July 20. If young had been raised in the SRC-I area, however, it is puzzling that none was captured, because about half of the females and young should have remained at the colony site until the end of July (extrapolating from Fig. 3 in ref. 2).

Because it could not be determined with absolute certainty that the females had been reproductive at one time, they may have been nonparous yearlings (one year old). Female gray bat yearlings (*Myotis grisescens*) do not raise young,¹² and about half of little brown bat yearlings (*Myotis lucifugus*) are nonparous.¹³ Whether Indiana bat yearlings raise young is not known.

K.1.6 Assessment of impacts

K.1.6.1 Impacts on habitat

None of the onsite riparian forest (in which Indiana bats are known to occur) along Martin Creek will be cleared for the SRC-I demonstration project or for the possible commercial facility. The Commonwealth of Kentucky and DOE are considering purchasing the timber rights from the present land owners prior to acquisition of the SRC-I site property; this might ensure that the forest would not be cleared by the present land owners as a direct result of purchase of the property for the SRC-I facility. Once the site property and/or the timber rights have been purchased, the DOE or the industrial partner will protect the onsite forest from cutting or clearing as long as the Indiana bat is listed by the USFWS as threatened or endangered.

Up to 3.6 ha of riparian forest along the Green River will be cleared for barge facilities and water intake structure (Sect. 4.2.1 and Appendix Y). The Indiana bat was not found in this forest during the survey.

The location of demonstration facilities with respect to Martin Creek and the Green River is shown in Fig. 2.3. Buildings or other permanent or temporary structures (except stockpiles) are shown located more than 305 m (1000 ft) from the Martin Creek forest. The topsoil stockpile, excavation stockpile, and the unsuitable material stockpile will be located at least 30.5 m (100 ft) from the edge of the Martin Creek forest and 183 m (600 ft) from the SRC-I site property line at Martin Creek. Facilities associated with the possible commercial phase will probably be located within 305 m of the Martin Creek forest.

To prevent foreign materials from entering Martin Creek, interception ditches, retention dams, or other control structures will be constructed in appropriate places near the facilities. These structures should adequately control any sediment-laden surface runoff during construction and any spills of oil or other toxic materials. (Control of spills is addressed in Sect. 2.2.1.) The relatively level terrain (about a 9.1 m or 30 ft drop from the center of the site to the edge of the forest along Martin Creek) minimizes the potential for sedimentation of Martin Creek.

Air pollutants will be emitted from construction equipment and from plant facilities during operation. Impacts of these emissions on vegetation are addressed in Sect. 4.2.1.3 and this appendix. To summarize, even at localities near the plant where ground-level concentrations of the major air pollutants (SO_2 , NO_x , and particulates) will be maximal during plant operation, these concentrations (resulting from operation of only the SRC-I facility, not including presently existing ambient concentrations) are predicted to be less than one-tenth of presently existing ambient concentrations. During abnormal or upset conditions, concentrations would be significantly higher over the short term. No gross vegetational changes are expected to occur in the Martin Creek forest as a result of the addition of air pollutants from the SRC-I plant to the existing air pollutants in the area.

Direct impacts on bats

Direct impacts on bats could result from felling of trees containing nursery colonies (or possibly solitary bats), from noise of equipment, and from air pollutant emissions. It is unlikely but possible that any nursery colonies of bats are located in trees in the woods to be cleared along the Green River. To avoid possible direct effects during clearing, trees will not be cut during April through September, if reasonably feasible. If any nursery trees are cut while bats are at the cave hibernacula, bats returning in the spring should be able to find other suitable trees in the vicinity [as bats did in one recorded instance (ref. 2)].

Noise from construction equipment, plant facilities, and railroad activities might significantly disturb the bats. Sources of noise will be located at least 30.5 m from the Martin Creek forest and 183 m from the Creek. The noise of steady plant operation is expected to result in sound levels slightly higher but comparable to existing ambient sound levels (Sect. 4.2.3.2).

However, noise from rail activity (unloading 300 coal cars per day in commercial operation) will be considerably greater. Where Martin Creek is closest to the rail yard, the maximum noise level is predicted to be 67 dB (John C. Tao, International Coal Refining Company, personal communication, September 8, 1980). The EPA recommended maximum residential noise level is 70 dB. Activity of earth-moving equipment on the stockpiles will extend for approximately one year and will not be continuous. Noise generated from bulldozers and other earth-moving equipment has a roughly similar sound level range to tractors, combines, and other farm equipment presently active in fields adjacent to the Martin Creek forest. The frequency and duration of the activity on the stockpiles will, however, be greater than that of the present farm machinery.

Most wildlife species appear to become accustomed to high noise levels, such as noise from highway traffic and farm equipment. Studies showing negative effects of noise on noncaptive wildlife are lacking, and various studies have shown that many wildlife species readily adapt to noise.¹⁴ No studies have shown that noise levels expected from construction equipment and plant facilities would interfere with the bats' ultrasonic sound communication and prey-location system. A study by Griffin et al. showed that the echolocation system of bats is resistant to jamming by extraneous noise;¹⁵ apparently the bats orient themselves so that the noise and the echolocation signal are received from different angles.¹⁶

Air pollutant emissions are not likely to have significant effects on bats. Ambient levels of air pollutants present in many areas with above average concentrations have not been shown to have direct adverse effects on terrestrial wildlife. Certain air pollutants such as toxic heavy metals, which can not be rapidly metabolized by biota, could accumulate in vegetation and animals, including Indiana bats. Because of their surprisingly great longevity, frequently 10 years or more,² bats may be relatively susceptible to accumulation of toxic substances. However, airborne concentrations of such substances emitted are expected to be very small (Sect. 4.2.3), and any predictions of impacts on bats would be highly speculative. There is no available information to adequately support the hypothesis that bats would be adversely affected. Animal populations that have been affected significantly by air pollutants have been subjected to extremely high concentrations of toxic substances¹⁷ — much higher concentrations than those expected at the SRC-I facility. The only chemical pollutants implicated in widespread declines of Indiana bat populations are certain pesticides, such as DDT.^{2,9,10}

Impacts of commercialization

The proposed SRC-I project is the construction and short-term operation of a 6000 tons per stream day (TPSD) facility to demonstrate the technical operability, economic viability, and environmental acceptability of the SRC-I process (Sect. 1.1.1). Following an approximately two-year operating period, the industrial partner has the right to purchase the facility from the government. Should the demonstration prove successful, it is anticipated that the first commercial SRC-I plant of about 30,000 tpsd capacity will be constructed at the site by the industrial partner.

The demonstration plant and support facilities will occupy approximately 101 ha of the 600-ha site. If a commercial facility is constructed, the additional facilities will require approximately 33 additional hectares. Based on the preliminary site layout, it appears that the proposed site can accommodate the planned expansion; however, if the slag from the commercial facility can not be utilized as concrete aggregate, additional area will be required for disposal. Commercial expansion will probably require use of the land presently planned to be vacant, except for stockpiles, between the demonstration facility and Martin Creek. No onsite forest along Martin Creek would be cleared for facilities associated with commercialization, but the proximity of the commercial facilities would cause additional stress on any Indiana bats using the Martin Creek forest.

Operation of a fivefold expanded commercial facility will increase the air quality impacts predicted for the demonstration plant, and ground-level concentrations of air pollutants will be higher than during the demonstration phase. The concentrations can not be predicted at this time.

Impacts from secondary activities

Secondary activities consist of growth in residential and industrial areas that may be induced by the construction and operation of the SRC-I facility. Most of the work force will be available in the Owensboro-Henderson area of Kentucky and the Evansville area of Indiana; therefore, large numbers of new residents are not likely as a result of the demonstration plant construction and operation. Direct and indirect growth is estimated to result in approximately 1635 to 1776 people, including both construction workers and secondary service workers and their families. This is an increase of approximately 2.5% over the 1975 population of the two-county area. It is expected that new housing for these people will be located in or near the cities of Owensboro and Henderson, rather than in the more rural areas near the SRC-I site.

There is little induced industrial growth expected to be associated with the demonstration plant, primarily because the SRC-I products are intended to be easily shipped long distances to replace other fuels. Thus, there is no incentive for new industry to locate near the plant to use the SRC-I product. Some service-industry growth related to maintenance needs of the SRC-I plant is possible (e.g., pipe suppliers and valve distributors), but most of these needs would be met through existing area firms, rather than through new industry. Again, any new service firms would probably locate in the urban areas having good transportation access, rather than in the rural areas near the SRC-I site.

Because the exact amount and location of habitat loss due to secondary activities can not be accurately predicted, impacts of these activities on Indiana bats can not be accurately predicted.

Cumulative effects

"Cumulative effects are defined as the direct and indirect impacts of the Federal action under consideration coupled with the identifiable effects of other reasonably foreseeable actions of the Federal agency; other Federal, State, and local agencies; corporations; and individuals upon a species or its Critical Habitat" (W. C. Hickling, U.S. Fish and Wildlife Service, personal communication, June 17, 1980). Other possible future DOE projects that could affect Indiana bats in the region of the SRC-I site include the proposed Sasol Plant in Henderson County west of Henderson, the proposed W. R. Grace gasoline plant at Baskett in Henderson County, and the proposed commercial H-Coal plant in Breckenridge County. All of these would be synthetic fuel plants. They might impact riverine habitat used by Indiana bats and will emit air pollutants. Another industrial project in the region is the Rockport Generating Station of the Indiana and Michigan Electric Company. It is under construction along the Ohio River near Rockport, Illinois, about 15 km NNE of Owensboro. The effects of emissions from the Rockport Station have been assessed in conjunction with the SRC-I facility (Sect. 4.2.3). All these projects will induce secondary activities of the same types as the SRC-I facility.

Significance

The Endangered Species Act of 1973, as amended, requires the Federal agency (DOE in this case) to determine whether its project will "affect listed species or their habitat" (ref. 18). The DOE has determined during this biological assessment that the proposed SRC-I plant will have some effect on Indiana bats. This determination is based on the location of the facilities near forested riparian habitat in which Indiana bats were found and the planned clearing of a small amount of other riparian woods (where Indiana bats were not found). However, the DOE believes that direct and indirect impacts of the construction and operation of the SRC-I demonstration facility will not jeopardize the continued existence of the species for the following reasons:

1. There is no critical habitat designated by the Secretary of the Interior located in the vicinity of the proposed SRC-I plant or on the site. Therefore, no critical habitat will be affected by the SRC-I Project. Because of the widespread distribution of the Indiana bat in small colonies during the summer, it is unlikely that any particular riparian habitats would be considered critical to the survival of the species.

2. Indiana bats may continue to exist in the Martin Creek forest on the site, in the absence of unforeseen impacts not related to the proposed SRC-I facility. This forest is the only onsite habitat in which Indiana bats were found. All of this forest on the site will be protected from cutting and clearing once the land and/or timber rights are purchased by DOE and/or Kentucky, and all temporary and permanent SRC-I facilities (including construction facilities) will be located more than 30.5 m from the forest and 183 m from Martin Creek. Air pollution, possible sedimentation of streams during construction, and possible spills of toxic substances will be highly controlled and should not have significant effects on Indiana bats. Although it is possible that noise (primarily from railroad yard operation) may adversely affect the bats, the lack of literature prevents making a confident prediction.
3. During the summer, when Indiana bats are present at the SRC-I site, the species apparently occurs in small colonies widely dispersed in riparian habitats in much of the eastern United States. Unpublished results of ongoing surveys in several states indicate that Indiana bats are found in a relatively high percentage of riparian habitats searched -- a higher percentage than would be expected for an endangered species. The widespread summer distribution of Indiana bats minimizes the significance of the effects of any single project such as the SRC-I project.
4. The SRC-I site appears to be located outside of the main summer geographic ranges of Indiana bats originating from the cave hibernacula nearest the site.
5. Population declines in the species have apparently been due to impacts of disturbance at cave hibernacula, large-scale clearing of forests for agriculture, and widespread application of pesticides. The SRC-I project will not involve any of these types of impacts.

K.1.7 Adequacy of the data

The Endangered Species Act as amended states that if the "Regional Director determines as a result of the threshold examination that insufficient information exists to conclude that an identified activity or program is not likely to jeopardize the continued existence of a listed species or result in the destruction or adverse modification of its critical habitat ... the Federal agency ... shall then obtain additional information and conduct ... studies to determine how the activity or program may affect listed species or their critical habitat" (ref. 18, p. 876). The DOE believes that the information it has obtained and presented is sufficient to determine that the proposed project will not jeopardize the continued existence of the species. This information includes descriptions in the DEIS and the ER of the proposed project, processes, projected emissions, noise levels, and the natural environment. Information presented in the present document concerns the formal biological assessment conducted specifically for the Indiana bat.

Information presented that is specific to the Indiana bat shows that (1) this species has a broad distribution in the eastern United States; (2) its estimated population size is about 509,000 individuals; (3) during the summer it occurs in relatively small colonies of females and their young in riparian forest; (4) the primary threat to the species is disturbance at the cave hibernacula where the bats concentrate in large numbers; (5) the SRC-I site lies outside of the main summer geographic ranges or concentrations of Indiana bats; (6) there may be no nursery colony on the site, even though adult females occurred on the site; (7) summer habitat on the site in which Indiana bats were found will not be cut or cleared for SRC-I facilities and will be protected upon acquisition of timber rights and/or the property; (8) temporary and permanent facilities (except stockpiles and commercial facilities) will be limited to areas more than 305 m from the Indiana bat habitat along Martin Creek; (9) air pollutant emissions will be limited to small amounts that should not have significant effects on Indiana bats or their habitat; and (10) no cave hibernacula or critical habitat will be affected. This information indicates that the SRC-I project is not expected to jeopardize the continued existence of the Indiana bat species.

Although the DOE considers that overall the information is adequate, certain types of information were lacking in the scientific literature and were not adequate to predict impacts with a great deal of certainty. This information concerns effects of noise and air pollutants on bats. Studies of the effects of noise on noncaptive wildlife in general have shown that wildlife usually appears to become accustomed to noise. However, virtually nothing has been published on the effects of noise on non-captive bat populations.

The effects of air pollutants on bats is another area in which virtually no information has been published. Although it is known that the SRC-I facility will emit the usual air pollutants (e.g., SO_2 , NO_x , and particulates) and unique pollutants or combinations of pollutants (e.g., certain organics and hydrocarbons), all pollutants to be emitted can not be identified at this time because of unknown aspects of the SRC-I process. This identification will have to wait until operation of the facility.

K.1.8 Recommendations for further studies

The field survey did not begin until July 25, by which time some young in any colony may have already been weaned and some individuals may have already dispersed to other areas. Therefore, the DOE and the industrial partner will support another survey on the site during the spring and summer of 1981. This survey will be initiated at the most desirable time to locate any nursery colonies that might be present. The results of this 1981 survey will be submitted to the USFWS. At that time, recommendations for any additional studies will also be submitted to the USFWS and will depend on the new results to be obtained as well as on the results presented in the present document.

K.2 AIR POLLUTION EFFECTS

Negative effects of air pollutants on plants include reduced growth and reproduction due to various physiological changes caused directly by the pollutants, increased susceptibility of plants to parasites and diseases, and mortality of individual plants. The many species of plants are generally divided into three levels of sensitivity to air pollutants: sensitive, intermediate, and tolerant. Under conditions of low dosage levels, vegetation and soils may function as important sinks for airborne contaminants without adverse effects. Under intermediate dosage, subtle adverse effects (e.g., reduced growth) may occur, particularly in sensitive plant species. Exposure to high dosage may induce acute morbidity or mortality in sensitive and intermediate plants. Effects of air pollutants on natural ecosystems in different areas have ranged from virtual elimination of vegetation to subtle changes, including slight reductions of species diversity due to the loss of one or a few sensitive species, and reduced productivity of certain species. In forest ecosystems, certain plant species could become less abundant because of the effect of air pollutants on the species' competitive interactions.¹⁹ Such species could be important to wildlife. Current ambient levels of air pollutants in many areas of the eastern U.S. adversely affect plant productivity.²⁰ Estimates of annual national economic losses to plants caused by effects on crops and ornamentals, for example, have ranged from 135 million²¹ to 500 million dollars.²² If all plant species and other factors are considered, it is estimated that annual loss would exceed a billion dollars.²² Increased air pollution from industrial development will increase this impact.

Sulfur dioxide, nitrogen dioxide, carbon monoxide, and other gases and particulates will be emitted during plant operations. Under normal operating conditions, applicable EPA air quality standards will not be violated (Sect. 4.2.3.1), although this does not guarantee the absence of subtle effects on vegetation. Unplanned, nonroutine emissions could release greater quantities of sulfur dioxide, dust, and hydrocarbons into the atmosphere than normal operations during short time periods. While plant species vary in their sensitivity to sulfur dioxide, nitrogen dioxide, carbon monoxide, and particulate matter, vegetation near the site will likely experience few directly observable effects from any of these pollutants, except, possibly, sulfur dioxide, assuming standards are not violated. Because the maximum pollutant concentrations due to plant operation would be a small fraction of existing levels, any impacts due to the plant would probably be undetectable.

K.2.1 Sulfur dioxide

At the localities where pollutant concentrations will be maximal as determined by wind direction, the normal operation of the plant is expected to increase ambient ground-level concentrations of SO_2 by $9.5 \mu\text{g}/\text{m}^3$ for the 3-h maximum, $2.4 \mu\text{g}/\text{m}^3$ for the 24-h maximum, and $0.2 \mu\text{g}/\text{m}^3$ for the annual average (Sect. 4.2.3.1). These concentrations compare to current ambient levels in the area of 824, 190, and $20 \mu\text{g}/\text{m}^3$, respectively. These ambient levels could already adversely affect sensitive plant species. Various of the following published studies indicate that the increased concentrations of SO_2 near the facility would have adverse effects on only the most sensitive plant species, although such effects could likely not be distinguished from effects of

current ambient levels of SO_2 . Four-h SO_2 concentrations that caused leaf injury to 22 different agricultural crops ranged from $629 \mu\text{g}/\text{m}^3$ to $1834 \mu\text{g}/\text{m}^3$ (ref. 23). In the presence of ozone or nitrogen dioxide, 4-h SO_2 concentrations that resulted in foliar injury in 10 agricultural crops ranged upward from $262 \mu\text{g}/\text{m}^3$ (ref. 24). For sensitive plants, it has been projected that 4-h SO_2 concentrations required to produce threshold injury are from 262 to $2620 \mu\text{g}/\text{m}^3$ (ref. 25). Similarly for intermediate plants, the concentrations required are 1310 to $13,100 \mu\text{g}/\text{m}^3$. For sensitive woody plants in the southeastern U.S., it has been estimated that 3-h SO_2 concentrations required to produce threshold injury are from 786 to $1572 \mu\text{g}/\text{m}^3$ (ref. 26).

These various studies and the predicted SRC-I emissions indicate that, at least over short periods, SO_2 emissions from the proposed facility should have little impact on most plant species. However, the increasing ambient concentrations of certain pollutants, such as ozone and peroxyacetyl nitrate (PAN),²⁰ may result in plant injury from SO_2 concentrations lower than the above levels, producing threshold injury. This speculation is supported by the findings of several studies that SO_2 concentrations below the threshold injury concentrations for SO_2 can cause injury when other pollutants are present.²⁷ Effects of chronic, low-level exposures are more difficult to assess than those of short-term exposures, because few long-term studies have been done, and there are, subsequently, insufficient data. Most field studies near polluting industries have not been able to separate the effects of acute and chronic exposures. In one long-term study, white pine (a sensitive species) continued to increase in volume over a 10-year period when concentrations of SO_2 averaged $21 \mu\text{g}/\text{m}^3$ during each 6-month growing season.²⁷

Soybean cropping is the predominant land use in the area; pasture and tobacco are minor uses. Soybeans, tobacco, and most pasture grasses are considered sensitive species²³ and could experience slightly reduced productivity in areas of maximum concentration near the site. Considering that the increase in concentration of SO_2 is very small in comparison to ambient levels, reduction in productivity would probably not be detectable.

During abnormal operating conditions, SO_2 concentrations offsite could be high for a few hours. This could affect the growth of very sensitive plant species to a greater extent than could the chronic low levels during operation.

K.2.2 Nitrogen oxides

Nitrogen dioxide's threshold of injury to vegetation appears to be severalfold higher than that of sulfur dioxide.²² Nitrogen dioxide concentrations in the ambient air rarely reach phytotoxic levels. When NO_2 concentrations are high, other pollutants are usually present; resulting plant injury is therefore most commonly from pollutant combinations, rather than from exposure to NO_2 alone.²⁰ Nitrogen oxide causes very little injury to trees and shrubs, except occasionally when they are adjacent to large point sources.²⁶

Normal plant operation is expected to increase the ambient annual average NO_x concentration of $16 \mu\text{g}/\text{m}^3$ by $2.7 \mu\text{g}/\text{m}^3$ (Sect. 4.2.3.1). Because this increase represents only 2.7% of the national ambient air quality standard ($100 \mu\text{g}/\text{m}^3$) and 17% of ambient levels, there should be no significant impacts on vegetation from nitrogen oxide emissions.

K.2.3 Carbon monoxide

Carbon monoxide has a relatively short life or residence time in the atmosphere and is not recognized as a pollutant having serious effects on vegetation. Because predicted increases in maximum concentrations due to facility operation represent less than 10% of the air quality standard (Sect. 4.2.3.1), no significant impacts are anticipated.

K.2.4 Hydrocarbons

During normal operations, most hydrocarbons are expected to be consumed by the controlled combustion system (Sect. 2.2.1). The maximum 1-h concentration of nonmethane hydrocarbons is conservatively predicted to be $236 \mu\text{g}/\text{m}^3$ (Sect. 4.2.3.1), which about equals the air quality guideline ($240 \mu\text{g}/\text{m}^3$). This should not cause significant impacts on vegetation near the site, but will add a small amount to regional impacts of hydrocarbon emissions.

K.2.5 Peroxyacetyl nitrate (PAN)

Peroxyacetyl nitrate is formed almost exclusively from the photochemical reaction of unsaturated hydrocarbons with oxides of nitrogen²⁰ and is a regional, rather than a site-specific, problem. A suspected phytotoxicant on vegetables, PAN has been an important problem in the Los Angeles basin.²⁶ Woody plants, however, are apparently very tolerant of PAN. The region around the SRC-I facility would experience a small increment to any impacts caused by PAN.

K.2.6 Particulates and trace metals

Highly concentrated airborne particulates can affect vegetation by clogging stomata and reducing light penetration into leaves (thus interfering with plant respiration and photosynthesis). Nonvolatile trace metals contained in particulates, volatile trace metals condensed on the surfaces of particulates, and trace metals in vapors can be deposited on the surfaces of vegetation and on the soil, resulting in toxic effects on vegetation and animals. However, two reports have indicated that trace metal emissions in the next several years will not have serious effects on biota.^{28,29} Both reports emphasized that knowledge of source terms and effects on biota is lacking and that further research is needed. Based on data from conventional coal combustion studies for power plants, Turner and Strojjan³⁰ concluded that atmospheric releases of trace elements do not present acute ecological problems. However, the effects of chronic exposure of ecosystems to long-term, low-level releases and accumulation in soils are not that well known. Thus, short-term effects to vegetation and wildlife are not expected to occur, but data are insufficient to predict what long-term effects, if any, will occur as a result of facility operation.

During facility operation, particulates containing trace metals will be released by coal handling and storage facilities and by coal conversion-related processes including coal combustion for steam production. Particles from coal handling and storage will primarily settle close to the facility and should have no significant effect on vegetation surrounding the site. Normal plant operation (excluding coal handling and storage) is expected to increase the ambient annual average particulate concentration of $42 \mu\text{g}/\text{m}^3$ by $1.0 \mu\text{g}/\text{m}^3$ (Sect. 4.2.3.1). This increase in concentration represents 2% of the secondary air quality standard ($60 \mu\text{g}/\text{m}^3$). No significant impacts on vegetation or animals due to particulates should occur.

K.2.7 Cooling tower impacts

During operation of the plant, small releases of cooling tower water termed "drift" will occur. The drift will contain salts, biocides, and inhibitors. Cooling tower installations at existing industries have not had significant effects on biota. Thus, significant impacts at the proposed facility would not be expected. The amount of salts deposited on vegetation in drifting water droplets from freshwater cooling towers is considered inconsequential based on numerous studies.³¹ The amount of rainfall in the site area is high and salts would be readily washed from vegetation.

Using process wastewater as makeup water for the cooling tower (an option not currently in project plans but one being considered as a possible alternative mode of operation) cannot be accurately assessed at this time, given the uncertain chemical characteristics of the priority organics of this water. A complex set of trace elements, organics, dissolved solids, and other constituents would be present in this water. These constituents, which would be heated during certain plant processes and could form chemical species such as chloroform and chlorophenols, would be emitted during cooling tower operations. The biological effects of these constituents after release from the tower is not known, although their concentrations would likely be so small that no significant impacts to biota would occur. Careful monitoring of the cooling tower makeup water and/or use of other than process water as a cooling tower makeup source would be mitigating measures.

K.3 FISH AND WILDLIFE MITIGATION FOR THE SRC-I PROJECT

K.3.1 Introduction

The U.S. Department of Energy (DOE), in cooperation with the Kentucky Department of Fish and Wildlife Resources (KDFWR) and the U.S. Fish and Wildlife Service (USFWS), is considering several options for mitigating the fish and wildlife impacts of the SRC-I project. The options

involve habitat acquisition and improvement, habitat improvement on the site, or providing funds for mitigation to KDFWR. Representatives of the three agencies met at the site on March 24, 1981, where the options were discussed. The purpose of this section is to present these options and to provide initial estimates of the amount of mitigation that would offset habitat value losses caused by SRC-I. Habitat value losses will result from habitat destruction on land to be occupied by facilities and from the reduced potential for wildlife use of habitats near the major industrial facility.

The term "mitigation" in this discussion refers to increasing the value of habitat for fish and wildlife to offset the value lost because of the proposed SRC-I project. Habitat values could be increased by improving a habitat that is currently in poor condition or by preserving existing high-quality habitats that might otherwise be destroyed (e.g., by clearing for agriculture).

Descriptions of fish and wildlife resources at the SRC-I site are given in Sects. 3.2.1.3 and 3.2.2.3, and the impacts needing mitigation are discussed in Sects. 4.2.1.3 and 4.2.2.4. Other mitigation is discussed in Sect. 4.6. Impacts on floodplains and wetlands are presented in Appendix D.

K.3.2 The options

The options being evaluated are:

1. improvement of wildlife habitat on the site by developing certain vegetation plantings or allowing natural succession to occur on land to be unoccupied by SRC-I facilities;
2. purchase of forested land on the east side of Martin Creek for management by the industrial partner or DOE, or for preservation in its natural state;
3. purchase of land adjacent to existing State wildlife management areas and transfer to the KDFWR for management;
4. purchase of the forested wetlands at Richland Slough and transfer to KDFWR for management; and
5. provision of funds to KDFWR for implementation of other mitigation options.

One or more of these options could be used to offset the impacts of the proposed project. The options can involve mitigating impacts of the demonstration plant alone or both the demonstration and commercial phases. The relative ecological values of the options are discussed in the following paragraphs. The final section estimates the amount of habitat acquisition necessary to offset habitat value losses. Currently, DOE has no authority to initiate action on any option except the first.

K.3.2.1 Improving fish and wildlife habitat on the site

The agricultural land on the site is very productive. Barring industrial use, the land could provide excellent wildlife habitat if desirable vegetation were planted and managed or if natural succession were allowed to occur. Vacant cleared or agricultural land on the site, if allowed to undergo natural succession, would develop first into old field habitat with dense herbaceous vegetation, which would be followed by shrubland habitats, then by young forest, and finally by mature forest. Management could involve developing certain plantings, manipulating the vegetation in some way to obtain a desired mix of habitat types, and creating ponds or other wetland habitats.

With a major industrial facility on the site, the actual value of improved onsite habitat to wildlife populations would be relatively low. Any forest that would develop on the site would occur in narrow strips or would be broken into relatively small blocks by the facilities, roads, and railroads and would be of little use to the many forest species that need larger blocks of relatively undisturbed forest. In addition, to assess conservatively the value of onsite habitat to wildlife, it must be assumed that such habitat would eventually be cleared for the commercial facility. Thus, any forest allowed to develop on the site would not become mature enough to provide much benefit to wildlife. Because a fence will surround the site, medium-sized and large mammals would be excluded. Ponds would have little value to the fisheries

resource because they would lack direct connection to the Green River or to a creek. In view of these factors, this option would not be likely to produce major benefits for fish and wildlife.

DOE plans to plant vegetation or allow natural succession on lands to be unoccupied by facilities (Sect. 4.2.1.1). Management will be conducted as necessary to restore natural vegetation on lands disturbed temporarily during construction. Five tracts of land on the site are considered to be suitable as mitigation areas (i.e., they have the potential to be more valuable to wildlife if managed properly in the presence of the demonstration facility than if used for intensive agriculture in the absence of demonstration facilities). All of these tracts would be more than 100 m from major facilities and are currently agricultural land. The sizes of the tracts are 4.8 ha, 9.5 ha, 30.5 ha, 40.8 ha, and 45.1 ha (total 130.7 ha or 323 acres).

K.3.2.2 Purchase of additional Martin Creek forest

Roughly 30.4 ha (75 acres) of forest lie adjacent to the site on the east side of Martin Creek. About one-third of the forest is in creek bottoms and represents a floodplain wetland habitat. This forest supports a high-quality wildlife community (Sects. 3.2.1.3 and 4.2.1.3). In addition, several individuals of the Indiana bat, an endangered species, have been observed in this forest. Portions (perhaps about one-half) of the forest have been selectively cut for timber and may be cut more in the future. About one-half of the forest could apparently be easily cleared for agriculture, based on its elevation of greater than 113 m (370 ft).

Acquisition of this forest would ensure its preservation for the diverse wildlife community that it currently supports. Protection from selective cutting as well as from clearing for agriculture would probably enhance its value to the Indiana bat, although the forest is not critical to the survival of the species. In addition, habitat of moderate value to fish and other aquatic biota would be preserved. The creek provides valuable spawning habitat for fish populations associated with the Green River, and there is a very small marsh near the creek's mouth. Because this forest contains a floodplain wetland, supports a very diverse wildlife community, is inhabited by the Indiana bat, and provides fish spawning habitat, its preservation could provide benefits to many species.

However, the uncertain future of the agricultural lands immediately surrounding this forest detracts from the benefits to be gained by preservation. Indirect effects of the SRC-I project may include some commercial or other development of land surrounding this forest. Such developments, in addition to the adjacent SRC-I facility, would have negative impacts on nearby wildlife communities and would reduce the value of the Martin Creek forest to wildlife. The KDFWR considers that this forest is too small to provide much potential benefit as a Kentucky wildlife management unit and would leave responsibility for management of the forest to DOE. Mitigation would likely involve preservation rather than management of vegetation because it is doubtful that any management would significantly improve the value of the forest to fish and wildlife.

Although not discussed at the three-agency meeting, a possible action that could be added to this option is the purchase of agricultural lands adjacent to the Martin Creek forest. Additional land would increase the size of the mitigation area and thus would reduce the potential for disturbance by indirect impacts such as commercial development and might make the area more adequate as a KDFWR management unit.

K.3.2.3 Purchase of land adjacent to Kentucky wildlife management areas

Approximately 78.5 ha (194 acres) of land at the Frank Sauerhaber Unit near Henderson and 94.8 ha (234 acres) at the Ash Flats Unit across the river from the proposed site could be purchased for transfer to the KDFWR. This action would enhance the value of the existing wildlife management areas, which are managed for waterfowl. The land at the Sauerhaber Unit is slightly more valuable for management because waterfowl are more numerous there than at the Ash Flats Unit.

At the Sauerhaber Unit, the land being considered for purchase consists of roughly 5 to 10% forest, 80 to 95% cropland, and 10% land with scattered permanent standing water. All of this land is subject to annual flooding. Management by KDFWR would probably involve maintaining about the same amount of cropland and forest as presently exists and increasing the amount of permanent standing water. The croplands would be managed for waterfowl and would thus be taken out of agricultural production.

At the Ash Flats Unit, the land consists of roughly 15 to 30% forest, 10 to 15% land with scattered permanent standing water, and 55 to 85% cropland. About one-half of this land is subject to annual flooding. Management would be similar to that at the Sauerhaber Unit. Barring purchase of the land for management, the forest in this area will probably be cleared for agriculture in the near future.

The properties at both units have limited value for fish and other aquatic life. The wetlands have limited value to fish because they lack direct connections to the Ohio or Green rivers or to a creek. During flooding, some of the habitat is valuable for spawning of numerous fish species.

Preserving the forested areas at these management area units would benefit many species that presently reside in the existing forests on the units. The amount of benefit, however, is limited by the small amount of woodland involved and the fact that the land would be maintained primarily in cropland, which is valuable to fewer species than forest.

K.3.2.4 Purchase of Richland Slough

Richland Slough consists of more than 263 ha (650 acres) of floodplain forest. Much of the forested area appears to be permanently wet or to have standing water. This forested area is highly valuable to a large number of game and nongame species including waterfowl. In addition, the Indiana bat may occur in the forest. The slough also provides high-quality habitat for fish and other aquatic species. This quality is enhanced by the slough's large area, the presence of substantial areas of standing water and emergent vegetation, and the slough's direct connection with the Green River. Spawning and nursery habitat for fish is provided, and the area is used for sport fishing by the local residents.

The slough forms a relatively large area of forest in a region that has lost most of its original forest to clearing for agriculture. Most wildlife species in the region (including amphibians, reptiles, birds, and mammals) require brushy or forested areas and are adversely affected by creation of cropland. Even most of those species that benefit from cropland in the region also benefit from forest or forested wetlands. Populations of these species in the area may be limited by the lack of forest or forested wetland because the amount of cropland in the region far exceeds the amount that would provide maximum benefits to such species.

Although Richland Slough is farther from the site than the forest on the east side of Martin Creek, it could still be affected by nearby commercial or other development that could result indirectly from the SRC-I project. However, because the Richland Slough covers a much larger area and extends for a long distance along a creek [approximately 8 km (5 miles)], only relatively small portions of it are likely to be affected.

Preservation of Richland Slough would prevent further loss of this important habitat, which has already been partly cleared for agriculture [U.S. Geological Survey topographic maps indicate that clearing has occurred in the slough below 113 m (370 ft) elevation] and is subject to additional clearing. The slough and adjacent areas that contain some forest as well as cropland could provide an area of sufficient size for a Kentucky wildlife management area.

K.3.2.5 Other possible mitigation options

Other options being considered include the purchase of other wildlife habitats in the region and the providing of funds to KDFWR for any fish and wildlife management they deem appropriate.

K.3.3 Estimation of habitat acquisition or improvement needs

Mitigation of the impacts of the proposed SRC-I project could consist of offsetting the loss of habitat values by increasing habitat values in areas not occupied by facilities. For example, this could be done by purchasing cropland and converting it to forest or by purchasing and preserving an equal amount of existing forest that would otherwise be cleared. These two approaches can be assumed to provide about the same quantity of improvement.

Objective quantification of habitat value loss and gain is desirable. However, any quantification cannot be highly objective because of the uncertainties involved. These uncertainties

include the extent to which wildlife are disturbed by nearby industrial facilities, the extent to which induced development will occur and affect a mitigation area, and the extent to which a forested area will be cleared if not purchased for mitigation.

During the March 24th meeting at the site, a preliminary estimate of the value of the site to waterfowl was made using a modification of the formal habitat evaluation procedure (HEP) being developed by the USFWS. The estimate was for waterfowl because they are the primary species of interest for management in this region. It was initially estimated that the approximately 223 ha (550 acres) of land to be used for demonstration facilities at the site represented a total value to waterfowl of 1200 habitat units and that land for the demonstration plus commercial facilities represented 3300 units. However, the 223 ha of land to be covered by demonstration facilities does not include small or narrow parcels of land between buildings and other facilities (Fig. 2.3). These small land parcels will be partially used for intraplant roads and parking lots and will be of virtually no value to fish and wildlife. Adding the area of these land parcels to the 223 ha to be covered by demonstration facilities yields a total loss to wildlife of 285 ha (704 acres). Therefore, construction of the demonstration facility would actually involve a value loss of about 1530 habitat units. This estimate does not include some temporary construction areas, the excavation area, topsoil stockpile, barge slip dredge spoil disposal area, and unsuitable material disposal area (Fig. 2.3), because impacts at these areas may be temporary. These areas total about 48 ha (119 acres). In addition, this estimate does not include the reduced potential for wildlife use of habitats near the demonstration facility. To provide sufficient mitigation, it is now estimated that 103 (Sauerhaber) or 125 (Ash Flats) ha (254 or 310 acres) of land near existing Kentucky wildlife management areas could be purchased and improved by KDFWR to obtain a value gain of 1530 habitat units. Similarly, a total of about 263 ha (650 acres) would have to be acquired and improved to mitigate the combined effects of the demonstration and commercial facilities.

Another major option is to purchase Richland Slough. The HEP could not be as objectively applied to Richland Slough because it is uncertain how much of the slough forest would be cleared for agriculture if not preserved and because most species that would benefit from preservation of Richland Slough are not yet covered by the HEP. Therefore, the following assessment has been prepared, which attempts to quantitatively compare the benefits of preserving Richland Slough to the benefits of managing the croplands and small amounts of forest at the existing wildlife management areas.

All of the mammalian and avian species that can be reasonably expected to be potential summer residents or breeders in the Owensboro-Henderson area were listed (Table K.1) based on their geographic ranges indicated in various publications. Then, for each mitigation option the benefit to each species was judged to be low, medium, or high, again based on various publications. A value of 1 was assigned to low, 2 to medium, and 3 to high. These values were then totaled for each option (Table K.1). Figure K.2 summarizes the results for all species and for fur/game species.

The greater value indicated for the Richland Slough in Fig. K.2 reflects the fact that many more species in this area would benefit from an increase in forest than an increase in cropland, even if cropland is managed for waterfowl. The magnitude of habitat value gain that would be obtained by purchasing Richland Slough depends primarily on the amount of this forest that would be saved from clearing for agriculture. Because the future amount of clearing cannot be accurately estimated, a subjective judgment must be made on how much value would be gained.

Based on the slough's value to wildlife and the fact that fish, other aquatic biota, reptiles, and amphibians would also benefit, DOE believes that preservation of an acreage of Richland Slough somewhat less than that which would be added at the existing wildlife management areas would offset the impacts of the SRC-I project. It is estimated that preservation of about 89 ha (220 acres) of Richland Slough would offset impacts of the demonstration phase and 222 ha (550 acres) would offset impacts of the combined demonstration and commercial phases.

Preservation of the Martin Creek forest could also benefit a large number of species because it also is a floodplain forest. However, because of its small size, the uncertainties involving indirect impacts, and the proximity to the SRC-I facility, the potential for habitat value gain through improvement is not as great as at the Richland Slough forest. DOE believes that preservation of the roughly 30-ha (75-acre) forest on the east side of Martin Creek would provide a gain of about 300 habitat units, which is about one-fifth the gain needed to mitigate for the demonstration facility. The remaining gain required might be provided by an additional habitat acquisition and improvement on about 125 ha (310 acres) of agricultural land adjacent to the Martin Creek forest.

Table K.1. Value to breeding birds and mammals of land with mostly crops and a small amount of forest and standing water compared to floodplain forest or forested swamp

Species ^a	Cropland and small amount of forest ^b	Floodplain forest ^b
Opossum ^c	M	H
Southeastern shrew	M	H
Least shrew	M	M
Shorttail shrew	M	H
Eastern mole	M	M
Little brown myotis	L	M
Keen myotis	L	M
Indiana bat	L	M
Small-footed myotis	L	M
Silver-haired bat	L	H
Eastern pipistrel	L	M
Red bat	L	H
Big brown bat	L	M
Hoary bat	L	H
Evening bat	L	M
Raccoon ^c	L	H
Longtail weasel ^c	M	H
Mink ^c	M	H
Striped skunk ^c	M	H
Spotted skunk	M	H
Red fox ^c	M	H
Gray fox ^c	M	H
Bobcat ^c	L	H
Eastern chipmunk	M	M
Gray squirrel ^c	L	M
Fox squirrel ^c	M	M
Flying squirrel	L	M
Beaver ^c	L	H
Harvest mouse	M	L
White-footed mouse	L	H
Deer mouse	L	M
Golden mouse	L	H
Eastern woodrat	L	H
Bog lemming	L	M
Meadow vole	L	M
Muskrat ^c	L	M
Meadow jumping mouse	M	L
Eastern cottontail ^c	M	M
Swamp rabbit ^c	L	H
Whitetail deer ^c	M	H
Mallard ^c	M	H
Black duck ^c	M	H
Pintail ^c	M	H
Gadwall ^c	M	H
Blue-winged teal ^c	M	H
Wood duck ^c	M	H

Table K.1 (continued)

Species ^a	Cropland and small amount of forest ^b	Floodplain forest ^b
Cooper's hawk	M	H
Sharp-shinned hawk	M	H
Marsh hawk	M	M
Red-tailed hawk	M	H
Red-shouldered hawk	M	H
Broad-winged hawk	M	H
Sparrow hawk	M	M
Bobwhite ^c	H	M
Great blue heron	L	H
Green heron	L	H
Black-crowned night heron	L	H
Spotted sandpiper	L	M
American woodcock	M	H
Mourning dove ^c	M	M
Yellow-billed cuckoo	M	H
Screech owl	M	M
Great horned owl	M	H
Barred owl	M	H
Chuck-wills-widow	L	M
Whip-poor-will	L	M
Belted kingfisher	L	H
Yellow-shafted flicker	M	M
Pileated woodpecker	L	H
Red-bellied woodpecker	L	H
Red-headed woodpecker	L	H
Hairy woodpecker	L	H
Downy woodpecker	L	H
Eastern kingbird	L	M
Crested flycatcher	L	H
Acadian flycatcher	L	H
Eastern wood pewee	L	H
Horned lark	M	L
Blue jay	L	H
Common crow	M	M
Carolina chickadee	L	H
Tufted titmouse	L	H
White-breasted nuthatch	L	H
Carolina wren	L	H
Catbird	L	M
Brown thrasher	L	M
Wood thrush	L	M
Eastern bluebird	M	M
Blue-gray gnatcatcher	L	H
Loggerhead shrike	L	L
White-eyed vireo	L	H
Yellow-throated vireo	L	M

Table K.1 (continued)

Species ^a	Cropland and small amount of forest ^b	Floodplain forest ^b
Red-eyed vireo	L	H
Black-and-white warbler	L	H
Prothonotary warbler	L	H
Swainson's warbler	L	H
Parula warbler	L	H
Yellow warbler	L	H
Cerulean warbler	M	H
Yellow-throated warbler	L	H
Prairie warbler	M	L
Ovenbird	L	M
Louisiana waterthrush	L	H
Yellowthroat	L	H
Yellow-breasted chat	M	M
Kentucky warbler	L	H
Hooded warbler	M	H
American redstart	L	H
Eastern meadowlark	M	L
Red-winged blackbird	L	M
Common grackle	M	M
Orchard oriole	M	M
Baltimore oriole	M	M
Scarlet tanager	L	H
Summer tanager	L	M
Cardinal	L	M
Blue grosbeak	L	L
Indigo bunting	M	M
American goldfinch	M	L
Dickcissel	H	L
Towhee	M	M
Grasshopper sparrow	M	L
Bachman's sparrow	M	L
Chipping sparrow	M	L
Field sparrow	H	L
Song sparrow	M	M

^aAll species are potential summer residents or breeders in the region surrounding the SRC-I site except the pintail, gadwall, and teal.

^bL, low value; M, medium value; and H, high value.

^cGame species or fur species.

Mitigation on the site would not produce major benefits for fish and wildlife, because of the problems noted in the previous section. It is estimated that management of the 131 ha (323 acres) of land suitable for mitigation would provide a value gain of about 400 habitat units. This gain is one-fourth of the mitigation needed to offset losses caused by the demonstration facility.

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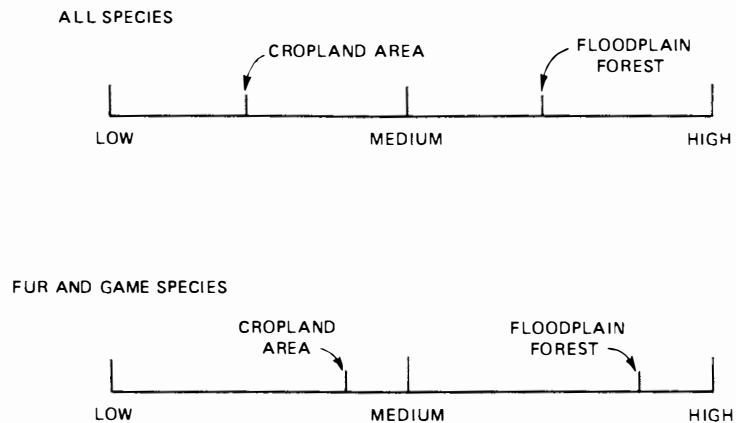


Fig. K.2. Comparison of habitat values of forest and cropland areas based on values assigned in Table K.1. The cropland area is assumed to contain a small amount of forest and standing water.

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Appendix L
GEOLOGY AND SOILS

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Appendix L

GEOLOGY AND SOILS

L.1 GEOLOGY

L.1.1 Physiography

The proposed site lies within the Western Coal Field portion of the Interior Low Plateaus Province (Fig. L.1.). The site is within the alluviated Ohio River Valley, a wide trench eroded in the bedrock surface and subsequently filled with sand and gravel by glacial meltwaters.¹ Both the Ohio River and the Green River flow in channels cut into this outwash deposit of alluvium. The Green River flows along the south edge of the site, while the Ohio River passes about 4.5 km (2.8 miles) north of the site.

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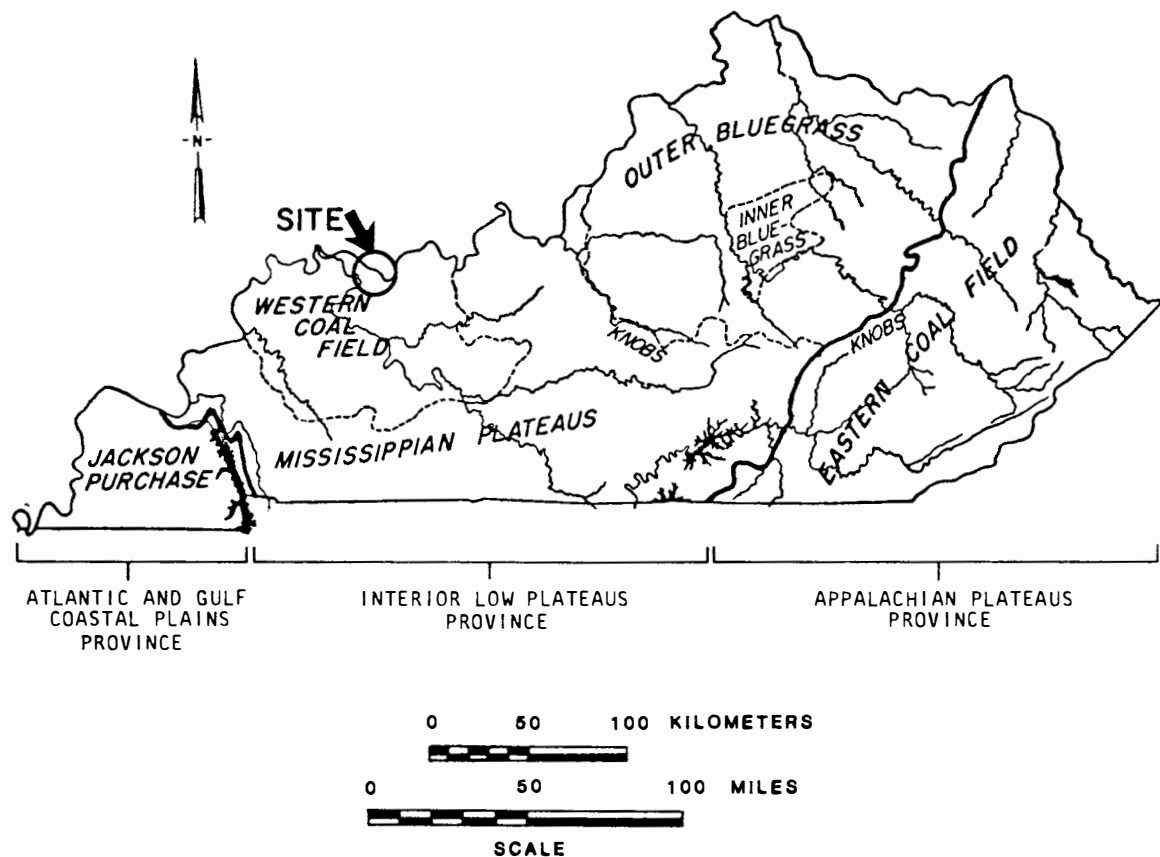


Fig. L.1. Physiographic provinces of Kentucky. Source: ER, Appendix B, Fig. B.1.

Surface drainage in the region is by small creeks and sloughs which drain into the Ohio or the Green river. Stream channel gradients in the alluvium are typically less than 5%, or 5-m fall per 100 m of length (5-ft fall per 100 ft of length). Most of the creeks are intermittent, but a few that originate in the bordering hills may be spring fed. Man-made drainage ditches and farm ponds have modified the surface drainage on the alluvium.

L.2 STRATIGRAPHY

L.2.1 Regional setting

The rock column in northwestern Kentucky includes up to 4267 m (24,000 ft) of young sediments and older sedimentary rocks. Figure L.2 presents the ages, formations, groups, thicknesses, and the character of these deposits in a generalized stratigraphic column. A generalized geologic map of the site region is shown in Sect. 3.2.2.

The surficial geology in this region resulted from glacial activity of the Pleistocene Epoch, although glaciers did not cover this part of Kentucky.¹ The deposits here formed during the ice melting of the Wisconsin glacial stage (the fourth and final glacial stage) and the Illinoian glacial stage (the third glacial stage). The meltwater from each ice recession was laden with silt, sand, and gravel that were subsequently deposited in the deeply eroded channel of the Ohio River Valley to form a broad alluvial plain extending to the present base of the hills surrounding the Ohio and Green River Valleys. Deposition of this sediment in the main valley caused tributary valleys to become dammed; and lake sediments of fine sand, silt, and clay were deposited behind these natural dams. In addition, fine silt picked up by the strong northerly winds was deposited as loess on the surrounding hills.

The top of the underlying bedrock in northwestern Kentucky consists of Pennsylvanian coal-bearing strata. Alternating beds of shale, sandstone, limestone, coal, and underclay constitute (in descending order) the Henshaw, Lisman, Carbondale, Tradewater, and Caseville formations. The Lisman and Carbondale formations contain the most coal.²

Underlying these Pennsylvanian formations are numerous Upper-Mississippian oil-producing limestones and sandstones. These and deeper rocks are known from subsurface data only.

L.2.2 Site conditions

L.2.2.1 Surficial deposits

Two major types of surficial deposits are found on the site: recent alluvial deposits of the Green River and Pleistocene terrace deposits from glacial meltwater. The thickness of these deposits varies, but the bedrock is overlain by approximately 40 m (130 ft) of unconsolidated material. Generalized north-south and east-west cross sections through the site, based on data from borings completed by ATEC Associates, Inc.,³ are shown in Fig. 3.6 (see Sect. 3.2.2).

L.2.2.2 Recent alluvium

Recent alluvium deposited during flooding of the Green River and consisting of interlensing clay, silt, and sand covers the lower portions of the site, usually below an elevation of 113 m (370 ft) above mean sea level (MSL). These deposits form a series of broad, shallow swales that are apparently near equilibrium, as they do not markedly aggrade or degrade when the river floods.¹

L.2.2.3 Pleistocene terrace deposits

A test boring (No. 3 in Fig. 3.6, Sect. 3.2.1.2) by ATEC (ref. 3) penetrates the total thickness of an onsite terrace. The sequence of deposits on the detailed log is presented in Table L.1.

The thicknesses of the clay and fine sand deposits vary over the site. One type of deposit commonly pinches out or grades into another type of deposit within a relatively short distance.

ERA	PERIODS OR SYSTEM	EPOCHS OR SERIES	GROUP OR FORMATION	(feet)	CHARACTER		
CENOZOIC	QUATERNARY	PLEISTOCENE	UNION FORMATION	0-68	LOESS: SILT AND SOME FINE-GRAINED SAND, MANTLES UPLANDS		
			ALLUVIUM OF OHIO VALLEY	0-130	OUTWASH SAND AND GRAVEL OVERLAIN BY SILT AND CLAY		
			ALLUVIUM OF TRIBUTARY VALLEYS	0-80	GLACIAL LAKE DEPOSITS: PRINCIPALLY SILT AND CLAY		
	TERTIARY?	UNASSIGNED	LaFAYETTE FORMATION	0-1	PEBBLES OF CHERT AND QUARTZ SCATTERED PATCHY DEPOSITS ABOVE ELEVATION 450		
MESOZOIC	NOT REPRESENTED AT STUDY AREA						
PALEOZOIC	PENNSYLVANIAN	UPPER	LISMAN FORMATION (STURGIS FORMATION)	253-308±	SHALE, SANDSTONE, COAL, AND SEVERAL THIN LIMESTONE BEDS. COARSE-GRAINED ANVIL ROCK SANDSTONE MEMBER, 20 TO 50 ft THICK, IN LOWER PART		
		MIDDLE	CARBONDALE FORMATION	300-450±	SHALE, COAL BEDS, SEVERAL THIN LIMESTONE BEDS, AND A PROMINENT WHITE, MEDIUM-GRAINED SANDSTONE, 20 TO 100 ft THICK		
			TRADEWATER FORMATION	400-600±	MAINLY SHALE WITH COAL SEAMS, AND A THIN PERSISTENT LIMESTONE BED. SEVERAL SANDSTONES USUALLY OCCUR		
		LOWER	CASEYVILLE FORMATION	300-600±	MASSIVE SANDSTONES, MEDIUM-GRAINED, PEBBLY; A FEW BEDS OF SHALE, COAL, AND LIMESTONE		
	MISSISSIPPIAN	UPPER	CHESTER GROUP	915±	LIMESTONE, SHALE, AND SEVERAL SANDSTONES		
		MIDDLE	MERAMEC GROUP	860±	MAINLY LIMESTONES, OOLITIC IN UPPER PART, DOLOMITIC IN LOWER PART		
		LOWER	OSAGE GROUP	650±	LIMESTONES AND SHALES		
	DEVONIAN	UPPER	NEW ALBANY GROUP	1,500±	BLACK SHALE		
		MIDDLE	HUNTON MEGAGROUP		MASSIVE DOLOMITIC LIMESTONE		
		LOWER					
	SILURIAN	NIAGARAN	MAQUOKETA GROUP	1,600±	MASSIVE DOLOMITIC LIMESTONE WITH SOME SILTSTONE, SHALE, AND SANDSTONE		
		ALEXANDRIAN					
	ORDOVICIAN	CINCINNATIAN	MAQUOKETA GROUP			700±	SANDSTONE AND SHALE
		CHAMPLAINIAN	OTTAWA MEGAGROUP				
			ANCELL GROUP (ST. PETER FORMATION)				
	CANADIAN	KNOX MEGAGROUP					
	CAMBRIAN	CROIXAN	POTSDAM MEGAGROUP	EAU CLAIRE FORMATION	MT. SIMON FORMATION		
PRECAMBRIAN		UNDIFFERENTIATED	BASEMENT ROCKS	?	IGNEOUS AND METAMORPHIC ROCK		

Fig. L.2. Generalized stratigraphic column of the study area. Source: H. D. Swann, "A Summary of Geologic History of the Illinois Basin," in *A Symposium on the Geology and Petroleum Production of the Illinois Basin*, joint publication of the Illinois, Indiana, and Kentucky geological societies, 1968.

Table L.1. Sequence of deposits in boring No. 3

Description of unit	Depth to surface m (ft)
Clay, silty, light brown and gray, slightly moist	0
Silt, sandy, brown, very moist	2.0 (6.5)
Sand, fine, silty, brown, moist, loose	2.4 (8.0)
Sand, brown, moist to wet, loose to medium-dense, with some silty fine sand	4.0 (13.0)
Sand, fine to medium, silty, brown to gray, with traces of coarse sand and fine gravel	12.3 (40.5)
Sand, fine to medium, brown, medium-dense to very dense, wet, with traces of coarse sand, fine gravel, and some organic material	20.7 (68.0)
Sand, fine to coarse, silty, brown, medium-dense to dense, wet, with traces of gravel and organic material; some gray, coarse, dense sands also noted	28.3 (93.0)
Shale, light gray, laminated (bedrock)	38.1 (125.0)

Source: ATEC Associates, *Preliminary Geotechnical Engineering Study*, 200 ST/D Project, Wheelabrator Cleanfuel Corporation, Kentucky Center for Energy Research, 1977.

L.2.2.4 Bedrock

The bedrock beneath the site has been interpreted from logs of oil and gas wells in the area. A bedrock topography map (Fig. L.3) indicates that the bedrock surface is at an approximate elevation of 80 m (260 ft) near sea level (MSL).⁴ The uppermost bedrock on the site consists of Pennsylvanian shale, sandstone, and coal beds and has been identified from logs of wells on and near the site as the lower part of the Carbondale Formation.

No outcrops of bedrock are present on the site. The closest outcrops are approximately 8 km (5 miles) southwest of the site, where the Carbondale Formation of Pennsylvanian Age crops out at an elevation of 122 m (400 ft) MSL. The No. 9 coal seam of the Carbondale Formation, found just below the alluvial-bedrock contact, has been mined in the hills south of the site. The hilltops are blanketed Pleistocene loess, but exposures of the Pennsylvanian Age Lisman Formation, which overlies the Carbondale Formation, can be found beneath the loess cover.

Beneath the Pennsylvanian rocks are Upper-Mississippian limestones and sandstones that produce oil in the site area but, evidently, not on the site (see Mineral Resources section of this appendix).

L.2.2.5 Structural geology

The site is located in the southeastern corner of the Illinois Basin in a subbasin called the Henderson Basin.² Located on the eastern limb of the structure, bedrock dip at the site is to the west, though minor local features cause some variation in bedrock attitude. General local bedrock structure is indicated on Fig. L.4, which is a structural contour map drawn on the base of the Mississippian Age Vienna limestone, showing a dip of approximately 7.6 m/km (40 ft/mile).⁵ Oil well logs indicate that while the Vienna limestone is locally absent, the underlying Glen Dean and Golconda limestones (respectively 30.5 and 64 m below the Vienna) are present at the expected depths.

Two fault zones of regional importance and one locally significant fault zone are located in the general site vicinity. Figure L.5 shows geologic structural elements of the region. The Rough Creek Fault Zone, an east-west trending structure, lies about 13 km (21 miles) south of the site. Normal and high-angle reverse faults predominate in this zone, though some scissor and shear faults are observed. Displacements of as much as 610 m (2000 ft) have been measured in this complex.² The northeast-southwest trending Shawneetown-Uniontown Fault Zone (also called the

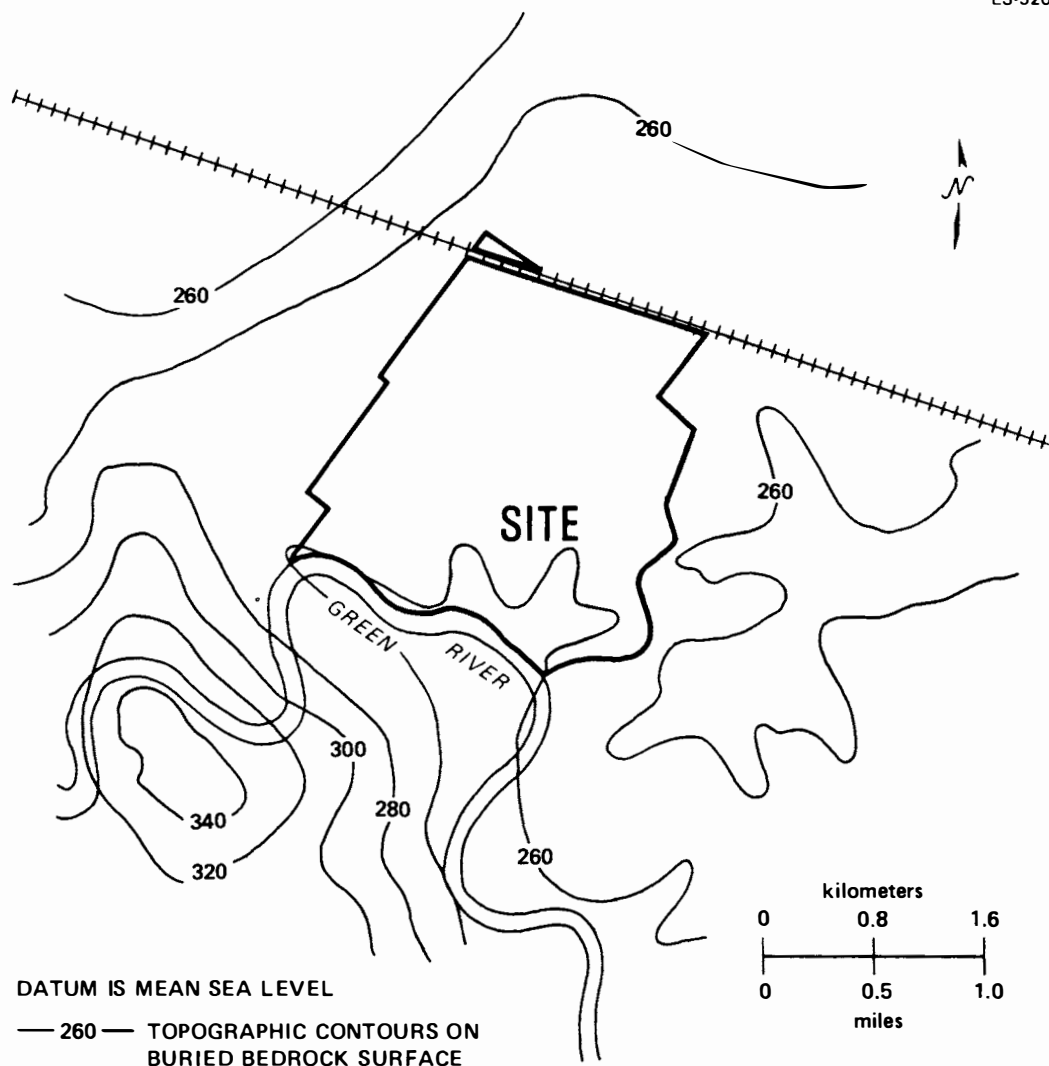


Fig. L.3. Bedrock topography within 2 km (1.2 miles) of site. Source: R. L. Norris, "Map Showing Bedrock Topography and Subcrop of Selected Beds Beneath Alluvial Deposits of the Reed Quadrangle, Kentucky-Indiana," Miscellaneous Geological Investigations Map I-802, U.S. Geological Survey, 1973.

Wabash Valley Fault Zone) lies approximately 56 km (35 miles) west of the site. Normal faults predominate in this zone with maximum displacements of approximately 120 m (400 ft).² The nearest known faults are in the northeast trending Curdsville Fault Zone, approximately 8 km (5 miles) southeast of the site.² These faults, as mapped by Schwalb, et. al.⁶ form a generally graben-like structure. Where exposed in outcrops of the Lisman Formation, overlying Pleistocene deposits are apparently undisturbed.⁷

L.2.2.6 Seismic hazard

Records of seismic activity in the central United States date back to the settlement of that portion of the country. Continuous records exist from the late 1700s to the present. Early records were subjective, consisting of newspaper articles and other written observations. The Modified Mercalli Intensity Scale of earthquake intensity was developed as a semiquantitative

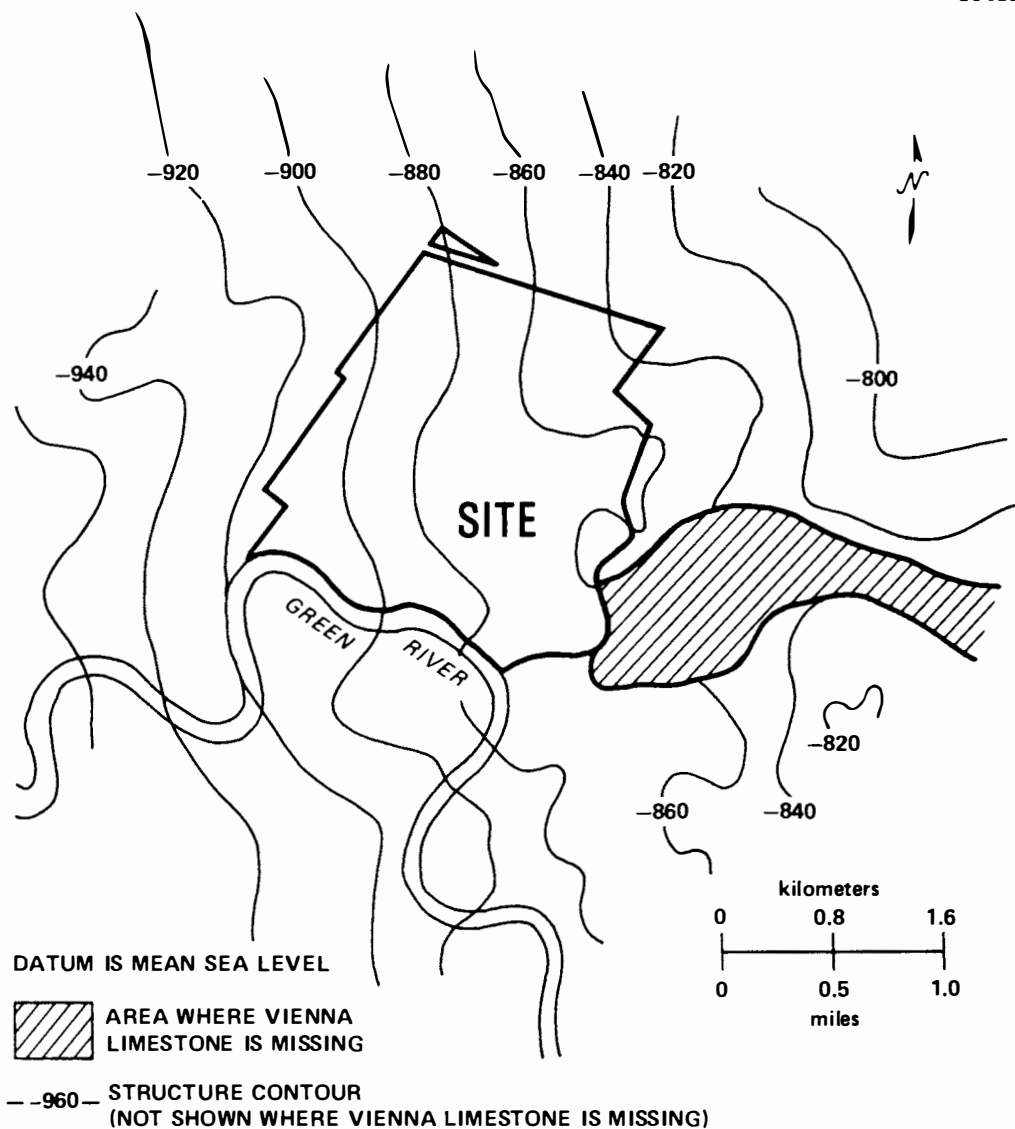


Fig. L.4. Structure contours drawn on the base of the Vienna limestone. Source: W. E. Johnson, "Geologic Map of the Reed Quadrangle, Kentucky-Indiana," U.S. Geological Survey Map GQ-1038, 1972.

measure of earthquake intensity based on the reactions of people to earthquakes and the amount of damage to buildings (Fig. L.6). The Modified Mercalli Intensity (MMI) is well suited to rating the intensity of earthquakes for which no scientific measurements are available.

Records prior to the early 1900s when the first seismographs were installed in the midwest were incomplete in that only widely felt events were recorded. Now, a sizable array of recording seismographic equipment monitors microseismic and earthquake activity throughout the region.

Within the last decade our understanding of mid-continent seismicity has improved through the applied use of geophysical research methods. Predictive capabilities, however, are limited to estimates of recurrence intervals of earthquakes based on approximately 200 years of observations.

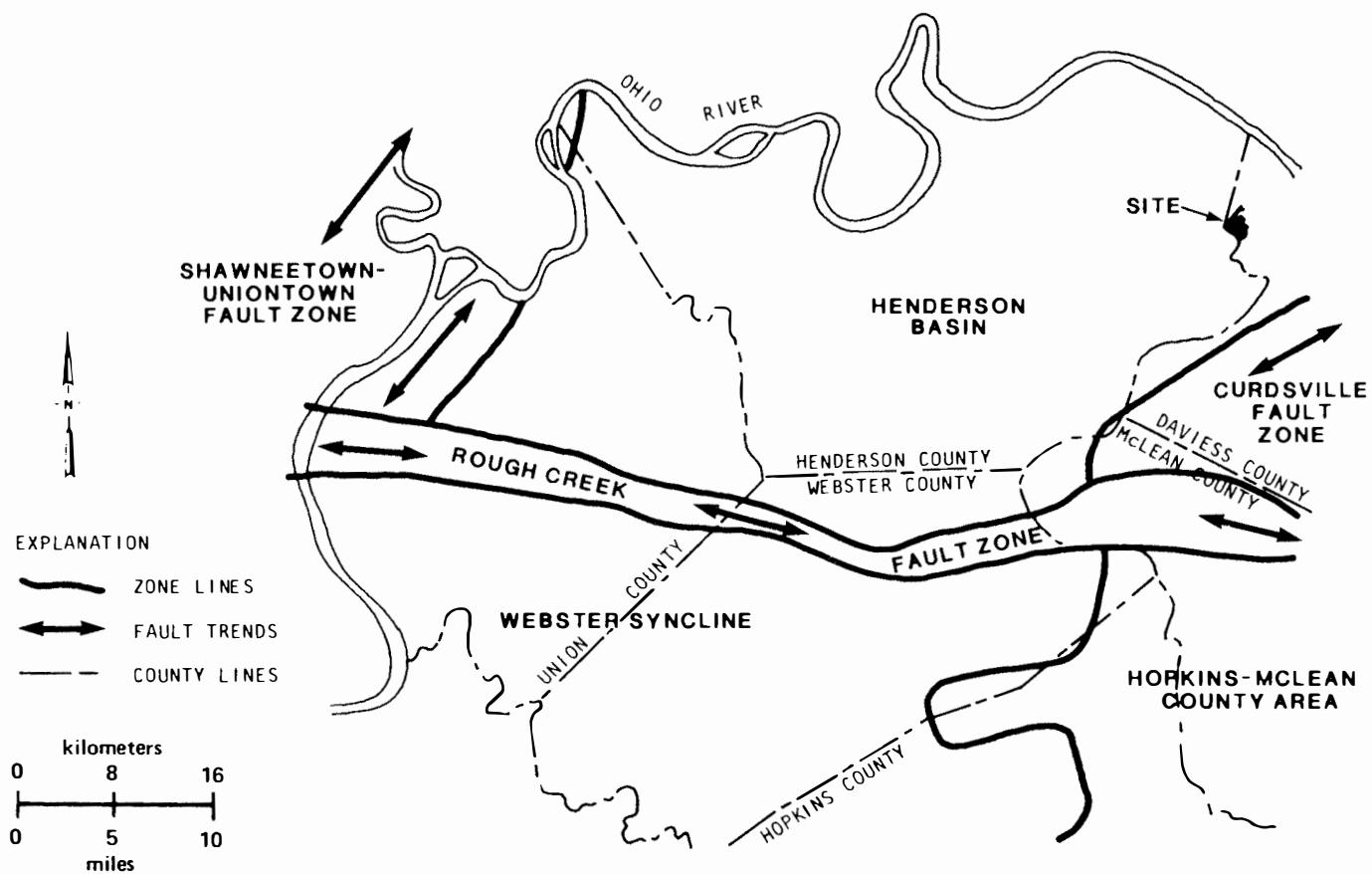
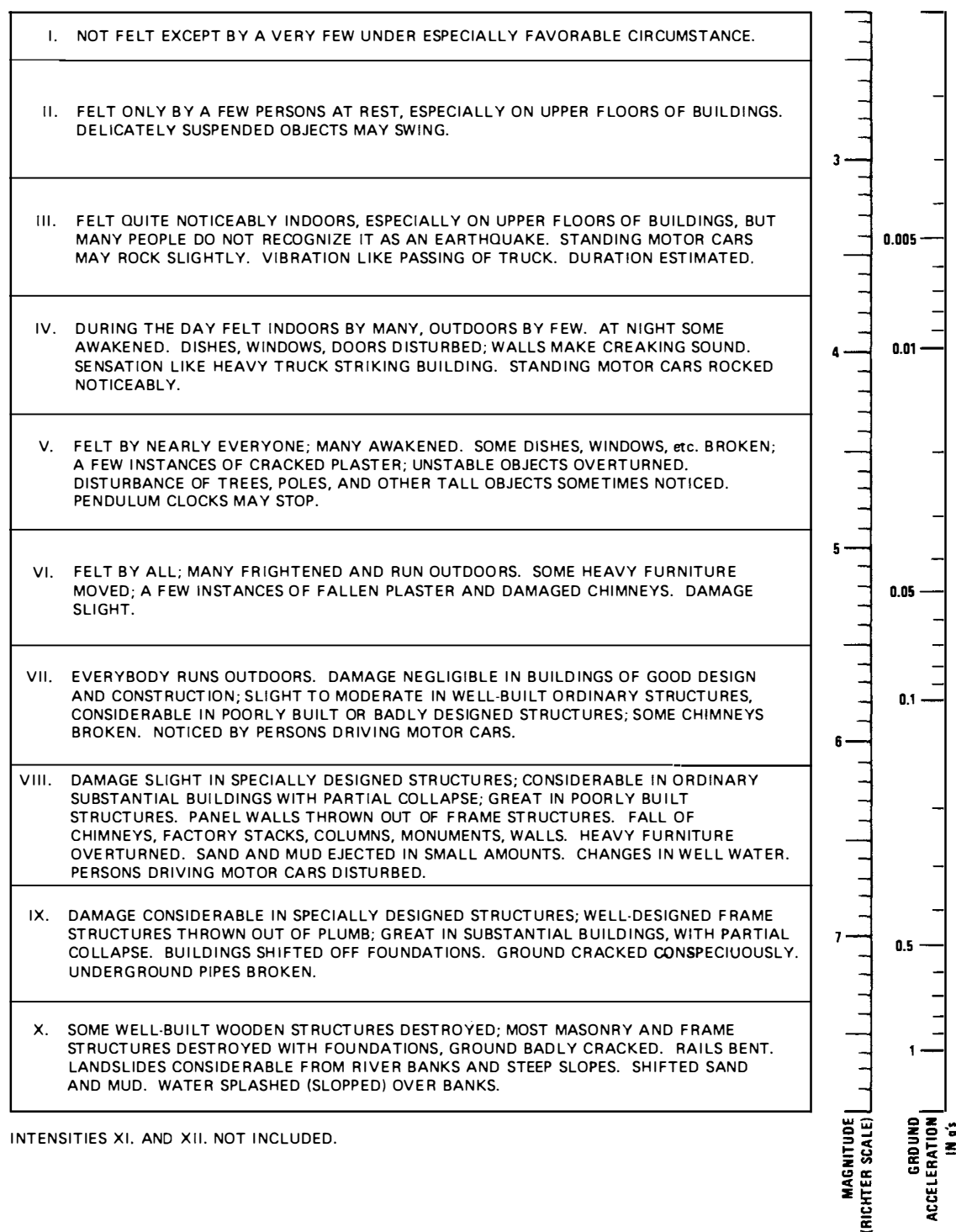


Fig. L.5. Structural areas of northwestern Kentucky. Source: A. T. Mullins, R. E. Lounsbury, and D. L. Hodgson, *Coal Reserves in Northwestern Kentucky*, Tennessee Valley Authority, Office of Power Fuels Planning Staff, Chattanooga, Tenn., 1965.



INTENSITIES XI. AND XII. NOT INCLUDED.

Fig. L.6. Modified Mercalli epicentral intensity scale for earthquakes. Sources: H. O. Wood and F. Neumann, "Modified Mercalli Intensity Scale of 1931," *Bull. Seismol. Soc. of Am.* 21: 278-283 (1931); U.S. Atomic Energy Commission, *Nuclear Reactors and Earthquakes*, Report TID-7024, Washington, D.C., 1975.

The most severe earthquakes that have affected the region occurred long before direct measurement of ground motion was possible; therefore, magnitudes have been estimated using the Modified Mercalli Scale and the size of the affected areas. Recent work cited in the following paragraphs is the best available information on the region; however, there is an element of uncertainty in predicting the frequency and magnitude of future events.

Seismicity in the mid-continent region is related to activity in the New Madrid, Wabash Valley, and St. Genevieve Fault zones (see Fig. 3.5 Sect. 3.2.1.2). As a result of the seismic history of the region, there is moderate to high risk of earthquake damage as shown on the Seismic Risk Zone Map in Fig. L.7. The site is located in Risk Zone 2 near the Zone 3 boundary. In Zone 2 the maximum anticipated intensity is VII on the Modified Mercalli Scale or horizontal ground acceleration of approximately 0.15 g. In Risk Zone 3 the maximum anticipated intensity and ground acceleration are expected to be greater than VII and 0.15 g.

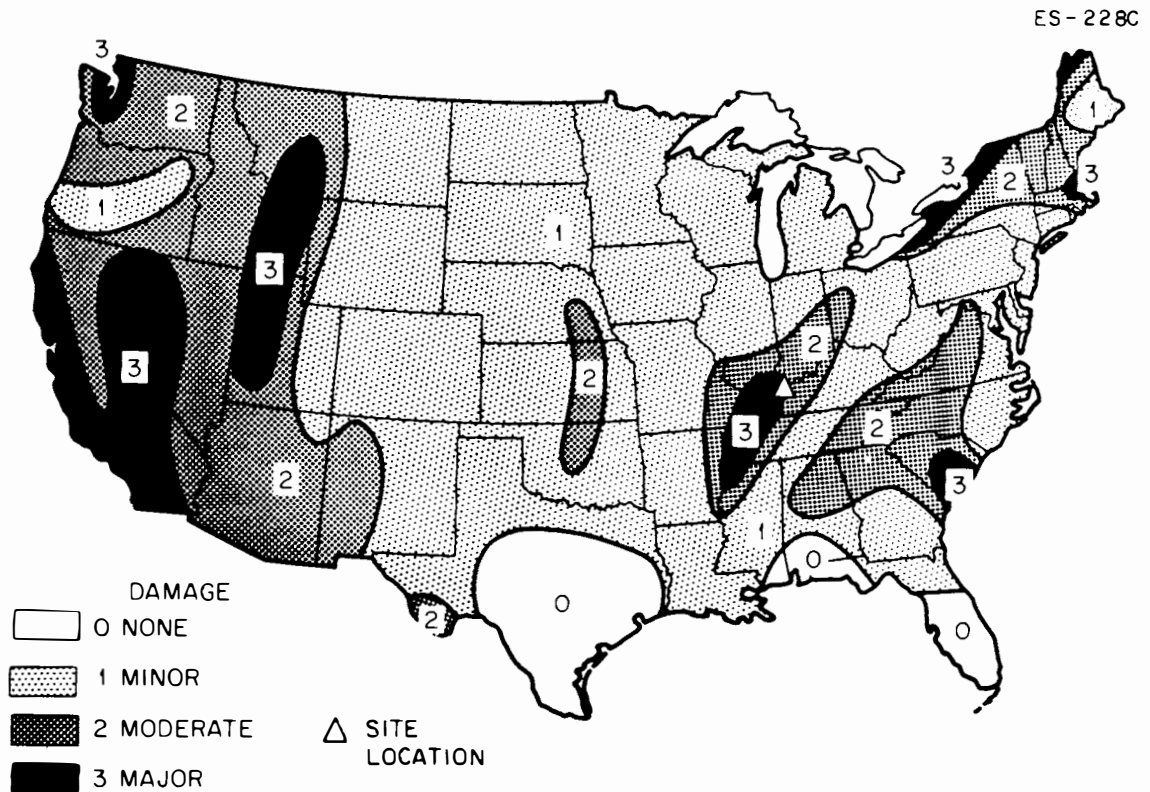


Fig. L.7. Seismic risk map of the United States. Source: S. T. Algermissen, *United States Earthquakes*, U.S. Government Printing Office, Washington, D.C., 1968, Fig. 2.4.

Table L.2 is a list of earthquakes which are believed to have affected the site at Mercalli Intensities of V or greater. Table L.3 lists all recorded Intensity V or greater earthquakes within a 320-km (200-mile) radius of the site and all earthquakes within a 40-km (25-mile) radius of the site. The historic maximum earthquake which has affected the site was the series of events during the 1811-1812 New Madrid earthquakes. Estimated Modified Mercalli Intensities at the site during those quakes were VII to VIII. According to Nuttli and Herrmann,⁸ the $m_b = 7.5$ event of February 7, 1812 was the maximum magnitude earthquake for the central United States. Attenuation of earthquake motion between an epicentral location and a point of interest is a function of distance, wave frequency, and properties of bedrock and alluvium. Assuming that estimates of the magnitude and intensity of the New Madrid event are reasonable, the maximum intensity expected at the site from occurrence of such a quake would be about MMI VIII. The recurrence interval for the maximum magnitude event is estimated to be on the order of

Table L.2. List of earthquakes believed to have affected the proposed site at modified Mercalli intensity levels of V or greater

Date	Epicentral location	Modified Mercalli intensity (Henderson)	Modified Mercalli intensity (Owensboro)	Henderson reference	Owensboro reference
1. Dec. 16, 1811	New Madrid, Mo.	VII	VII	The Weekly Register	Estimated
2. Jan. 23, 1812	New Madrid, Mo.	VI-VII	VI-VII	Estimated ^a	Estimated ^a
3. Feb. 7, 1812	New Madrid, Mo.	VII-VIII	VII-VIII	Estimated ^a	Estimated ^a
4. June 9, 1838	Southern Illinois	VI	V	Estimated on the basis of isoseismal of Nuttli (1974)	Estimated on the basis of isoseismal of Nuttli (1974)
5. Jan. 4, 1843 ^b	Shelby County, Tenn.	V	V	Estimated on the basis of isoseismal of Nuttli (1974)	Estimated on the basis of isoseismal of Nuttli (1974)
6. Aug. 7, 1860	Western Kentucky	V	IV	Louisville Daily Courier	Estimated
7. Aug. 31, 1886 ^b	Charleston, S.C.	V	V	Estimated	Bollinger and Stover (1976)
8. July 27, 1891	Southern Illinois	VI	Felt	Henderson Daily Gleaner (at Zion, Kentucky)	Louisville Times
9. Sept. 26, 1891	Cairo, Ill.	V	IV	Henderson Daily Gleaner	Estimated
10. Oct. 31, 1895	Charleston, Mo.	V-VI	VI-VII	Henderson Daily Gleaner	Owensboro Daily Tribune
11. Aug. 21, 1905	Missouri (Near Sikeston)	IV	V	Henderson Daily Gleaner	Owensboro Daily Messenger
12. Apr. 27, 1925	Indiana	V	IV	Henderson Morning Gleaner	Owensboro Messenger
13. Sept. 2, 1925	Kentucky	VI	VI	Henderson Daily Gleaner	Owensboro Messenger
14. Nov. 9, 1968	Southern Illinois	VI-VII	VI-VII	Unpublished data	Unpublished data

^aThe epicentral intensity of this event is listed by Nuttli (1973) as being one-half unit lower than the Dec. 16, 1811 event.

^bThis event occurred more than 200 miles from the proposed site.

Source: R.I. Street, Assistant Professor, University of Kentucky, Department of Geology, personal communication, 1979.

Table L.3. Earthquakes of epicentral intensity V, or greater, within 200 miles of the site and all earthquakes occurring within 25 miles of the site

Date of occurrence	Time of occurrence			Approximate location	Latitude north	Longitude west	MMI ^a	Distance from site	
	H	M	S					km	miles
Dec. 16, 1811	8	0	0.0	New Madrid, Mo.	36.6	89.6	XII	243	151
Jan. 23, 1812	15	0	0.0	New Madrid, Mo.	36.6	89.6	XII	243	151
Feb. 7, 1812	9	45	0.0	New Madrid, Mo.	36.6	89.6	XII	243	151
Nov. 9, 1820	22	0	0.0	Cape Girardeau, Mo.	37.3	89.5	V	201	125
Aug. 7, 1827	4	30	0.0	New Albany, Ind.	38.3	85.8	VI	142	88
Aug. 7, 1827	7	0	0.0		38.3	85.8	VI	142	88
Mar. 9, 1828	16	30	0.0		38.6	83.8	V	319	198
Mar. 10, 1828	6	0	0.0		38.6	83.8	V	319	198
June 9, 1838				Southern Illinois	38.5	89.0	VIII	167	104
Dec. 27, 1841				Western Kentucky	36.6	89.2	V	214	133
Nov. 4, 1842				Western Kentucky	36.6	89.2	V	214	133
Nov. 4, 1842				Western Kentucky	36.6	89.2	V	214	133
Dec. 18, 1853				Western Kentucky	36.6	89.2	V	214	133
Oct. 8, 1857	10	0	0.0	Southern Illinois	38.7	89.2	VII	193	120
Sept. 21, 1858				Western Kentucky	36.5	89.2	VI	220	137
Aug. 7, 1860				Western Kentucky	37.8	87.5	V	16	10
Aug. 17, 1865	15	0	0.0	Near Missouri-Tennessee border	36.0	89.5	VII	278	173
Sept. 24, 1876				Southern Illinois-Indiana border	38.5	87.8	VI	89	55
Sept. 25, 1876	6	15	0.0	Southern Illinois-Indiana border	38.5	87.7	VI	84	52
May 26, 1877					38.2	87.9	IV	68	42
Mar. 12, 1878	10	0	0.0	Missouri-Kentucky border	36.8	89.1	V	193	120
Nov. 18, 1878				Missouri-Kentucky border	36.7	89.3	VI	214	133
Nov. 19, 1878	5	52	0.0		36.7	90.4	VI	299	186
July 20, 1882	10	0	0.0	Missouri-Illinois-Kentucky border region	38.0	90.0	V	238	148
July 20, 1882				Missouri-Illinois-Kentucky border region	36.9	89.2	V	195	121
Sept. 27, 1882				Near Springfield, Ill.	39.0	89.5	VI	233	145
Sept. 29, 1882	10	20	0.0		39.0	90.0	VI	270	168
Oct. 14, 1882				Near Springfield, Ill.	39.0	89.5	V	233	145
Oct. 15, 1882	6	0	0.0	Near Springfield, Ill.	39.0	89.5	V	233	145
Jan. 11, 1883	7	12	0.0	Cairo, Ill.	37.0	89.2	VI	190	118
April 12, 1883	8	30	0.0	Cairo, Ill.	37.0	89.2	VII	190	118
July 14, 1883				Cairo, Ill.	37.0	89.2	V	190	118
Feb. 6, 1887	22	15	0.0	Vincennes, Ind.	38.7	87.5	VI	101	63
Aug. 2, 1887	18	36	0.0	Cairo, Ill.	37.0	89.2	V	190	118
July 27, 1891	2	28	0.0	Southern Illinois	37.9	87.5	VI	19	12
Sept. 26, 1891				Cairo, Ill.	37.0	89.2	V	190	118
Oct. 31, 1895	11	8	0.0	Charleston, Mo.	37.0	89.4	IX	206	128
Apr. 25, 1897				Missouri-Tennessee border	35.8	89.6	V	301	187
Apr. 30, 1899	2	5	0.0		38.5	87.0	VII	80	50
Jan. 24, 1902	10	48	0.0	Missouri-Illinois border	38.6	90.2	VI	269	167
Feb. 9, 1903	0	21	0.0		37.8	89.3	VI	175	109
Oct. 4, 1903				New Madrid, Mo.	37.0	90.0	VI	254	158
Nov. 4, 1903	18	18	0.0	Missouri-Illinois-Kentucky border region	36.9	89.3	VII	203	126
Nov. 4, 1903				Missouri-Illinois-Kentucky border region	36.9	89.3	VI	203	126
Nov. 27, 1903	9	20	0.0	New Madrid, Mo.	36.5	89.5	V	241	150
Aug. 21, 1905				Missouri-Illinois-Kentucky border region	36.8	89.6	VII	232	144
May 11, 1906	6	15	0.0	Southwestern Indiana	38.5	87.2	IV	77	48
May 21, 1906	19	0	0.0	Southern Illinois	38.7	88.4	V	138	86
Sept. 7, 1906					38.2	87.7	IV	56	35
Jan. 29, 1907				Southern Illinois	39.5	86.6	V	198	123
Jan. 30, 1907				Near Springfield, Ill.	38.9	89.5	V	227	141
Oct. 28, 1908	0	27	0.0		37.0	89.2	V	190	118
Sept. 22, 1909				Ohio Valley	38.7	86.5	V	121	75
Sept. 27, 1909	9	45	0.0	Southern Illinois-Indiana border	39.5	87.4	VII	188	117
Oct. 23, 1909	7	10	0.0	Southeastern Missouri	37.0	89.5	VI	214	133
Oct. 23, 1909	9	47	0.0	Near Robinson, Ill.	39.0	87.8	V	140	87
Apr. 28, 1915	23	40	0.0	New Madrid-Tiptonville, Mo.	36.5	89.5	V	241	150

Table L.3 (continued)

Date of occurrence	Time of occurrence			Approximate location	Latitude north	Longitude west	MMI ^a	Distance from site	
	H	M	S					km	miles
Oct. 26, 1915	7	40	0.0	Mayfield, Ky.	36.7	88.6	V	167	104
Dec. 7, 1915	18	40	0.0	Near mouth of Ohio River	36.7	89.1	VI	200	124
Dec. 19, 1916	5	42	0.0		36.6	89.2	VI	214	133
Apr. 9, 1917	20	52	0.0	Eastern Missouri	38.1	90.2	VI	256	159
Feb. 10, 1919				Illinois-Indiana-Kentucky border region	37.8	87.5	IV	16	10
May 25, 1919	9	45	0.0	Southern Indiana	38.4	87.5	V	68	42
May 1, 1920	15	15	0.0	Missouri	38.5	89.5	V	208	129
Dec. 24, 1920	8	30	0.0	Rockwood, Tenn. area	36.0	85.0	V	285	177
Mar. 31, 1921				Illinois-Indiana-Kentucky border region	37.9	87.8	IV	45	28
Jan. 10, 1922				Illinois-Indiana-Kentucky border region	37.9	87.8	V	45	28
Mar. 22, 1922				Southern Illinois	37.3	88.9	V	151	94
Mar. 22, 1922	22	30	0.0	Southern Illinois	37.3	88.9	V	151	94
Mar. 30, 1922				Missouri-Tennessee border	36.1	89.6	V	278	173
Nov. 26, 1922				Southern Illinois	37.8	88.5	VII	105	65
Nov. 28, 1923				Kentucky	37.5	87.3	III	32	20
Mar. 2, 1924	11	18	0.0	New Madrid, Mo.	37.0	89.1	V	182	113
June 6, 1924					36.4	89.5	V	249	155
Apr. 27, 1925	4	5	0.0		38.3	87.6	VII	61	38
July 13, 1925				Missouri-Illinois border	38.8	90.0	V	261	162
Sept. 2, 1925	11	55	0.0	Kentucky	37.8	87.5	VI	16	10
Sept. 20, 1925				Kentucky	37.8	87.5	IV	16	10
Oct. 3, 1926					38.3	87.6	III	61	38
July 20, 1927					35.8	86.0	VI	249	155
Aug. 13, 1927				New Madrid, Mo.	36.4	89.5	V	249	155
Feb. 14, 1929	20	12	0.0		38.3	87.6	IV	61	38
Sept. 1, 1930	20	30	0.0	New Madrid, Mo.	36.6	89.4	V	229	142
Jan. 5, 1931				Elliston, Ind.	39.0	87.0	V	135	84
Jan. 6, 1931	2	51	0.0		39.0	87.0	V	135	84
Dec. 31, 1931					38.5	87.2	II	7	48
Aug. 19, 1934	23	47	0.0	Rodney, Mo.	36.9	89.2	VI	195	121
Nov. 17, 1937	17	4	0.0	Centralia, Ill.	38.6	89.1	V	180	112
Nov. 23, 1939	15	14	54.0	Near Griggs, Ill.	38.2	90.1	V	249	155
May 31, 1940				Paducah, Ky.	37.1	88.6	V	138	86
Nov. 23, 1940	21	15	0.0	Missouri-Illinois border	38.2	90.1	VI	249	155
Dec. 28, 1940					37.9	87.3	III	10	6
Oct. 8, 1941				New Madrid, Mo.	36.2	89.7	V	277	172
Oct. 8, 1946	1	12	2.5		37.5	90.6	V	293	182
June 30, 1947	3	23	53.0		38.4	90.2	VI	262	163
Jan. 5, 1948				Southern Illinois	38.6	89.1	V	180	112
Jan. 13, 1949				New Madrid, Mo.	36.4	89.7	V	264	164
Feb. 20, 1952	22	34	39.0	Tennessee-Missouri border	36.4	89.5	V	249	155
July 16, 1952				Dyersburg, Tenn.	36.2	89.6	VI	270	168
Sept. 11, 1953	18	26	28.0	Southwestern Illinois	38.8	90.1	VI	269	167
Feb. 2, 1954				Missouri-Arkansas border	36.7	90.3	V	291	181
Aug. 9, 1954					38.5	87.3	IV	77	48
Jan. 25, 1955	7	24	30.0	Tennessee-Arkansas-Missouri border	36.0	89.5	VI	278	173
Mar. 29, 1955				Finley, Tenn.	36.0	89.5	VI	278	173
Apr. 9, 1955	13	1	24.0	West of Sparta, Ill.	38.1	89.9	VI	230	143
Sept. 5, 1955				Finley, Tenn.	36.0	89.5	V	278	173
Dec. 13, 1955				Dyer County, Tenn.	36.0	89.5	V	278	173
Jan. 29, 1956	4	44	15.0		35.6	89.6	VI	319	198
Oct. 29, 1956				Caruthersville, Mo.	36.1	89.7	V	285	177
Nov. 26, 1956	4	12	44.0		37.1	90.6	VI	301	187
June 23, 1957	6	34	18.0		36.5	84.5	V	286	178
Jan. 26, 1958				North of Memphis, Tenn.	36.1	89.7	V	285	177
Jan. 27, 1958				Illinois-Kentucky-Missouri border	37.1	89.2	V	185	115
Apr. 8, 1958				Obion County, Tenn.	36.3	89.2	V	237	147
Apr. 26, 1958				Lake County, Tenn.	36.4	89.5	V	249	155

Table L.3 (continued)

Date of occurrence	Time of occurrence			Approximate location	Latitude north	Longitude west	MMI ^a	Distance from site	
	H	M	S					km	miles
Nov. 8, 1958	2	41	43.0		38.4	87.9	VI	84	52
Feb. 13, 1959				Bogota, Tenn.	36.1	89.5	V	272	169
Aug. 12, 1959	18	6	7.0	Alabama-Tennessee border	35.0	87.0	VI	311	193
Dec. 21, 1959				Finley, Tenn.	36.0	89.5	V	278	173
Jan. 28, 1960				Dyer County, Tenn.	36.0	89.5	V	278	173
Apr. 21, 1960				Lake County, Tenn.	36.3	89.5	V	256	159
Feb. 2, 1962	6	43	28.8	New Madrid, Mo.	36.5	89.6	VI	249	155
June 27, 1962	1	28	55.7		37.8	88.9	V	140	87
July 23, 1962	6	5	18.4	Southern Missouri	36.1	89.8	V	291	181
Mar. 3, 1963	17	30	11.4	Southeastern Missouri	36.7	90.0	VI	268	167
Aug. 3, 1963	0	37	50.3		37.0	88.8	V	159	99
Dec. 5, 1963	6	51	2.5		37.2	87.0	III	71	44
Dec. 14, 1963					37.2	87.1	III	68	42
May 23, 1964	11	25	34.2	New Madrid, Mo.	36.5	89.9	V	272	169
Aug. 14, 1965	5	46	17.4	Southwestern Illinois	37.2	89.3	VI	188	117
Aug. 14, 1965	13	13	54.1	Southeastern Illinois	37.1	89.2	VII	185	115
Aug. 15, 1965	6	7	25.3	Southwestern Illinois	37.4	89.5	V	198	123
Aug. 15, 1965				Southwestern Illinois	37.4	89.5	V	198	123
July 21, 1967	9	14	48.9	Missouri	37.5	90.4	VI	275	171
Nov. 9, 1968	17	1	41.1	South-Central Illinois	38.0	88.5	VII	108	67
Dec. 11, 1968				Louisville, Ky.	38.2	85.9	V	130	81
Mar. 29, 1972	20	38	31.9	Southeast Missouri	36.2	89.6	V	270	168
Jan. 7, 1973	22	56	6.1		37.4	87.3	III	31	24
Jan. 8, 1974	1	12	37.4	New Madrid, Mo.	36.2	89.4	V	256	159
Apr. 3, 1974	23	5	2.5	Southern Illinois	38.6	88.1	VI	111	69
May 13, 1974	6	52	18.8		36.7	89.4	VI	220	137
June 5, 1974	8	6	11.3	Southern Illinois	38.6	89.9	V	248	154
Aug. 22, 1974	22	33	59.6	Southern Illinois	38.2	89.7	V	217	135

^aModified Mercalli intensity.

Source: ER, Appendix B, Table 8.3.

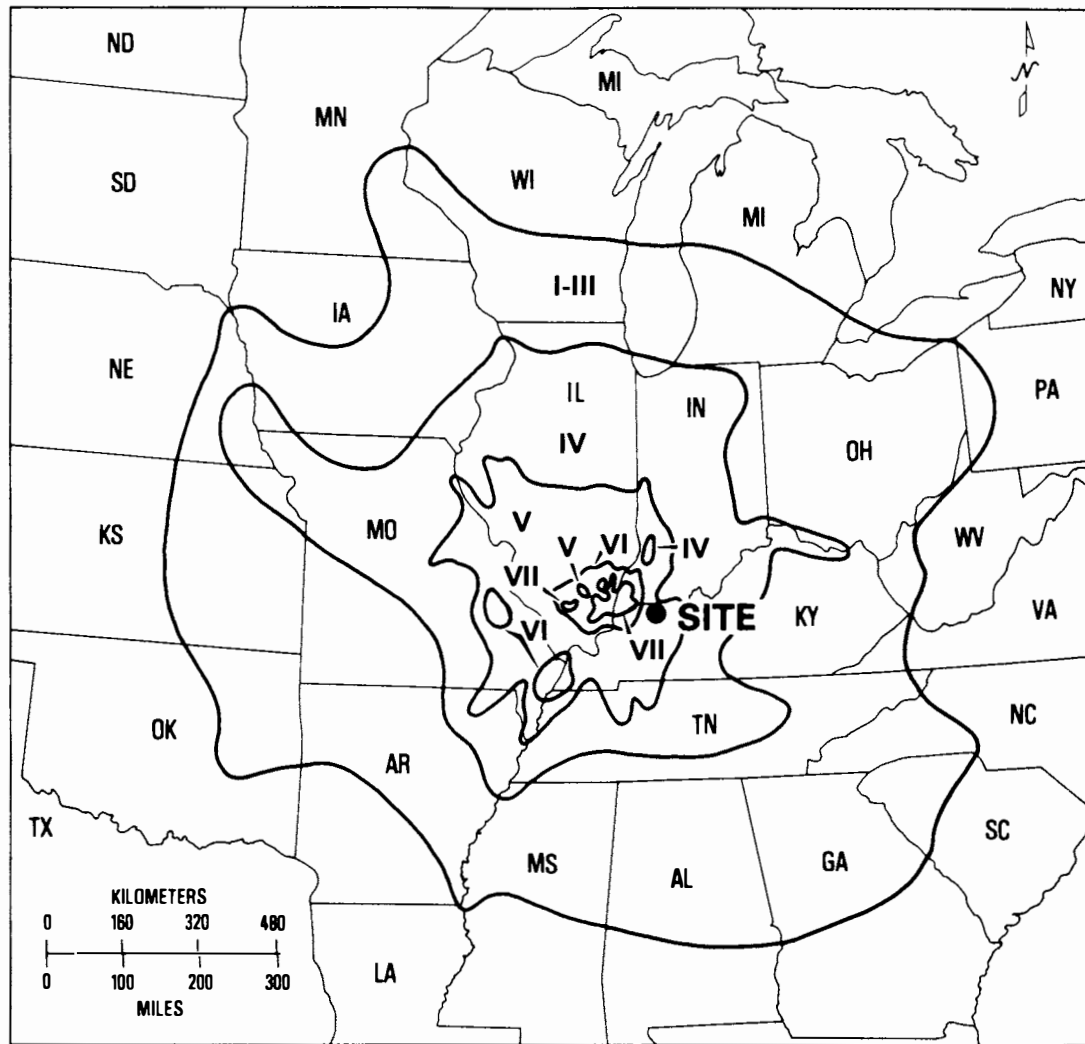
660-1000 years.⁸ Factors which affect the reliability of such estimates are the relatively short period of record and lack of quantitative data for earthquakes in the 1800s.

The site is located on the edge of the Wabash Valley seismic source zone. Maximum magnitude for earthquakes with a recurrence frequency of 1000 years is estimated to be m_b = approximately 6.6 (ref. 8). The maximum observed event during the approximately 200 years of record was the m_b = 5.5 of 9 November 1968 (ref. 8). This event resulted in MMI VII effects at the proposed site; isoseismals are shown on Fig. L.8. Other earthquakes originating in the Wabash Valley Zone have had MMI V and VI effects in the Henderson-Owensboro area. Seismic activity in the Wabash Valley Zone, though less intense than that of the New Madrid Zone, has the potential to affect structures in the site area.

L.2.3 Foundation conditions

Subsurface investigations and soil testing were completed by ATEC Associates for the proposed 2000 TPD facility in 1977, and a Preliminary Geotechnical Report was prepared at that time. A proposal for a foundation-preparation test program was issued in 1979. The summary, the section on liquefaction potential of the *Preliminary Geotechnical Report of 1977*, and the soil liquefaction analysis issued by ATEC Associates in June 1980, are included in this section.

During the preliminary investigation, a zone of poorly consolidated sand was encountered beneath the high terrace area that constitutes the southern portion of the site area. The lower portion of this zone is below the observed water table. The presence of this material is of concern in foundation design for the facility because of its potential to cause differential settlement of structures. Evaluation of existing soil conditions using methods developed by Seed^{9,10,11} indicate that the lowest density zones within the loose sand horizons may be susceptible to liquefaction. This would occur under conditions of 0.15 g acceleration and a water table elevation of 111.3 m (365 ft) if other factors that lead to liquefaction are present.



I—VII MODIFIED MERCALLI INTENSITIES AS OBSERVED IN 1968 EARTHQUAKES.

Fig. L.8. Generalized isoseismal map of the South Central Illinois earthquake, November 9, 1968. Source: D. W. Gordon, et al., "The South Central Illinois Earthquake of November 9, 1968: Macroseismic Studies," *Bull. Seismol. Soc. Am.* 60: 953-971 (1970).

Factors which contribute to soil failure by liquefaction are

1. loose packing of soil particles giving low density,
2. fine sand and silt content of about 65% or more,
3. saturation of the soil,
4. relatively low confining pressure,
5. exposure to a sufficient number of stress cycles to induce excess pore pressure, and
6. low permeability within the soil that promotes pore pressure buildup.

Densities and particle size distributions of the loose, near-surface sands are similar to those of sands which have liquefied in observed natural conditions.^{9,10} Subsurface investigations

and piezometer monitoring were carried out during September, a season of typically low ground-water levels. At the time of investigation, the lower part of the loose sand horizon was saturated; during winter and early spring, groundwater elevations would be expected to be several feet higher, saturating more of this horizon. In order to calculate overburden pressure on the saturated zone, unit weights of representative overburden materials are required. Unit weights are known for the approximately 2.5 m (8 ft) of surficial soils; however, weight of the loose sand itself is not accurately known. The tendency of soils to liquefy is reduced if confining pressure is greater than excess pore pressures which develop during seismic vibration. Anticipated ground accelerations at the site which could result from seismicity in the Wabash Valley or New Madrid Fault Zones are in the 0.10 g and 0.20 g range. This range of ground motion is sufficient to induce liquefaction if other prerequisite conditions exist.¹⁰

Liquefaction is considered a worst-case failure for this site. The more probable occurrence would be differential settlement of the foundation under load conditions. Data obtained during the preliminary testing program were not intended to give specific design parameters; consequently, settlement estimates cannot be produced. Figure L.9 shows the areas underlain by loose sand based on the preliminary subsurface investigations. Foundation pretreatment will be necessary beneath critical structures and areas expected to carry heavy loads. Additional subsurface investigations planned to provide data for foundation design will be included in Phase I of the project.

SECTIONS FROM THE PRELIMINARY GEOTECHNICAL REPORT BY ATEC ASSOCIATES

SUMMARY

The preliminary geotechnical engineering study was conducted for the Rust Engineering Company at the site of the proposed 2000 ST/D SRC Project in Daviess County, Kentucky. Subsurface information was gathered at 12 locations and laboratory tests were conducted on samples taken from the site. Engineering analyses were conducted by using these field and laboratory data to develop preliminary foundation and earth work recommendations for the proposed facilities. These preliminary findings are summarized in the following paragraphs:

(i) Borings made through the high terrace (Borings 3 through 9 and PVC-1, relate), where ground surface is at about El 388, disclosed about 8 ft of surface silty clay and silt underlain by a layer of uniform, loose fine sand. The loose sand appears to be variable in thickness ranging from several feet to a thickness which extends to El 345. Below this loose sand, a more competent medium dense, fine sand is present which extends to rock.

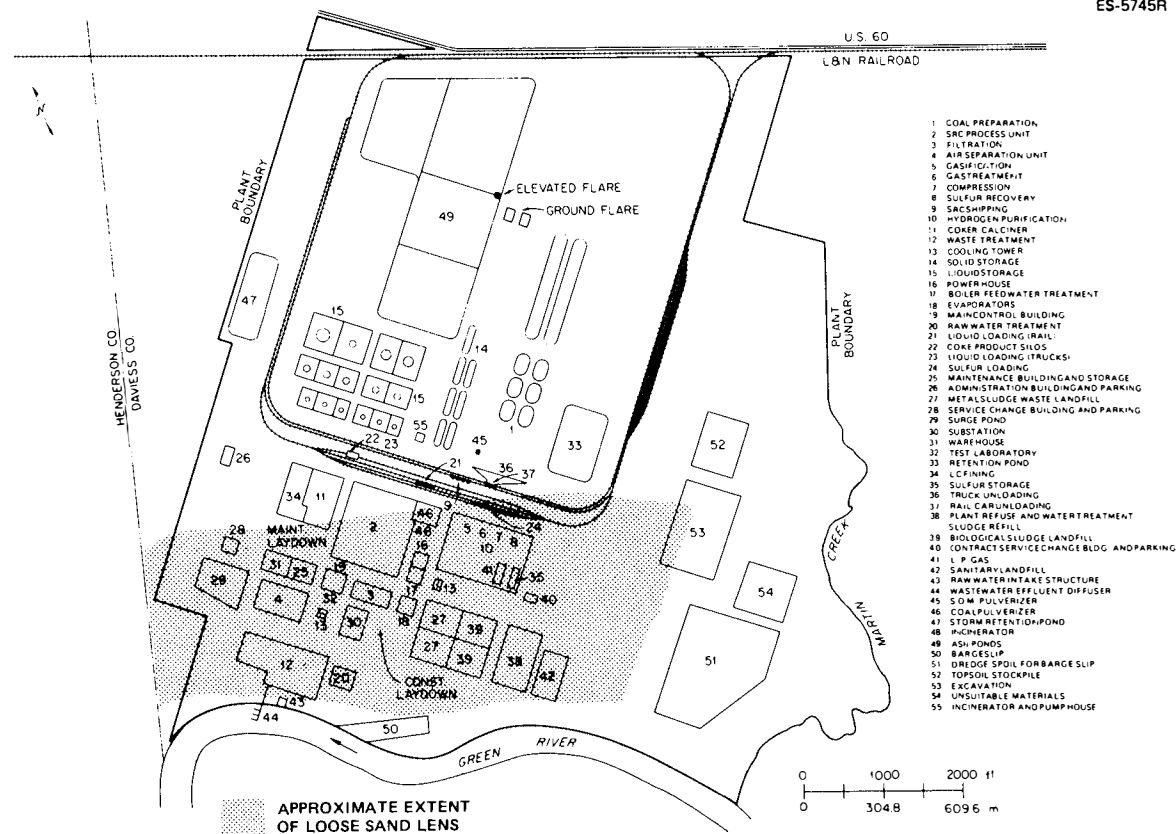
(ii) Borings made through the low terrace or the transition area between the two terraces (where ground surface is at about El 380) disclosed a somewhat thicker layer of silt and clay (approximately 13 to 17 ft). Of the three borings made within this general area, the loose sand was disclosed at only one location. Conditions below the loose sand and upper alluvium were noted to be more or less similar to those disclosed on the high terrace.

(iii) Boring 10, made in the floodplain of Green River, disclosed soft clay soils to about El 297 (a thickness of approximately 69 ft). Below this material, a medium dense sand was generally present to rock. The presence of a thin clay layer with the sand indicates that this material may be more recent than the other granular deposition at the site.

(iv) Bedrock was disclosed beneath the site at elevations which ranged from El 261 to El 263. At all locations, the rock encountered was a thinly bedded shale.

(v) The ground water level at the time of our field study was at El 358. Normal pool of the Ohio and Green Rivers are El 358 and El 348, respectively. The levels of these major streams will largely influence the water level beneath the site. During periods of flooding, a higher ground water level should be anticipated.

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L-18

Fig. L.9. Approximate extent of loose sand lens in foundation.

(vi) The loose sands where present at or slightly below the water table, present a potential liquefaction problem. The Simplified Procedure for Evaluating Soil Liquefaction Potential indicates that liquefaction could initiate if ground accelerations on the order of 0.15 g develop. Because of the uncertainty regarding expected seismic activity, the probability of a liquefaction problem cannot be assessed quantitatively. It is recommended, however, that the liquefaction considerations be included in the design for all major structures which are essential to the utilization of this facility.

(vii) Where loose sands are present beneath major structures, improvement of the foundation soils will be required in order to control settlements associated with static and dynamic loads.

(viii) Shallow foundations can be used to support most proposed facilities. For major facilities, foundations bearing on granular soil improved to a relative density of at least 65 percent can be designed for net allowable soil pressures not exceeding 4000 lbs/sq ft. For secondary structures, individual footings bearing over loose sand can be designed for allowable net soil pressures not exceeding 2000 lbs/sq. ft., provided the column loads do not exceed 100 kips.

(ix) Piles can be used to support concentrated loads. Individual loads per pile up to 70 tons can be developed by auger cast, steel pipe or step-taper piles of conventional size and length. Individual loads per pile of over 100 tons can be developed by steel H-piles extending to rock or by Franki piles (pressure injected footings) bearing in the medium dense sand below about El 335.

(x) Methods of compacting the loose sand include total removal and recompaction, large vibratory surface rollers, compaction piles, dynamic compaction and vibro-flotation. The most suitable method for providing this improvement will depend on the thickness of both the loose sand and the overlying clay and silt. The most suitable method can be better assessed once the thickness of loose sand is determined at the specific structure locations. The details of any method of compaction should be determined by using a trial section prior to the production compaction. It may be advantageous to conduct these field tests during the final geotechnical engineering study.

(xi) The embankments, which will form the ash ponds, are to be only about 20 ft high. Therefore, the embankment slopes will be dictated primarily by maintenance or erosion control. Slopes no steeper than 2.5 (horizontal) to 1 (vertical) or preferably 3 to 1 will be required. The near surface clayey soils present over the high terrace will produce an estimated coefficient of permeability (k) of about 1×10^{-7} to 1×10^{-8} cm/s, which is normally acceptable for lining ash ponds.

(xii) Based on the findings at Boring 10 location, pile foundations should be anticipated for all shore line and offshore structures. Because of the large thickness of soft clay present within this area, the addition of even a modest thickness of area fill will probably produce large movements and should be avoided if possible. Because of the possible presence of clay within the sand at this location, pile foundations must extend to rock.

4.2 Liquefaction potential

Liquefaction of granular soils can be caused by earthquake motion if sufficient strain within the soil mass occurs to produce an excess pore water pressure at least approximately equal to the effective weight of the overlying soil. Therefore, the material in question must be below the groundwater table to initiate liquefaction. Other important considerations are the grain size distribution, relative density of the sand, and effective confining pressure of the soil mass; however, the most pertinent factor is probably the characteristics of the earthquake motion. Both the magnitude of ground acceleration and the number of stress cycles of strong motion greatly influence the probability of liquefaction occurring.

The permeability of the sand must be sufficiently low such that substantial excess pore pressures can occur. Case histories where liquefaction has taken place relate to granular

soils that are primarily fine sands (low permeability sands) or silts. No case histories of liquefaction have been recorded where more than approximately 45% by weight of the sand material was of the medium sand grain size or larger. A grain size distribution range of soils found to be susceptible to liquefaction (based on a series of case histories available in the literature) is shown on Plate 8.

Laboratory tests were conducted to determine the grain size distribution of the sandy soils present at the site. The results of these tests are shown as individual grain size characteristics of the near surface loose sand, which is most susceptible to the liquefaction problem; an illustration showing the gradation range is provided on Plate 9. As indicated by this illustration, the majority of loose material falls within the fine sand range, which is the most susceptible material.

The water table at the study area is at about El 358, approximately 30 ft below the level of the high terrace. The weight of soil above the water level will produce an effective confining pressure in the most critical area (at the ground water level) of about 3500 lb/ft². This relatively high confining pressure is a relevant factor that reduces the overall liquefaction potential of the site under the condition of the normal water level. Under periods of flooding, however, the shallower loose sand will be saturated and will also be subject to a lower confining pressure, and consequently liquefaction potential increases.

The liquefaction potential is also influenced by the relative density of granular materials. To aid in assessing this condition, the results of the standard penetration tests (N-values) have been tabulated for the borings made on the high terrace (see Plate 10) and the low terrace (Plate 11 relates). These illustrations indicate that the upper, loose sands typically have a relative density of less than about 50%, whereas the deeper materials have an average relative density on the order of 60%. The relative density indicated for the near surface loose materials falls well within the range of concern regarding a liquefaction problem.

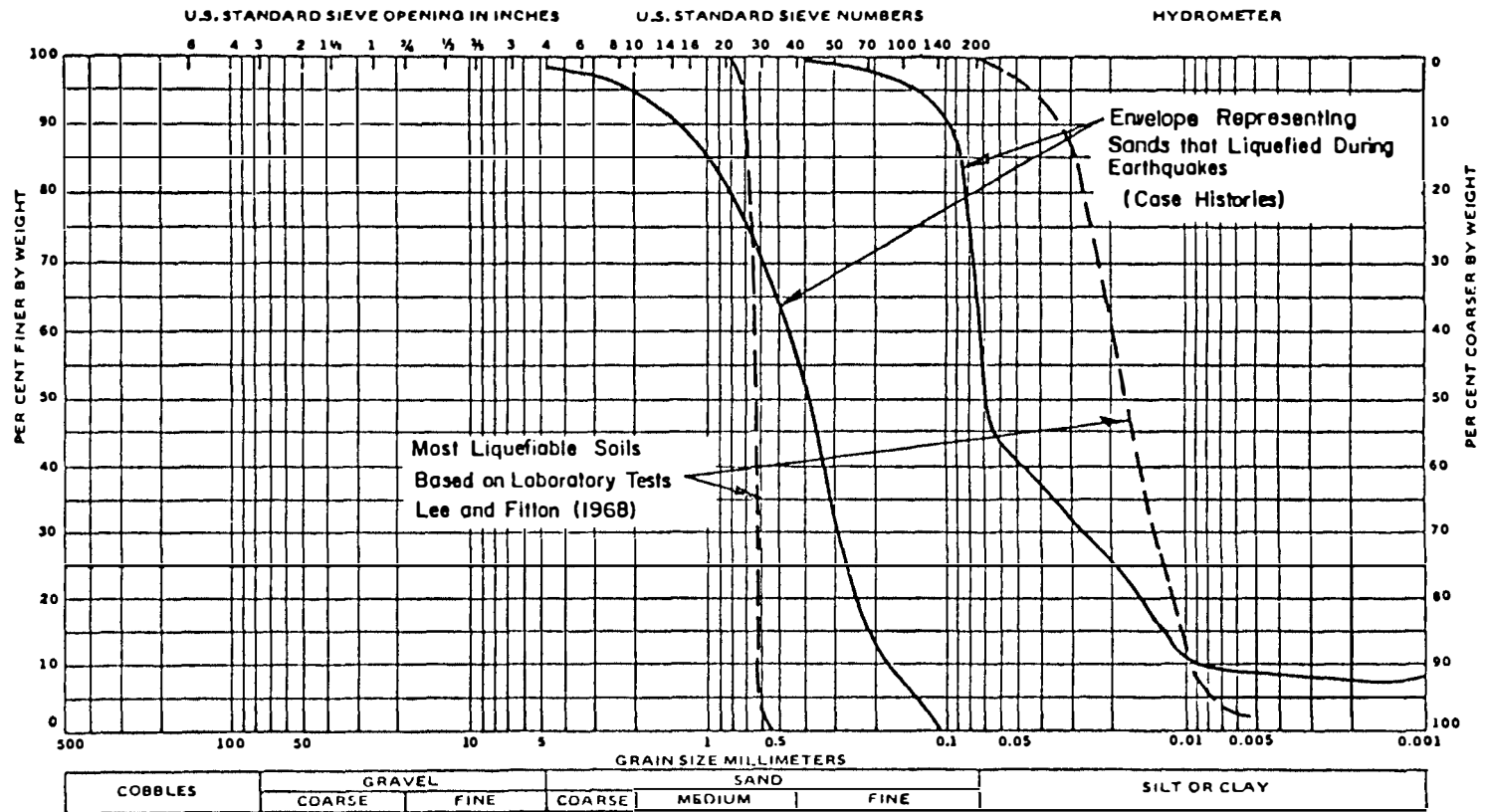
To provide some quantitative measure of the liquefaction potential, computations were made to relate this to sand density and depth. This analysis is shown graphically on Plate 12. The curves were developed using procedures available in the literature. Points which fall to the right of the given ground acceleration line theoretically should not liquefy under that particular ground acceleration. The mean grain size diameter (D_{50}) of the sand was taken as 0.2 mm, and 10 significant shear stress cycles were assumed for the earthquake motion. The liquefaction potential lines for earthquakes which produce a ground acceleration of 5, 15 and 25% of gravity are shown on Plate 12 superimposed over the relevant N-values.

Plate 12 may also be used to evaluate conditions at a specific boring location on either of these terraces by entering the chart with the appropriate N-value and depth. It must be emphasized that these computations relate to a simplified procedure which is empirical in nature and utilizes data gathered in another portion of the United States. In addition, because of the infrequent occurrence of seismic activity in the Midwest, it is difficult to select an appropriate design-ground acceleration for design purposes.

Recent publications are available which suggest estimated values of horizontal base rock acceleration for use in the Midwest (USGS Open File Report 76-416, 1976). Based on this map, the study area falls between the 4 and 10% of gravity contour lines. These values are qualified by the author as a preliminary map of horizontal acceleration in rock with 90% probability of not being exceeded in 50 years. It must also be noted that these values of horizontal acceleration relate to base rock motion. The curves represented on Plate 12, however, show ground acceleration. The magnitude of acceleration experienced by the soil will generally be greater than that of the base rock. The extent to which the base rock motion will be amplified is a function of the stiffness and thickness of the soil overlying rock (site period) and the characteristics of the earthquake motion (acceleration level and period).

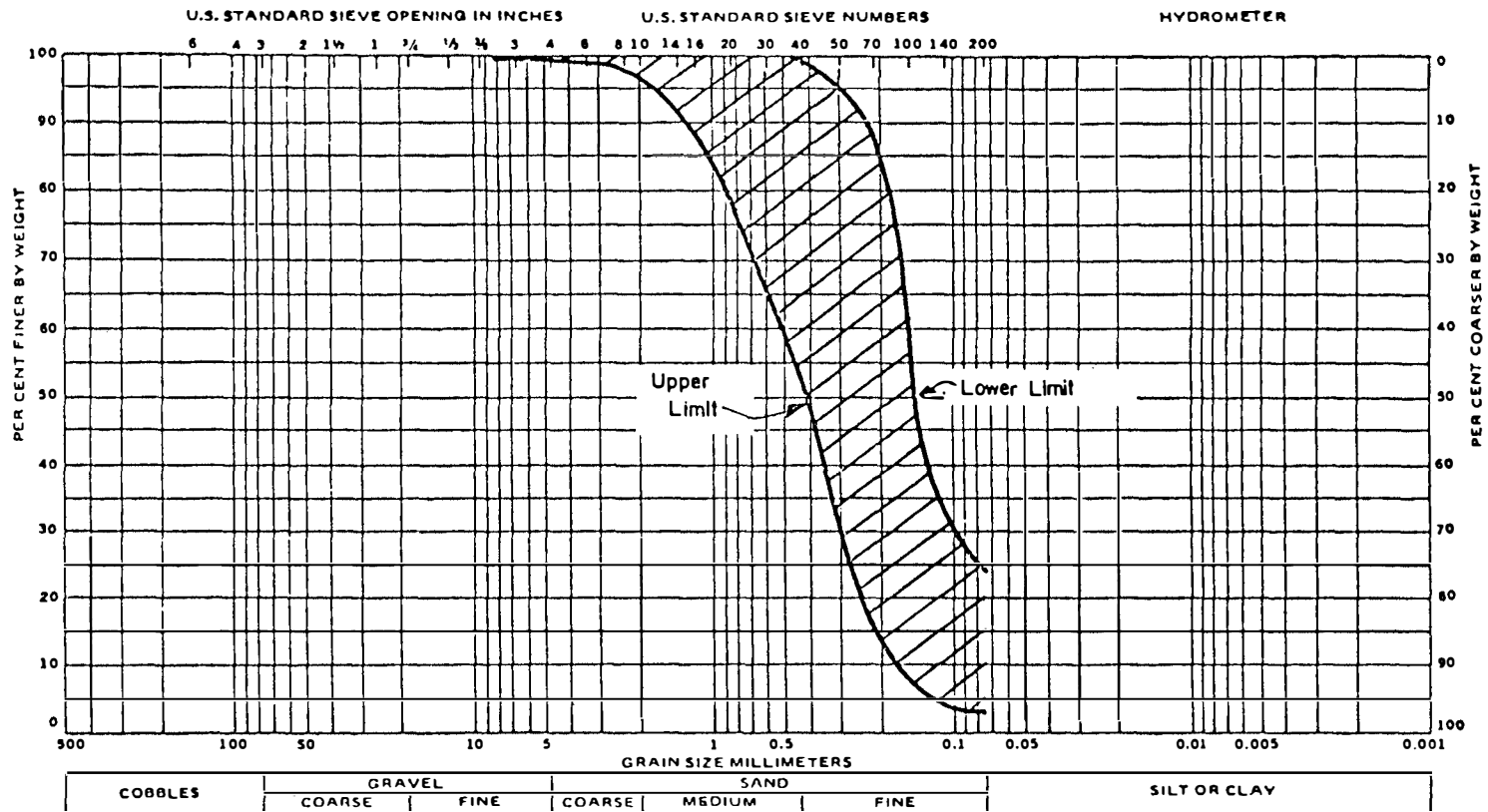
In summary, the loose near-surface sand, present primarily over the high terrace, is susceptible to liquefaction. Because of the state of knowledge regarding the seismicity of the Midwest, the liquefaction problem cannot be quantitatively assessed on a probability basis.

GRADATION CURVES

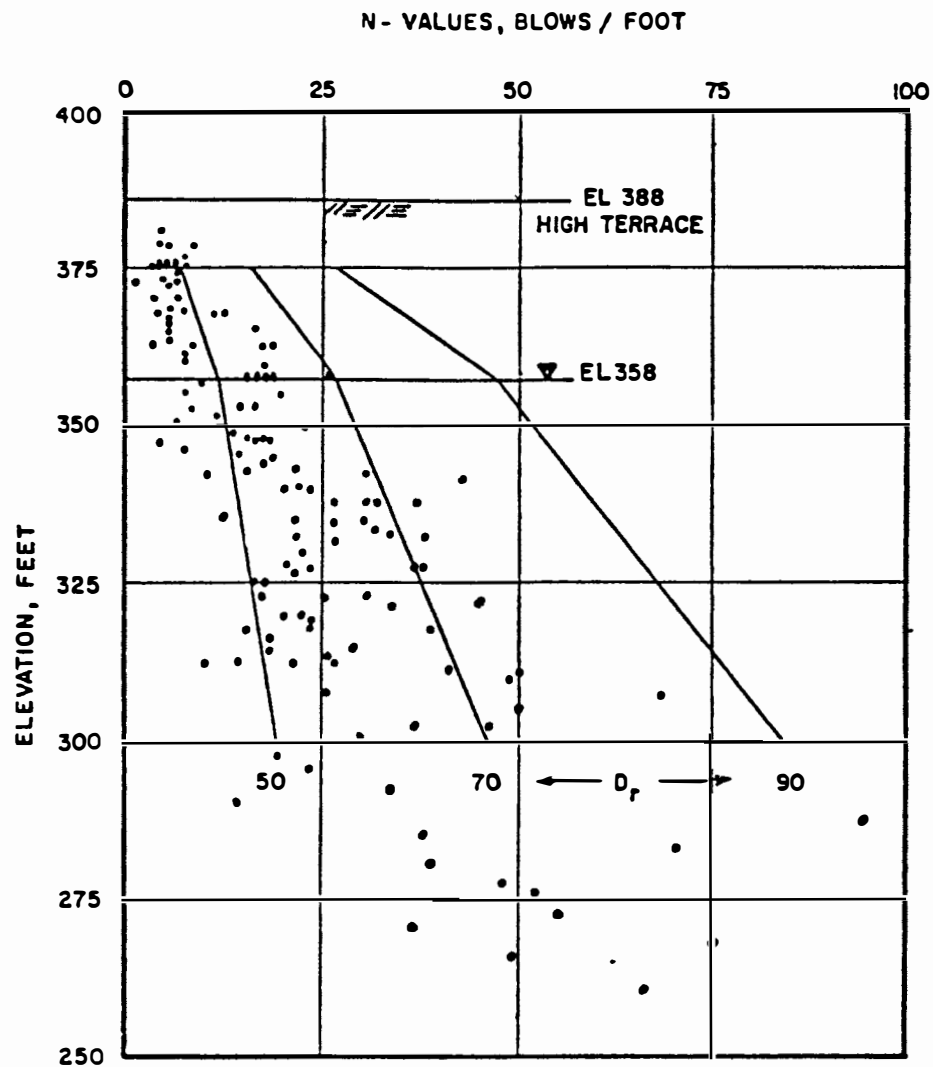


SOILS SUSCEPTIBLE TO LIQUEFACTION

GRADATION CURVES

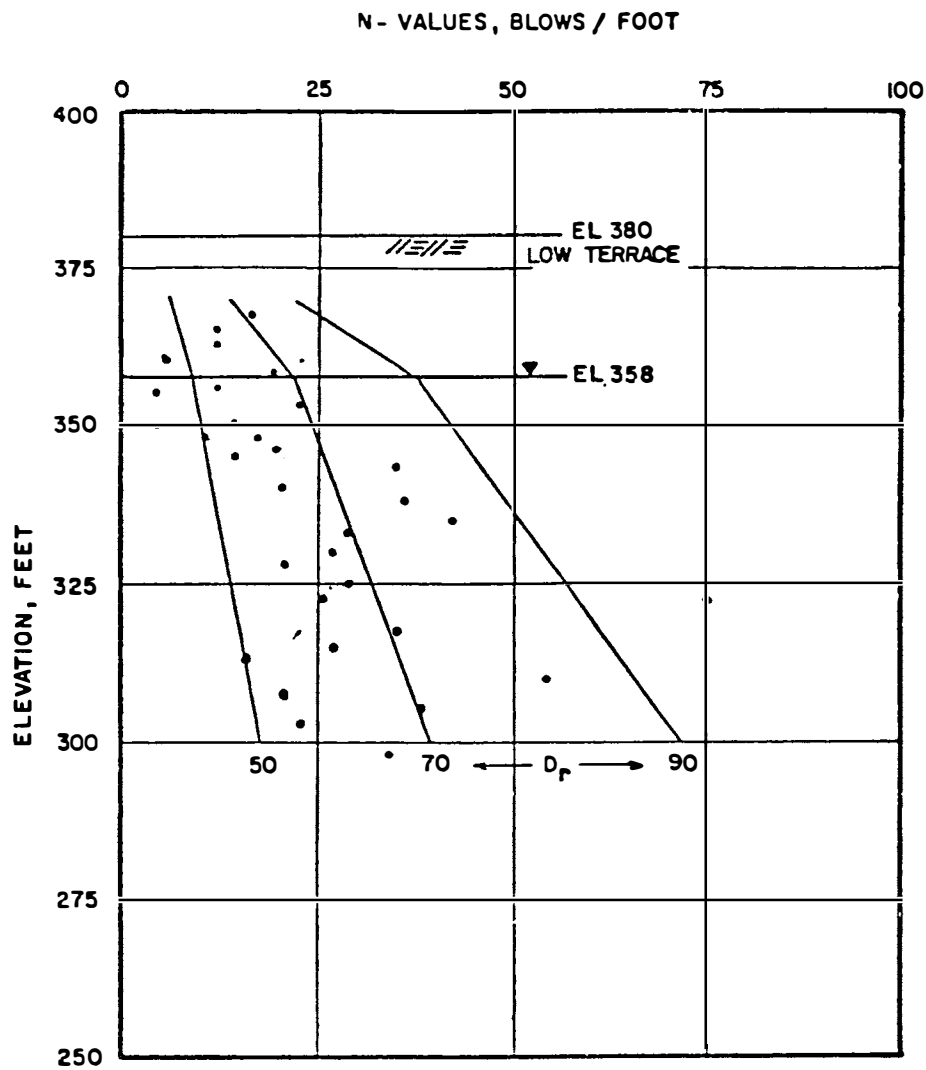


GRADATION RANGE
NEAR-SURFACE LOOSE SANDS



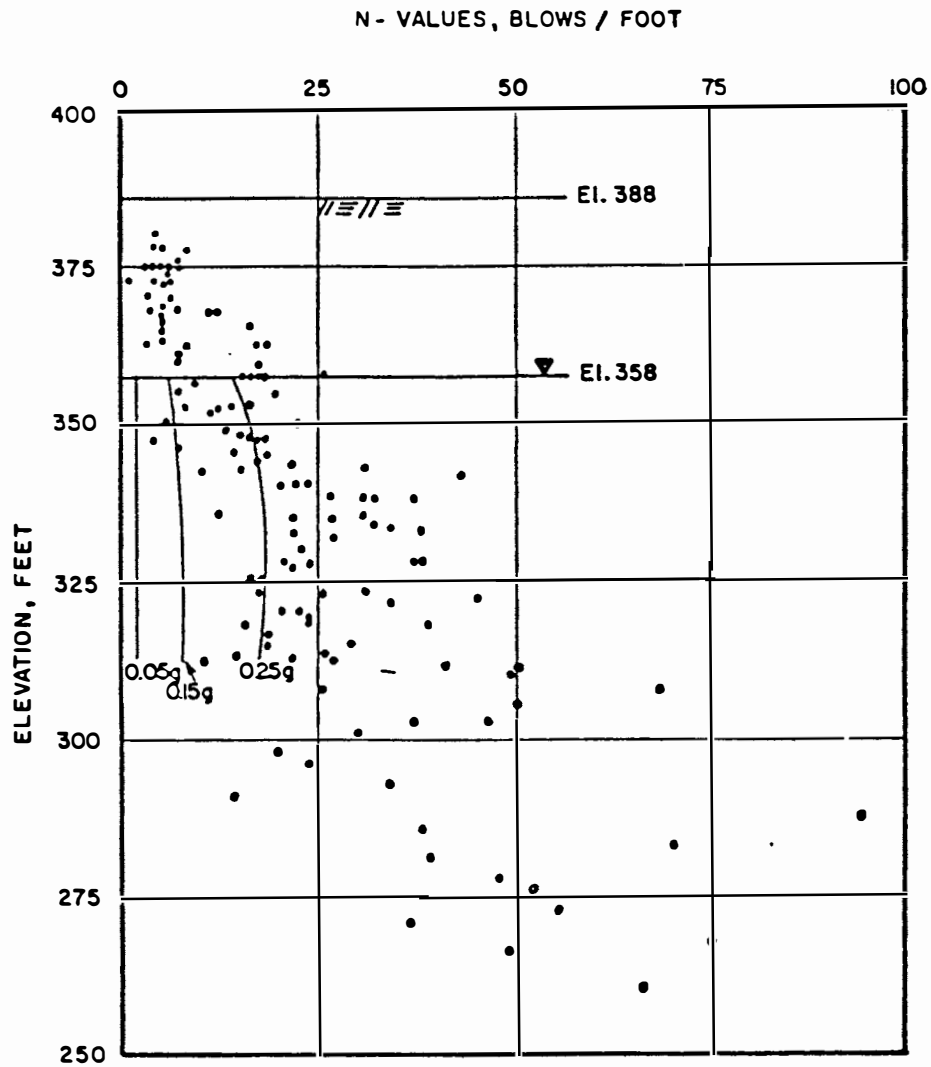
RELATIVE DENSITY vs. DEPTH

GROUND SURFACE AT EL 388
2000 ST/D SRC PROJECT
OWENSBORO, KENTUCKY



RELATIVE DENSITY vs. DEPTH

GROUND SURFACE AT EL 380
2000 ST/D SRC PROJECT
OWENSBORO, KENTUCKY



N - VALUES WHICH PLOT TO THE RIGHT OF A
GROUND ACCELERATION LINE IMPLY THAT
LIQUEFACTION WILL NOT OCCUR AT THAT
ACCELERATION LEVEL.

LIQUEFACTION POTENTIAL

GROUND SURFACE AT EL 388
2000 ST/D SRC PROJECT
OWENSBORO, KENTUCKY

CONCLUSIONS AND RECOMMENDATIONS OF ATEC LIQUEFACTION ANALYSIS

CONCLUSIONS

Even though the data presented in Section 3.0 has been qualified as extremely approximate, it does provide a guide for assessing liquefaction potential at the Newman site. In general, the highest probability of liquefaction occurring exists under normal groundwater conditions. Under these conditions, the instability will be deep and the most likely distress will be in the form of an area subsidence (on the order of 5 in.) with some differential settlement likely. On the other hand, should liquefaction occur during high groundwater levels, the occurrence and magnitude of ground distortion will be considerably greater than for the lower groundwater condition, although the probability of both the earthquake and a major flood occurring simultaneously is extremely remote.

Based on these conclusions, the following recommendations are made regarding the liquefaction problem:

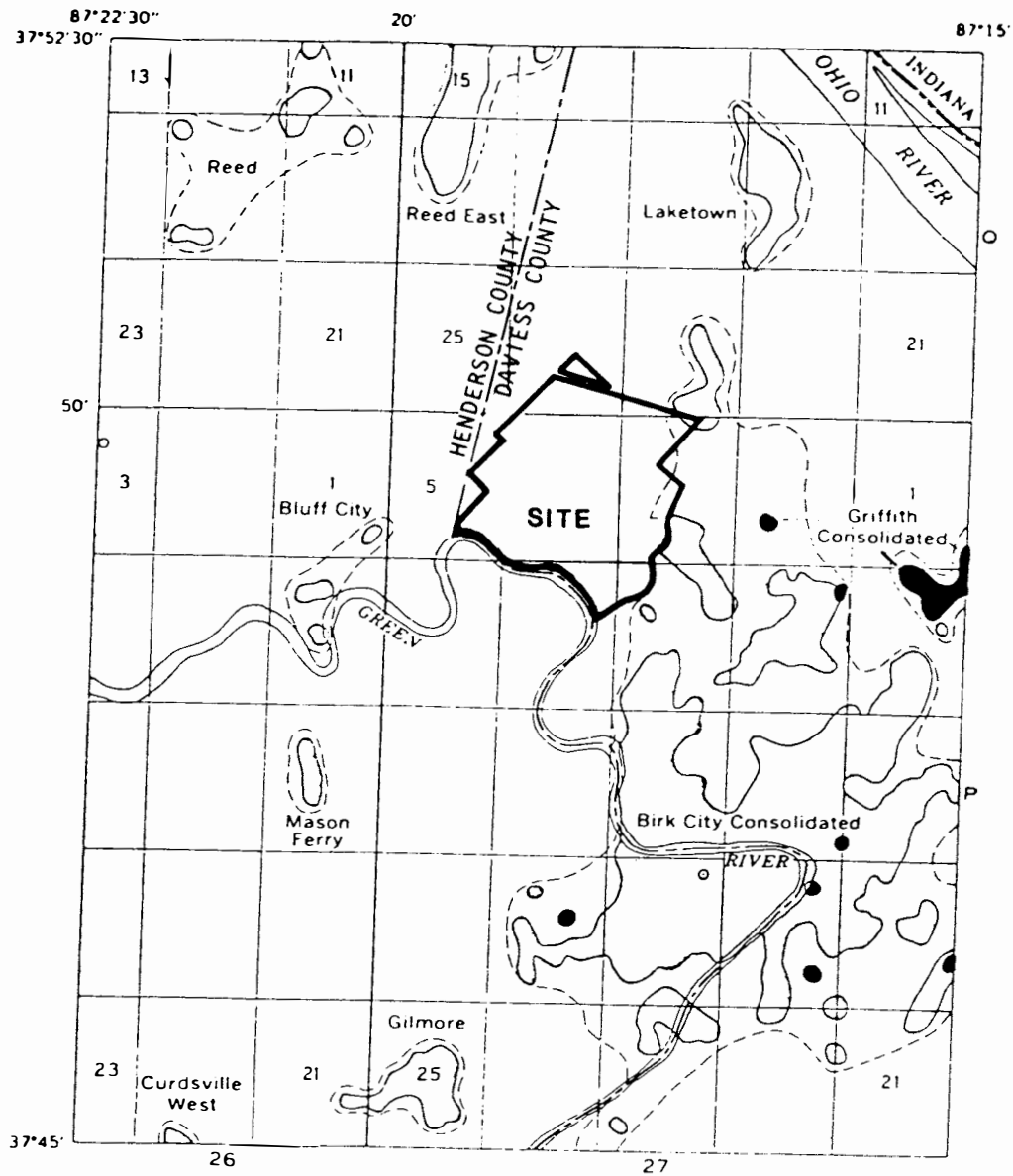
- (i) Since there is only a remote possibility that a critical earthquake will occur during a major flood, it is recommended that only structures that present a serious threat to the public safety in the event of a liquefaction failure be designed for this case. Therefore, subgrade improvement of the near-surface loose granular soil to reduce the liquefaction potential will be required in only very limited areas (if at all). The subgrade should be improved to be safe against an earthquake induced ground acceleration of 15% of gravity. In addition, the granular soils above the normal groundwater level should be improved to an average *N*-value of 15.
- (ii) It is recommended that liquefaction be considered only under normal groundwater conditions for all other structures. Subgrade improvement for the sole purpose of reducing liquefaction potential should be based on a ground acceleration of 15 percent. Considering the data generated to date, it appears that subgrade improvement below the normal groundwater level necessary to satisfy this criterion will be required over only limited portions of Area B and C.
- (iii) A relatively thick layer of clayey soil is present over the majority of Area C. This clay will tend to minimize differential movement in the event of deep seated liquefaction. Therefore, it will probably not be necessary to improve the subgrade (as implied in statement ii above) beneath the structures that are currently planned within Area C.
- (iv) There may be certain combinations of structure characteristics and soil conditions which provide additional liquefaction considerations not discussed herein. This possibility must be reviewed during the final phases of design.

L.2.4 Mineral resources

Petroleum, coal, sand, and gravel are commercially produced in the counties around the site.

L.2.4.1 Petroleum

Oil, the most important mineral resource in the local area, was first discovered in Daviess County in 1938, in what is called the Birk City Consolidated Field.⁵ Since then, the local area has been explored extensively for additional reserves of oil. Seven oil fields have been discovered in the local area: Birk City Consolidated, Bluff City, Griffith Consolidated, Laketown, Mason Ferry, Reed, and Reed East (Fig. L.10). A summary of each field — its producing formation(s) and its production through June 1977 — is presented in Table L.4. The total production of oil in 1978 was 403,388 bbl for Daviess County and 715,783 bbl for Henderson County (ER, Appendix). No production data for natural gas are available.

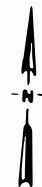


EXPLANATION

Oil pool

Gas pool

Approximate field boundary



0 1 2 KILOMETERS



0 1 2 MILES



SCALE

Fig. L.10. Oil and gas pools in site vicinity. Source: ER, Appendix B, Fig. B.11.

Table L.4. Oil and gas pools near the proposed SRC-I site

Name	Producing formation	Approximate depth		Location (Carter coordinates)	Year discovered
		m	ft		
Birk City	Palestine	313.7	1032	P-27	1938
	Waltersburg,	337.7	1111		
	oil and gas				
	Tar Springs	380.9	1253		
	Jackson	459.6	1512		
	Cypress	502.2	1652		
	Paint Creek	531.4	1748		
	Bethel	495.5	1630		
	Renault	578.8	1904		
	Aux Vases	526.8	1733		
	O'Hara	532	1750		
Bluff City	McClosky	551.7	1815	10-P-26	1956
	Aux Vases	594.6	1956		
	Pennsylvanian	167.2	550		
	Palestine,	308.3	1014		
	oil and gas				
	Menard, Chapman	325.3	1070		
	Waltersburg,	339.0	1115		
	oil and gas				
	Tar Springs	356.5	1176		
	Jackson	460.3	1514		
	Sample	495.5	1630		
Griffith Consolidated (includes Stanley)	McClosky	548.7	1805	9-P-28	1946
	Aux Vases	538.4	1771		
	O'Hara	541.1	1780		
	McClosky	551.7	1815		
Laketown	Aux Vases	538.4	1771	19-Q-27	1952
	O'Hara	541.1	1780		
	McClosky	551.7	1815		
Mason Ferry	Tar Springs	417.7	1374	11-P-26	1955
Reed	Aux Vases	608.0	2000	11-Q-26	1939
	O'Hara	445.0	1964		
Reed East	Waltersburg	364.8	1200	15-Q-27	1939
	Aux Vases	561.2	1846		
	O'Hara	565.4	1860		

Source: H. R. Schwalb, E. N. Wilson, and D. G. Sutton, Oil and Gas Map of Kentucky, Kentucky Geological Survey, Series 10, 1972.

Based on published information, the site appears to be outside the boundaries of known oil fields. Figure L.11 shows the oil and gas wells within a 1-km (0.6-mile) radius of the site. Table L.5 lists these wells and indicates operator, farm name, elevation, total depth, and well status. This table indicates that all 12 wells drilled on the site were dry holes, but 11 of the 17 wells located adjacent to the site are producing or have produced oil.

Petroleum is pumped from the wells into holding tanks that are located near access roads. Periodically, a tank truck empties these holding tanks for transport to a distribution center. A 20-cm (8-in.) underground oil pipeline owned by the AMOCO Pipeline Complex traverses the site. Its nominal depth of burial is 91 cm (36 in.).

One well, No. 15, Fig. L.11, is used as a water-injection well for secondary oil recovery by waterflooding. This well uses water pumped from an abandoned oil well that has been converted to a water well on the site property (No. 8, Fig. L.11).

L.2.4.2 Coal

In value, coal production now exceeds petroleum production in Daviess County.¹² The mining nearest the site has been in the No. 9 coal bed at the base of the hills 8 km (5 miles) to the

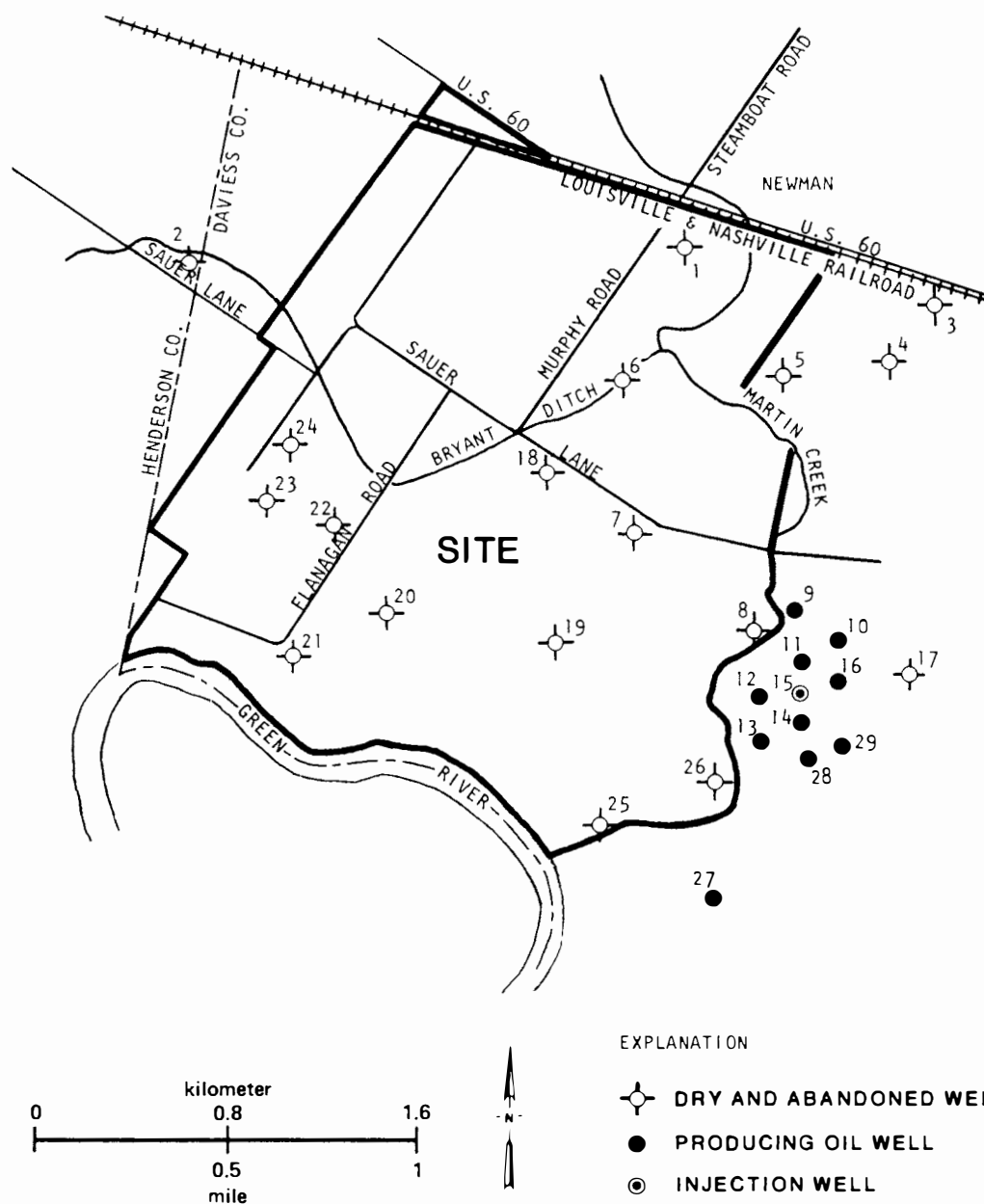


Fig. L.11. Oil and gas wells within 1 km (0.6 mile) of site. Source: ER, Appendix B, Fig. B.12.

Table L.5. Oil and gas well records for a part of the Reed Quadrangle, Henderson and Daviess counties, Kentucky

Map ^a	Farm name	Operator name	Well number	Completion date	Distance from section lines (location by Carter coordinates)	Elevation (MSL)	Total depth from surface		Well status
							m	ft	
1	Kruger	Ashland-Basin-Kauffman	1		600' SL X 1050' WL (23-Q-27)	382	611.0	2010	D&A ^b
2	J. P. Blair	Carter Drilling Co.	1	4-26-52	550' SL X 900' EL (25-Q-27)	383	618.0	2033	D&A
3	Lee Robinson	Combs & Jenkins	1	12-14-38	265' NL X 250' EL	383	587.6	1933	D&A
4	Joe L. Rudy	George A. Hoffman	1	7-27-68	900' NL X 1030' EL	384	574.8	1891	D&A
5	Chas. A. Drury	Indiana Farm Bureau	1	6-11-59	950' NL X 11800' EL	383	601.0	1977	D&A
6 ^c	W. J. Foster	Obie Shaw	1	1-16-69	940' NL X 300' WL	385	588.2	1935	D&A
7 ^c	W. J. Foster	J. C. Miller Ashland	1	2-09-52	3380' NL X 400' WL	385	598.9	1970	D&A
8 ^c	W. J. Foster	Barron Kidd	6	8-28-68	1485' SL X 2000' WL	382	471.8	1552	D&A
9	W. J. Foster	Barron Kidd	4	6-28-68	1780' SL X 2300' EL	381	474.2	1560	Oil
10	W. J. Foster	Barron Kidd	5	8-25-68	1400' SL X 1685' EL	382	471.2	1550	Oil
11	W. J. Foster	Barron Kidd	3	11-16-67	1130' SL X 2200' EL	383	472.4	1554	Oil
12	Fed. Land Bank et al.	George A. Hoffman	2	11-01-67	650' SL X 2100' WL	382	474.7	1555	Oil
13	Fed. Land Bank et al.	George A. Hoffman	3	8-22-75	40' SL X 2120' WL	381	470.3	1547	Oil
14	Fed. Land Bank et al.	George A. Hoffman	1	10-07-67	280' SL X 2200' EL	382	472.7	1555	Oil
15	W. J. Foster	George A. Hoffman	1	11-12-68	700' SL X 2190' EL	382	474.2	1560	WIW ^d
16	W. J. Foster	Barron Kidd	1	9-10-67	780' SL X 1670' EL	381	475.4	1564	Oil
17	W. J. Foster	Barron Kidd	2	10-08-67	1025' SL X 680' EL (3-P-27)	382	468.7	1542	D&A
18 ^c	W. J. Foster	George A. Hoffman	1	10-29-53	2400' NL X 950' EL	383	404.9	1332	D&A
19 ^c	Prudential Life Ins.	Major Oil Company	1		1400' SL X 750' EL	392	624.1	2053	D&A
20 ^c	W. J. Foster	Barron Kidd	5	12-19-67	1830' SL X 1820' WL	390	608.0	2000	D&A
21 ^c	Prudential Life Ins.	Robert Reilly	1	5-26-43	1180' SL X 500' WL	391	613.5	2018	D&A
22 ^c	Murphy	Kingswood	1	8-30-50	3200' NL X 850' WL	391	625.0	2056	D&A
23 ^c	R. C. & Thelma Murphy	Harper, Harte & Pearce	1	3-25-72	2625' NL X 50' WL	390	417.7	1374	D&A
24 ^c	Leo Murphy	Bogg Oil Company	1	12-30-76	2075' NL X 475' WL (4-P-27)	388	413.4	1360	D&A
25 ^c	W. J. Foster	Slagter Producing Corp.	1	1-06-61	1100' NL X 100' EL (7-P-27)	389	493.1	1622	D&A
26 ^c	W. J. Foster	J. D. Turner	1	1-06-58	550' NL X 1520' WL (8-P-27)	388	492.5	1620	D&A
27	Ebelhar Brothers	R. O. Wilson, II	1	12-10-63	2100' NL X 1380' WL	375	469.1	1543	Oil
28	Fed. Land Bank et al.	George A. Hoffman	5		2150' EL X 250' NL	373			Oil
29	Fed. Land Bank et al.	George A. Hoffman	4 ^e	11-24-68	70' NL X 1700' EL	377	471.2	1550	Oil

^a Locations are shown in Fig. L.11.^b D&A = dry and abandoned well.^c Onsite well.^d WIW = water injection well.^e Location only; filed 9-77.Source: A. E. Smith, *Well Index List, Reed Quadrangle, Henderson and Daviess Counties, Kentucky*, Open File Report, U.S. Geological Survey, 1973.

south. This coal seam is found at an approximate elevation of 119 m (390 ft) MSL. Two additional coal seams mapped in this general area, No. 11 and No. 13, lie above the No. 9 seam.⁵

The No. 11 seam is typically 58.4 to 96.5 cm (23 to 38 in.) thick and lies approximately 24.3 to 32 m (80 to 100 ft) above the No. 9 seam. The No. 13 seam is less than 30.5 cm (12 in.) thick in this area and is found about 6 to 8 m (20 to 25 ft) above the No. 11 seam. The No. 12 coal seam is locally present but is very thin; in some places it is represented by only a black shale. Unnamed coal beds less than 30.5 cm (12 in.) thick are also found above the No. 9 seam.⁵

Coal mines opened in the Green River Valley and inundated by the great flood of 1937 have not been reopened.⁵ No coal has been mined on or adjacent to the site, although deep coal beneath the site has been reported in drillers' logs. This coal is below river level and is not now economically feasible to mine.

L.2.4.3 Sand and gravel

No sand or gravel has been mined on or near the site. Sand and gravel resources in place above the water table on the 425-ha (1050-acre) site are estimated to be approximately 115 million m³ (150 million yd³), based on information on boring from ATEC Associates, Inc.³

Sand and gravel in Daviess and Henderson Counties are mined in sand pits and by dredging along the Ohio River. In 1977, approximately 1,089,547 t (1,201,000 short tons) were excavated in Daviess county by these methods; and approximately 208,000 t of sand and gravel, in Henderson County.

L.2.5 Surficial soils

L.2.5.1 Regional conditioning

In Daviess County, six major soil associations are present: Elk-Otwell-Ginat, Uniontown-Patton-Henshaw, Belknap-Karnak-Waberly, Loring-Memphis-Belknap, Loring-Wellston, and Wellston-Frontdorf-Zanesville.¹³ These surficial soils, which support vegetation, are only the topmost few feet of the engineering soils (alluvium and terrace deposits) described in the stratigraphy section of this appendix.

The soils of northwestern Daviess County, in the region of the site, are predominantly deep alluvial floodplain or stream terrace soils of the Elk-Otwell-Ginat Association. Regionally, this association consists of 17% Elk soils, 10% Otwell soils, 9% Ginat soils, and 64% minor soils. The general relationships among the three soils are shown in Fig. L.12.

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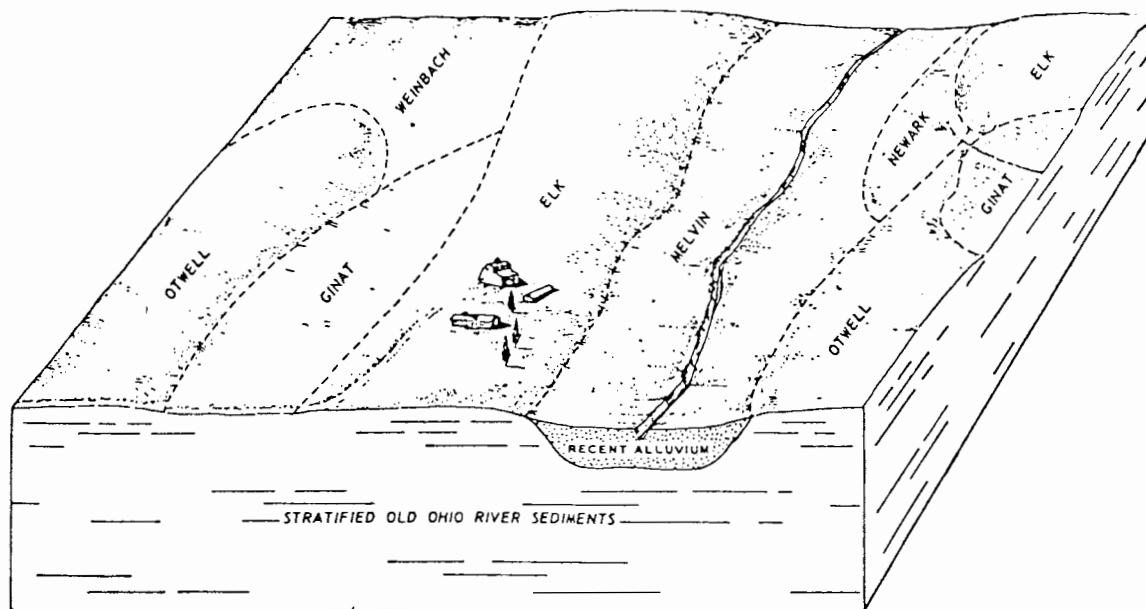


Fig. L.12. Schematic relationships of soils in area. Source: ER, Appendix, Fig. B.12.

The surface texture of the soils is mainly silt loam with a minor amount of silty clay loam. Subsurface textures are silty clay loam, loam, heavy silt loam (fragipan), silty clay, and silt loam. In addition, recent deposits of alluvium are present along the Green River. In some areas the soil is severely eroded.

Most of the soils in this area are suited for extensive cultivation; corn, soybeans, wheat, tobacco, and hay are crops common to the area. Due to acidic pH, some of these soils require liming for optimum crop production. Since these soils vary from moderately permeable and well-drained to nonpermeable and waterlogged, soil wetness can be a problem during the growing season, especially in soils along the Green and Ohio Rivers that are subject to flooding in the winter or spring. Installation of subsurface drains may be required for optimum crop production where drainage is a problem.

L.2.6 Site conditions

A soil map of the proposed site is shown in Fig. L.13. Soils of the Elk-Otwell-Ginat Association predominate onsite. They consist of nearly level-to-sloping, deep, well-to-poorly drained, medium-textured soils on stream terraces and floodplains.¹² Representative soil profiles of this association are shown in Table L.6.

The Elk and Otwell soils are common on ridges, and the Ginat soils are typical on flat areas. Elk soils are brown, deep, and well-drained, have fine-textured subsoils, and are nearly level to sloping. Otwell soils have a deep fragipan, are moderately well-drained, and are nearly level to gently sloping. Ginat soils are gray, have a fragipan, are poorly drained, have medium or moderately fine-textured subsoils, and are nearly level.

The soils of the Elk-Otwell-Ginat Association on the proposed site consist of seven major loams: Elk silt loam, Ginat silt loam, Weinbach silt loam, Otwell silt loam, Jacob silty clay loam, Huntington silt loam, and Newark silt loam. A summary of selected characteristics of these soils at the proposed site is given in Table L.7; each soil series is briefly summarized below.

The Elk silt loam occupies 26% of the site. This soil series consists of brown, deep, well-drained, nearly level-to-sloping soils with moderately fine-textured subsoils.

The Ginat silt loam, present on 23% of the site, consists of grayish-brown, deep, poorly drained, nearly level soils that have a fragipan.

The Weinbach silt loam consists of dark grayish-brown, deep, poorly drained, nearly level soils that have a fragipan. This soil series covers approximately 21% of the site.

The Otwell silt loam occupies approximately 20% of the site and consists of dark brown, deep, moderately well-drained, nearly level and gently sloping soils that have a fragipan.

The Jacob silty clay loam consists of grayish-brown, deep, poorly drained, nearly level soils that occur on floodplains between the low ridges that are parallel to streams. This soil series covers 6% of the site.

The Huntington silt loam consists of dark brown, deep, poorly drained soils that occur in bands parallel to the closest stream or river. This type of silt loam occupies only 2% of the site.

The Newark silt loam consists of brown, deep, poorly drained level soils that occur in long narrow deposits adjacent to streams. This soil series occupies 1% of the site.

L.2.7 Agricultural value

Designation of the soils as prime farmland is based on a large number of physical and chemical properties of the soils which determine the level of management required to provide sustained high crop yield. Soil capability classification is based, in part, on factors which are used in designating prime land; in general, prime land includes all soils in Class I, more than 80% of soils in Class II, and less than one third of soils in Class III. The U.S. Soil Conservation Service was consulted regarding identification of soils present on the site which qualify as prime agricultural soils,¹² and it was determined that the soils on approximately 90% of the site qualify as prime farmland soils. A figure showing the distribution of prime land is included in Sect. 3.2.1.2.

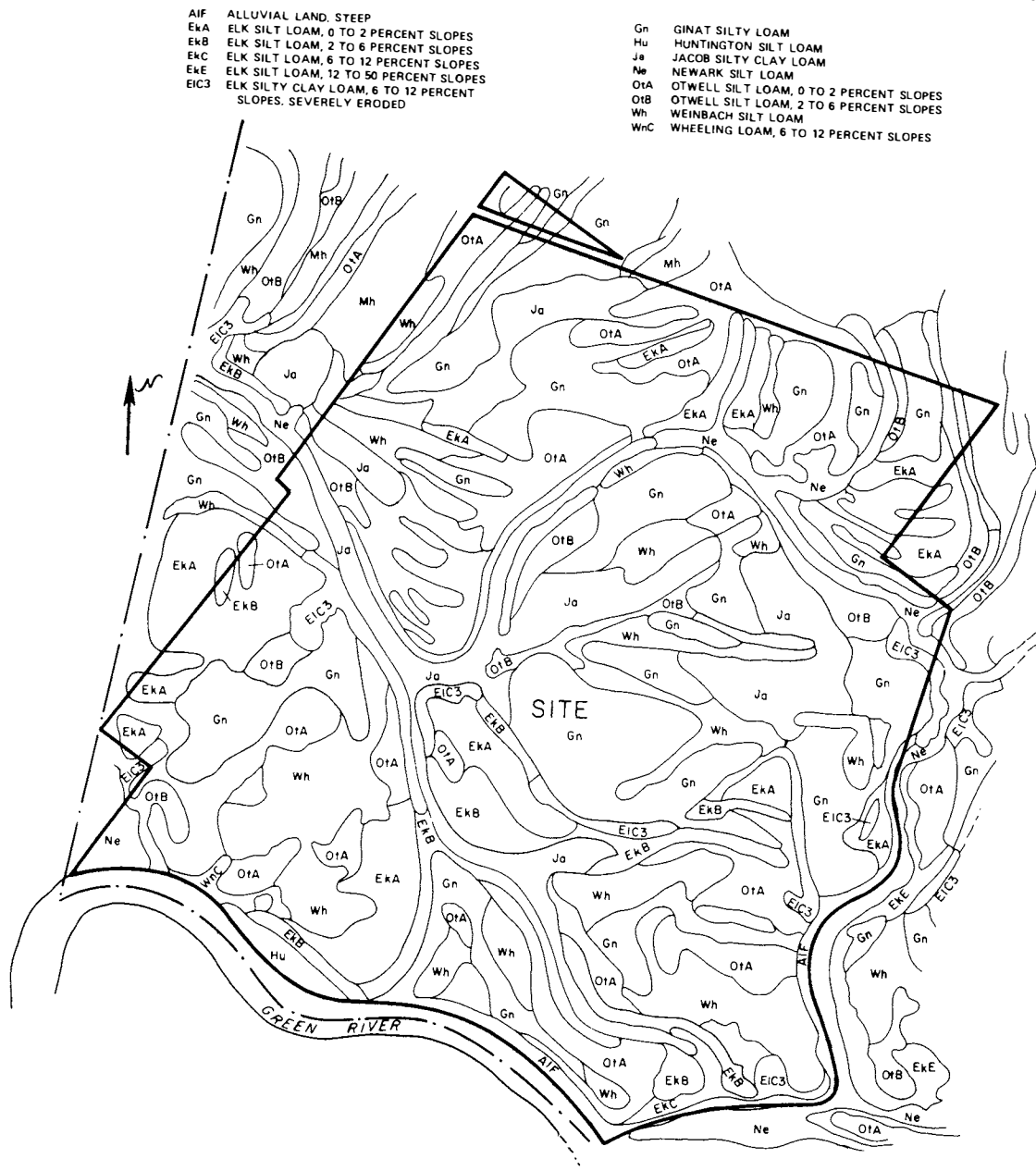


Fig. L.13. Surficial soils map of proposed site. Source: F. R. Cox, *Soil Survey of Daviess and Hancock Counties, Kentucky*, U.S. Dept. of Agriculture, Soil Conservation Service, 1974.

Table L.6. Representative surficial soil profiles of the Elk-Otwell-Ginat association

Elk Series, typical of ridges			Ginat Series, typical of terraces			Otwell Series, typical of ridges		
Depth ^a		Horizon	Characteristics	Depth ^a		Horizon	Characteristics	Horizon
cm	in.			cm	in.			
0		Ap (silt loam)	Weak, fine, granular structure; very friable; medium acid; clear smooth boundary	0		Ap (silt loam)	Weak, fine, granular structure; very friable; medium acid; abrupt smooth boundary	Ap (silt loam)
20.3	8	B1 (light silty clay loam)	Weak, coarse, subangular blocky structure; friable; very strongly acid; clear smooth boundary	22.9	9	B2tg (heavy silt loam)	Moderate, medium, subangular blocky structure; very friable; very strongly acid; clear smooth boundary	B1t (silt loam)
30.5	12	B21t ^b (light silty clay loam)	Moderate, medium, subangular blocky structure; firm; very strongly acid; gradual smooth boundary	50.8	20	Bx1 (heavy silt loam)	Weak, fine, subangular blocky structure; firm, brittle, and compact; very strongly acid; gradual smooth boundary	B21t (silt loam)
66.0	26	B22t (light silty clay loam)	Weak, coarse, subangular blocky structure; firm; very strongly acid; gradual smooth boundary	66.0	26	Bx2 (silty clay loam)	Weak, fine, subangular blocky structure; firm, brittle, and compact; strongly acid; gradual smooth boundary	B22t (silt loam)
91.4	36	C (loam)	Massive; friable; strongly acid	101.6	40	C (silty clay loam)	Massive; firm; very strongly acid	Bx (heavy silt loam)
127.0	50	Bottom ^c		132.1	52			C (heavy silt loam)
								Bottom ^c

^aDepth from surface to top of indicated horizon.^bt indicates alluvial clay.^cBottom of typical soil profile.Source: F. R. Cox, *Soil Survey of Daviess and Hancock counties, Kentucky*, U.S. Department of Agriculture, Soil Conservation Service, 1974.

Table L.7. Selected characteristics of surficial soil series on the proposed site^a

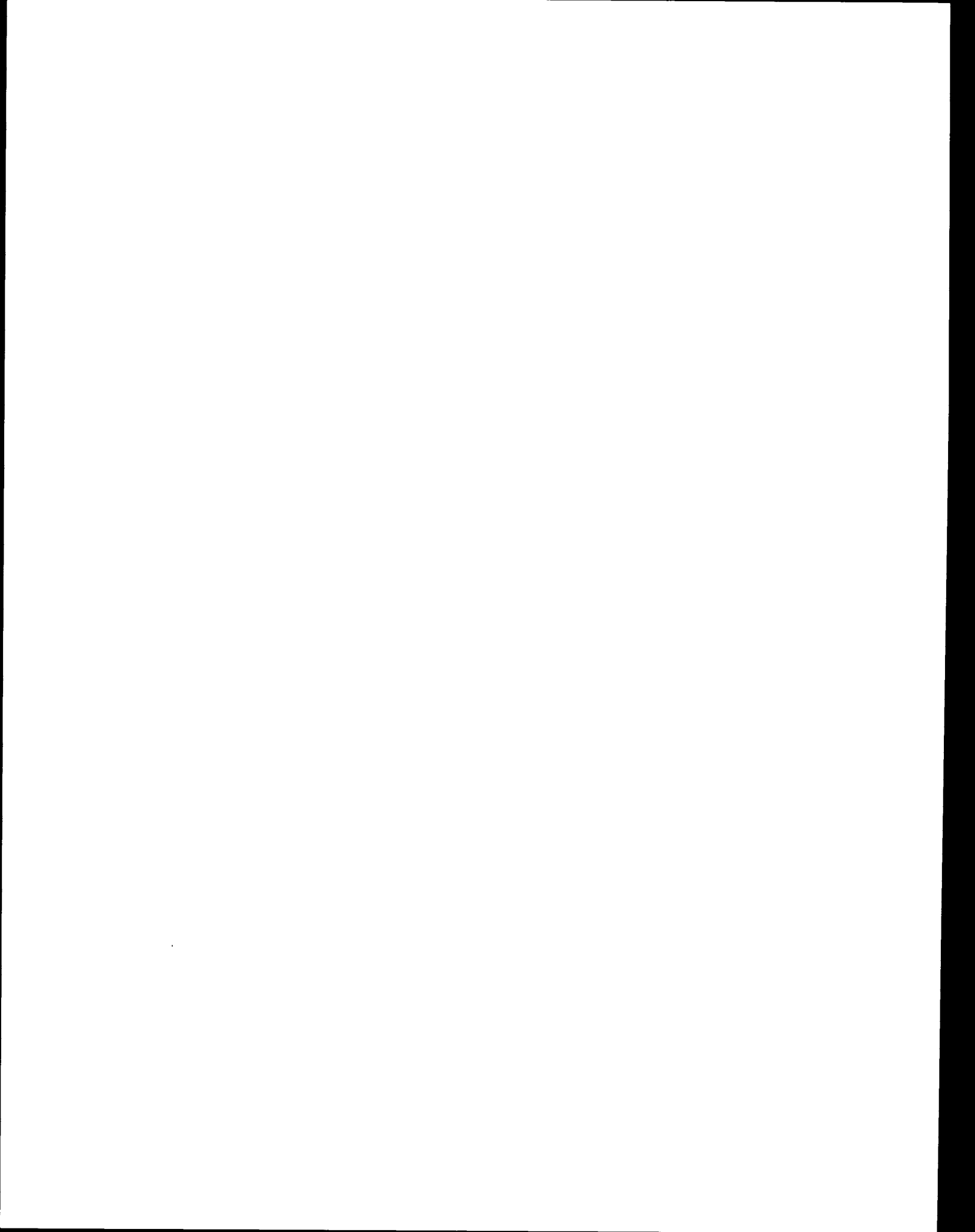
Characteristic	Elk silt loam	Ginat silt loam	Huntington silt loam	Jacob silty clay loam	Newark	Otwell silt loam	Weinbach silt loam
Expected CEC, ^b meq/100 g	33-37	33-37	26	50+	5+	33-37	33-37
Soil order	Alfisol	Alfisol	Molisol	Inceptisol	Entisol	Alfisol	Alfisol
Depth to bedrock, m (ft)	15+ (50+)	15+ (50+)	15+ (50+)	15+ (50+)	6+ (20+)	15+ (50+)	15+ (50+)
Seasonal high water table, m (ft)	1.8+ (6+)	0-0.16 (0-0.5)	0.85+ (3+)	0-0.16 (0-0.5)	0.16-0.46 (0.5-1.5)	0.46-0.76 (1.5-2.5)	0.16-0.46 (0.5-1.5)
Depth of profile from surface, cm (in.)	125 (50)	135 (52)	155 (60)	125 (50)	125 (60)	155 (60)	125 (50)
Typical clay fraction, %	<30	<30	<30	<40	<30	<30	<30
U.S.D.A. texture	Silt loam	Silt loam	Silt loam	Silt clay loam	Silt loam	Silt loam	Silt loam
Unified (surface) soil classification	ML-CL ^c	ML or CL-ML	ML-CL	ML-CL	ML-CL	ML	ML
Typical liquids limit, units	<50	<50	<50	<50	<50	<50	<50
Permeability	Moderate	Slow	Slow	Moderately slow	Moderate	Slow	Slow
Natural soil drainage	Well drained	Poorly drained	Poorly drained	Poorly drained	Poorly drained	Poorly drained	Poorly drained
Use limitations	Erosion	Seasonal high water table	Subject to flooding	Subject to flooding	Subject to flooding	Seasonal high water table	Seasonal high water table
Shrink/swell potential	Low	Low	Low	Low	Low	Low	Low
Natural fertility	Good	Poor	Good	Poor	Fair	Good	Fair
Parent material	Ohio River alluvium	Ohio River alluvium	Alluvium from loess	Mixed alluvium	Ohio River alluvium	Ohio River alluvium	Alluvium
Erosion hazard	Moderate to high	Low	Low	Low	Low	Moderate	Low
Percentage of site	26	23	2	6	1	20	21

^aAbout 40% of the soils onsite are severely eroded; 1% is recent alluvial deposits.^bCEC = cation exchange capacity.^cML-CL indicates Unified Soil Classification designations.Source: F. R. Cox, *Soil Survey of Daviess and Hancock counties, Kentucky*, U.S. Department of Agriculture, Soil Conservation Service, 1974.

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12. L. H. Frey and P. McGrain, *The Mineral Industry of Kentucky, 1973*, K. Geol. Sur., Ser. 10, Reprint 45, 1976.
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Appendix M
GROUNDWATER HYDROLOGY



Appendix M

GROUNDWATER HYDROLOGY

M.1 HYDROLOGY

M.1.1 Regional properties of alluvial aquifers

Sand and gravel aquifers in the alluvial plain of the Ohio and Green rivers are the best source of groundwater in the region and yield large quantities to shallow wells. Regional groundwater availability is shown in Fig. M.1. Aquifer extent and thickness may vary in some locations over relatively short distances, depending partly on whether the sands and gravels were deposited by recent stream activity or as Pleistocene glacial outwash. Sand, silt, and clay are typically more closely interbedded in the recent deposits. The rapid changes in sediment type result in thinner aquifers, perched water tables, and partially confined aquifers; nevertheless, wells completed in alluvial aquifers normally yield adequate water for industrial supplies. Wells completed below 39.6 m (130 ft) in Daviess County yield large quantities of water suitable for public water supply systems. Typical rates of groundwater flow in the Ohio River alluvium attain a maximum of 1.2 m/d (4 ft/day), depending on the soil structure (F. Wolf, U.S. Environmental Protection Agency, personal communication, 1979).

Recharge to alluvial aquifers is derived from three sources: infiltration from rivers flowing through the alluvial plain, direct precipitation, and underflow along the top of bedrock.

The Green and Ohio rivers are the greatest source of recharge to these aquifers since a hydraulic connection typically exists between the river and the alluvium. The Owensboro Municipal Utilities water plant withdraws over 9 million gpd via 29 active wells, 39 to 45 m (130 to 150 ft) deep in similar alluvium within an area of about 1 sq mile (C. Brown, Superintendent, Owensboro Municipal Waterworks, personal communication, 1979). This well field may utilize induced infiltration from the Ohio River to maintain the high yield.

River recharge to the alluvium varies seasonally. During high river flow periods (winter and spring), water flows from the river into the alluvium,¹ with the greatest recharge probably occurring during flood periods. During low-flow periods (usually summer and fall), the alluvial aquifer discharges into the river.

Of the 112-cm (44-in.) annual precipitation in the site area, approximately 37% [41 cm (16 in.)] is surface runoff. The remainder infiltrates the soil and is probably largely held in the surface soils where it evaporates or is transpired by plants. Estimates of the amount of recharge to the alluvial aquifer from direct infiltration range from 2.9 million to 4.9 million liters per day per sq km (0.3 to 0.5 million gpd per sq mile).²

In areas adjacent to the incised valley wall, some groundwater may flow from bedrock aquifers into the alluvial aquifer. Recharge from bedrock is called underflow. In areas upstream along the Green River, recharge by underflow has been estimated to be 0.005 m (0.16 ft) or 3.3 million gpd per sq mile.¹ This type of recharge requires adequate head along the valley edge and would require artesian conditions near the center of the alluvial valley to constitute a substantial source of recharge to the alluvium.

M.1.2 Local properties of the alluvial aquifer

Alluvium beneath the site is composed of mixed sediment from the Ohio and Green rivers.¹ Glaciofluvial deposits from the Ohio River are gravelly sands, and the valley fill formed by the Green River is predominantly sandy. Site classification of alluvial samples by ATEC Associates³ shows that below surficial soils and loose sands the alluvium is fine to medium sand with a

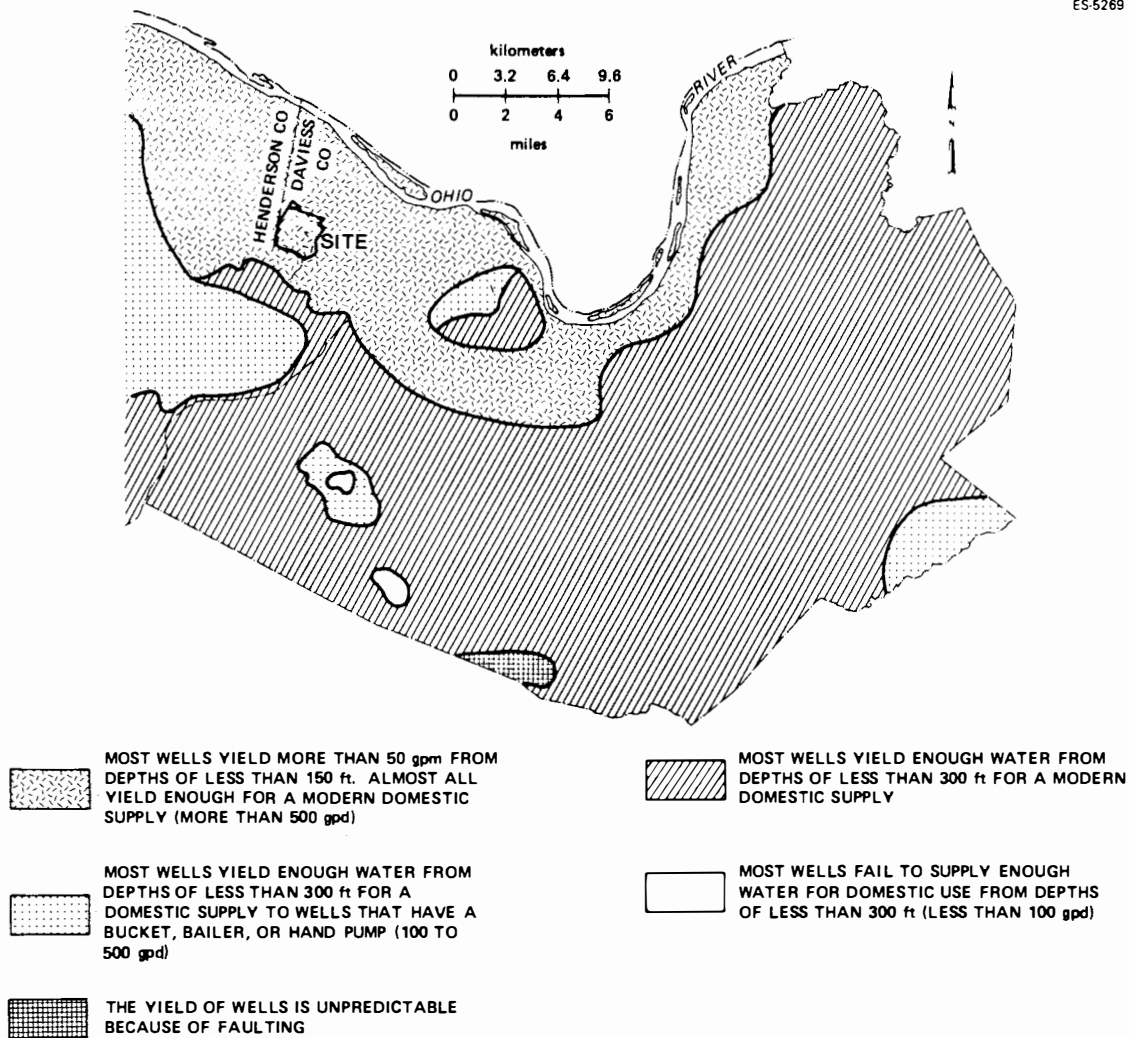


Fig. M.1. Availability of groundwater in Daviess County and Henderson County. Sources: A. W. Devaul and B. W. Maxwell, *Availability of Groundwater in Daviess and Hancock Counties, Kentucky*, U.S. Geological Survey, Hydrological Investigations Atlas HA-27, 1962; B. W. Maxwell and A. W. Devaul, *Availability of Groundwater in Union and Henderson Counties, Kentucky*, U.S. Geological Survey, Hydrological Investigations Atlas HA-28, 1962.

minor amount of gravel. Table M.1 is a listing of the alluvial materials penetrated by exploratory boring No. 3. Sand and gravelly sand range in thickness beneath the central site area from 24 to 30 m (80 to 100 ft). Boring No. 10 was located on the bank of the Green River and encountered 21 m (69 ft) of clay silt, probably representative of the recent sediment load deposited by the river. The presence of this thick, poorly permeable deposit raises questions regarding the hydraulic connection between the river channel and the alluvial aquifer in this particular stretch of river.

Eight additional piezometers were installed in April 1980; a total of 10 piezometers have been monitored between April 1980 and March 1981. Figure M.2 shows the locations of the existing piezometers. Hydrographs for each piezometer and for the Green River are shown in Fig. M.3. The

Table M.1. Sequence of deposits in boring No. 3

Description of unit	Depth to surface	
	m	ft
Clay, silty, light brown and gray, slightly moist	0	
Silt, sandy, brown, very moist	2.0	6.5
Sand, fine, silty, brown, moist, loose	2.4	8.0
Sand, brown, moist to wet, loose to medium-dense, with some silty fine sand	4.0	13.0
Sand, fine to medium, silty, brown to gray, with traces of coarse sand and fine gravel	12.3	40.5
Sand, fine to medium, brown, medium-dense to very dense, wet, with traces of coarse sand, fine gravel, and some organic material	20.7	68.0
Sand, fine to coarse, silty, brown, medium-dense to dense, wet, with traces of gravel and organic material; some gray, coarse, dense sands also noted	28.3	93.0
Shale, light gray, laminated (bedrock)	38.1	125.0

Source: ATEC Associates, *Preliminary Geotechnical Engineering Study, 200ST/D Project*, Wheelabrator Cleanfuel Corporation, Kentucky Center for Energy Research, 1977.

hydrographs show that the piezometers located closest to the Green River (piezometers C, 8, 65, and 66) respond to elevated river stages. This indicates that some extent of hydraulic interaction between the river and the alluvial aquifer exists. Groundwater flow directions based on piezometric surface maps drawn from monitoring are shown in Fig. M.4.

Hydrologic characteristics of Ohio River alluvial deposits have been determined at several locations along the river in Kentucky.⁴ Median permeabilities and transmissivities determined are 18.4 m/d (460 gpd/ft²) and 652 m²/d (52,150 gpd/ft).⁴ Ryder calculated transmissivities of 90 to 150 m²/d (7200 to 12,000 gpd/ft) for Green River alluvium at two upstream locations.²

Using Hayden's approximation for permeability and particle size classification from ATEC, permeability of alluvium beneath the site is estimated to be 14.7 m/d (367 gpd/ft²). Assuming a saturated thickness of 31 m (100 ft), transmissivity of the alluvial aquifer is estimated to be approximately 452 m²/d (36,700 gpd/ft). This estimate is an approximation of aquifer characteristics based on groundwater modeling. Variations in sediment characteristics beneath the site may result in local areas of greater or lesser water transmitting capability.

M.1.3 Regional and local properties of bedrock aquifers

Bedrock aquifers in the Owensboro/Henderson area have not been widely developed since the Ohio River alluvial aquifer provides an abundant supply of potable water. Exploratory wells drilled for petroleum penetrate the bedrock units which contain potential aquifers. Figure M.5 summarizes the aquifer potential of bedrock in the region. Permeabilities of most units in the upper part of the Carbondale Formation are too low for extensive development. In addition, saline water occurs at a relatively shallow depth in bedrock north of the Rough Creek fault zone.

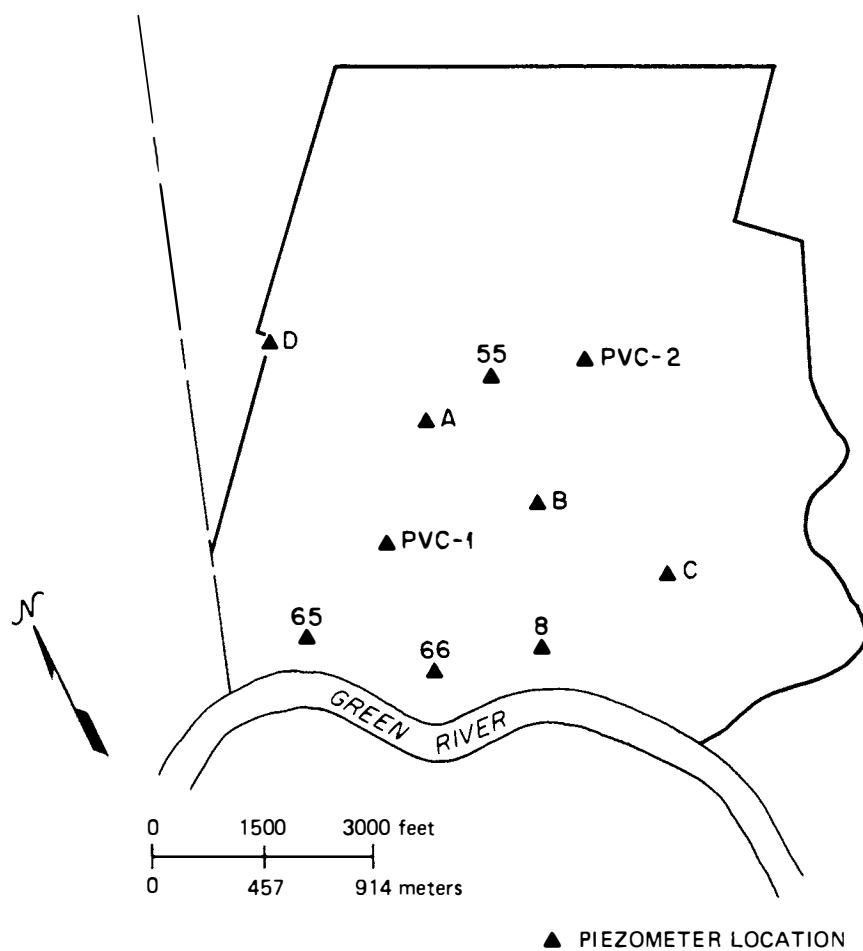


Fig. M.2. Piezometer well locations.

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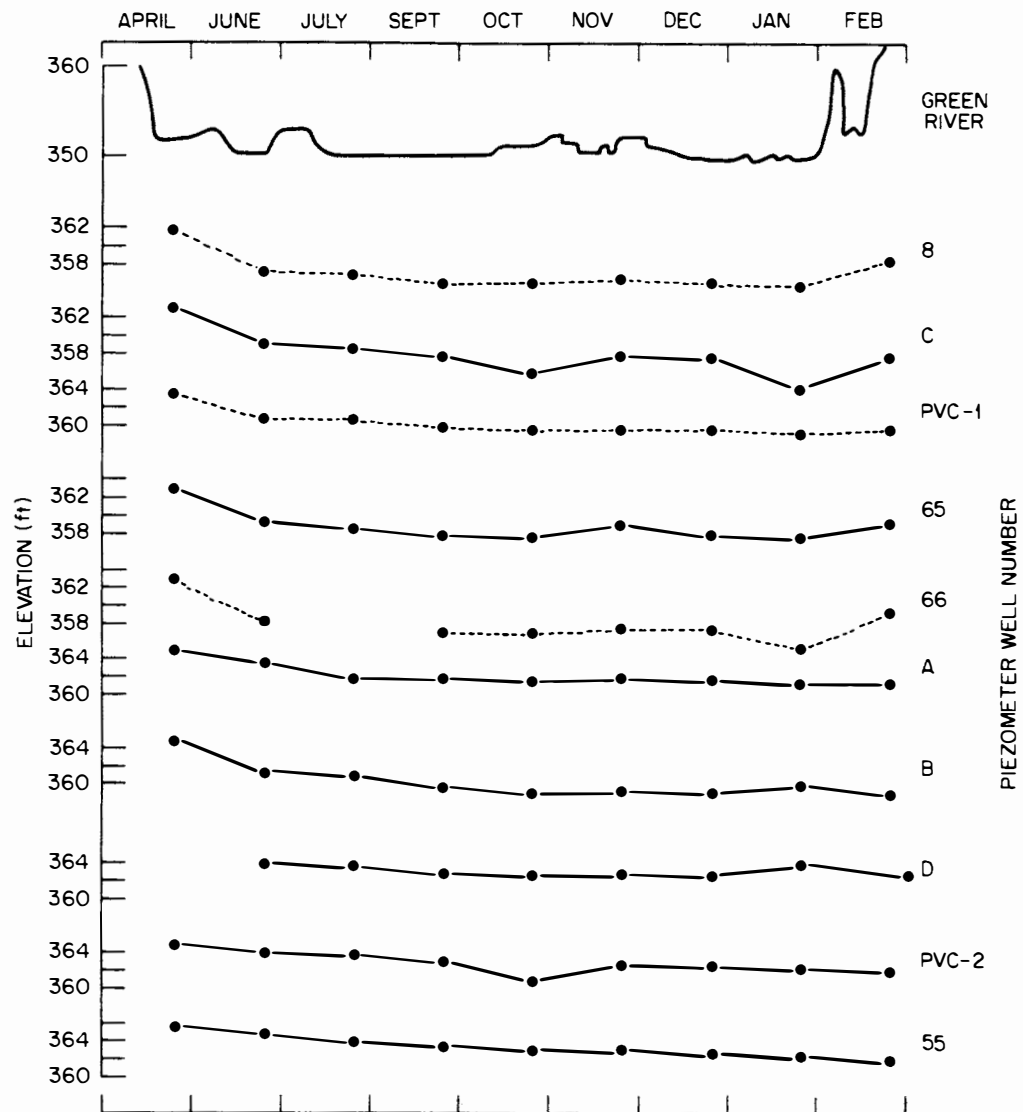


Fig. M.3. Hydrographs of the Green River and SRC-I site piezometers - April 1980 through February 1981.

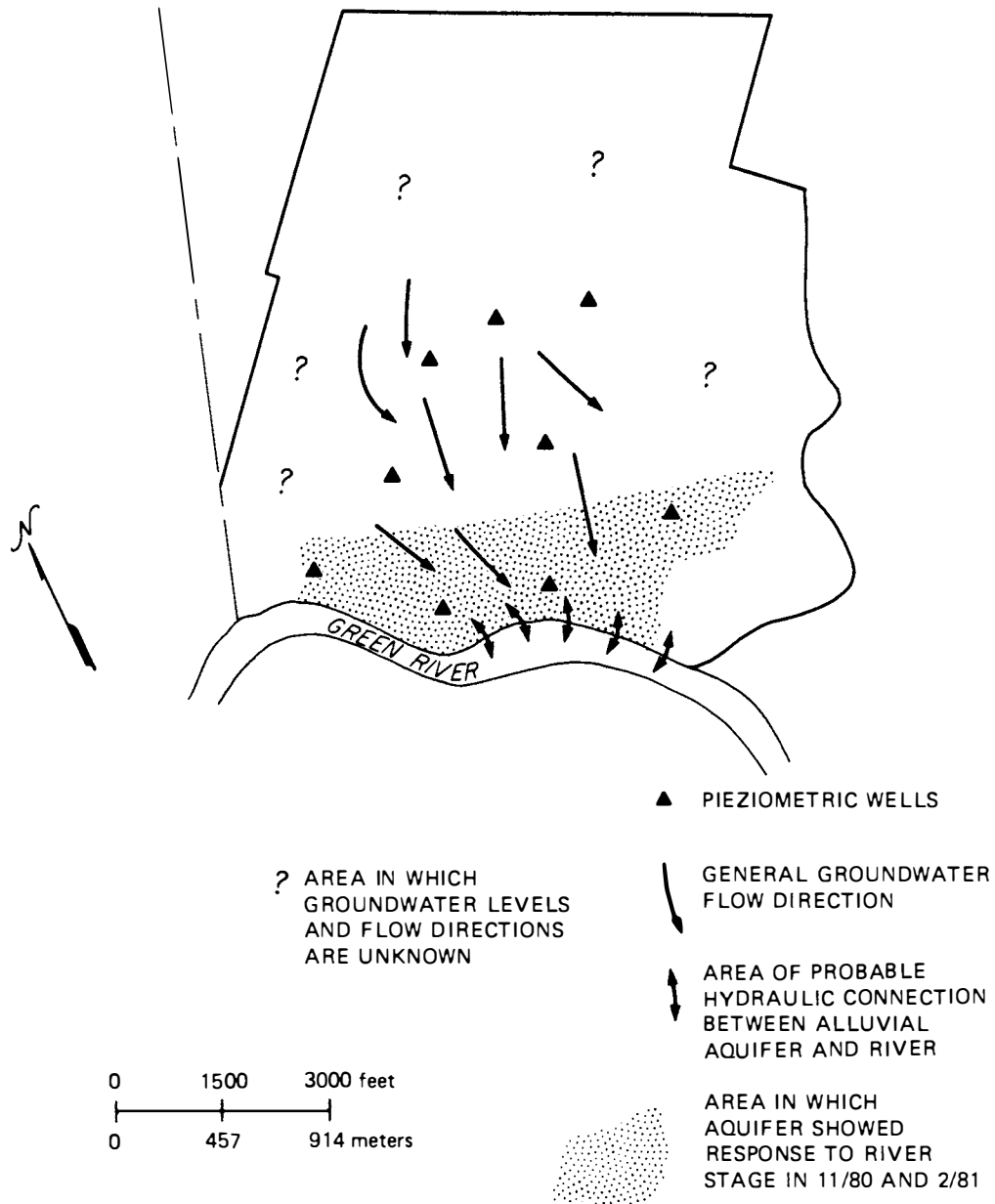


Fig. M.4. Groundwater hydrologic setting.

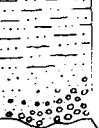
STRATIGRAPHIC UNIT		THICKNESS (IN FEET)	SECTION	HYDROLOGY
PLEISTOCENE AND RECENT	Loess	0-70		Yields practically no water to wells.
	Alluvium	0-145		Yields large quantities of water along the Ohio River. Vertical wells produce more than 1,000 gpm and collector-type wells produce as much as 5,000 gpm. Yields enough water for a modern domestic supply (more than 500 gpd) to wells in larger tributary valleys. Yields little or practically no water to wells in small valleys. Water is hard to very hard and may contain objectionable amounts of iron, although the dissolved-solids content may be low.
PENNSYLVANIAN CARBONDALE FORMATION	No. 9 coal	300-450		Yields practically no water to wells.
	Pleasant-view(?) sandstone			
	Schultztown coal Sebree sandstone			Yields enough water for a modern domestic supply to wells penetrating sandstone. Locally yields as much as 20 gpm. Water north of the Shawneetown-Rough Creek fault zone and in the deepest part of the Moorman syncline is salty.

Fig. M.5. Columnar section for Newman site. Source: B. W. Maxwell and R. W. Devaul, *Availability of Groundwater in Union and Henderson Counties, Kentucky*, U.S. Geological Survey, Hydrological Investigations Atlas HA-28, 1962.

The potential existence of a potable bedrock aquifer beneath the site is low. The top of bedrock is at an elevation of about 80 m (260 ft), and shale was encountered in the three boring which reached bedrock. The saline/fresh water interface (1000 ppm total dissolved solids) occurs at an elevation about 60 m (200 ft) beneath the site.⁵ Electric logs from oil wells on the site indicate that the salinity of groundwater increases markedly at elevations between 4 and 91 m (12 to 62 ft) below sea level. Local well drillers report finding from a trace to 500 ppm of chloride in groundwater at elevations ranging from 26 to 47 m (88 to 153 ft) in western Daviess County (W. Johnson, Owensboro Pump and Supply, personal communication, 1979).

M.2 STATEMENT OF WORK FOR GROUNDWATER STUDIES

M.2.1 Introduction and objectives

The proposed groundwater investigation is designed to determine the specific hydrogeologic regime of the plant site. DOE/ICRC has had studies made by Dames & Moore in connection with the development of the Environmental Impact Statement (EIS).⁶⁻⁸ The groundwater investigation included the installation of 10 observation wells with constant head in situ permeability tests performed in two wells. This investigation has revealed a complex flow pattern in the study area including a possible groundwater divide near the western boundary. The complex pattern may be the result of a low-permeability clay channel fill paralleling the Green River as determined in the preliminary foundation investigation.⁹

The ongoing groundwater investigation includes monthly monitoring since April 1980 of 10 observation wells within the site boundaries⁷ and quarterly groundwater quality measurements for select parameters from five domestic wells on the perimeter of the site.⁸ These studies have provided background information on general flow patterns and selected water quality parameters for the site.

Evidence of a complex hydrogeologic flow pattern and discrepancies between published and field determinations of site aquifer parameters warrants a more detailed investigation, because soil deposit patterns in alluvial river bottoms can cause unexpected groundwater behavior.

Specific questions to be addressed are

1. What are the aquifer characteristics?
2. What are the shape and boundaries of the alluvial aquifer?
3. What are the temporal and spatial flow patterns in the aquifer?
4. What is the background groundwater quality at the site?
5. Considering all these factors, what are the environmental and human health implications?

Further investigation, therefore, is warranted to accurately determine aquifer characteristics. This will allow (1) proper design of the required monitoring well system that will reliably depict subsurface conditions and (2) determination of the actual direction of groundwater flow. The occurrence of any confining clay layers and intermediate permeability zones on the site will be determined to allow predictions of the possible routes of groundwater contamination. If the aquifer is found to have a high degree of potential to become contaminated, mitigation measures could be taken during construction to prevent degradation of the aquifer.

The investigation would entail an expansion of the existing piezometric net to include the remaining portion of the plant site. Additional observation wells would facilitate characterization of subsurface conditions throughout the site and current water quality. In addition to physical aquifer conditions, determination of groundwater chemical quality characteristics would facilitate design of an accurate monitoring well system to determine any groundwater degradation. Such monitoring capability is required by state and Federal regulations and is necessary to accurately measure any degree of aquifer contamination and the effectiveness of aquifer decontamination measures. Additional applicable data obtained on site during other studies, such as those to be performed on groundwater supply potential or foundation design, will be integrated in the design.

M.2.2 Scope of work

Hydrogeologists will be assigned to the study to obtain the data to answer the preceding questions. During the studies, the following components will be completed:

1. well-water user inventory,
2. well installation,
3. aquifer characterization, and
4. groundwater quality sampling.

M.2.3 Study description and methodology

M.2.3.1 Well-water user inventory

A well-water users survey will be conducted within a 5-km radius of the plant site. This survey will gather data concerning well depth, water level (both static and dynamic, where applicable), type of well, and pertinent history, including amount of pumpage, history of water level lowering below the bottom of the well, and any fluctuations in water level. Water quality data will also be collected if available. All wells, their depths, and their water levels will be plotted on a regional map. Data will be gathered within as short a time as possible to allow correlation of static water levels.

M.2.3.2 Well installation

About 14 observation wells will be installed; existing and proposed observation wells are shown in Fig. M.6. Each observation well will consist of polyvinyl chloride (PVC) casing, cement and bentonite seals, and a protective cap and PVC screen installed below the water table. Those wells north of Bryant Ditch will be installed below the confining clay unit into the alluvial aquifer. Typical construction of the observation wells is shown in Fig. M.7.

ES-5748

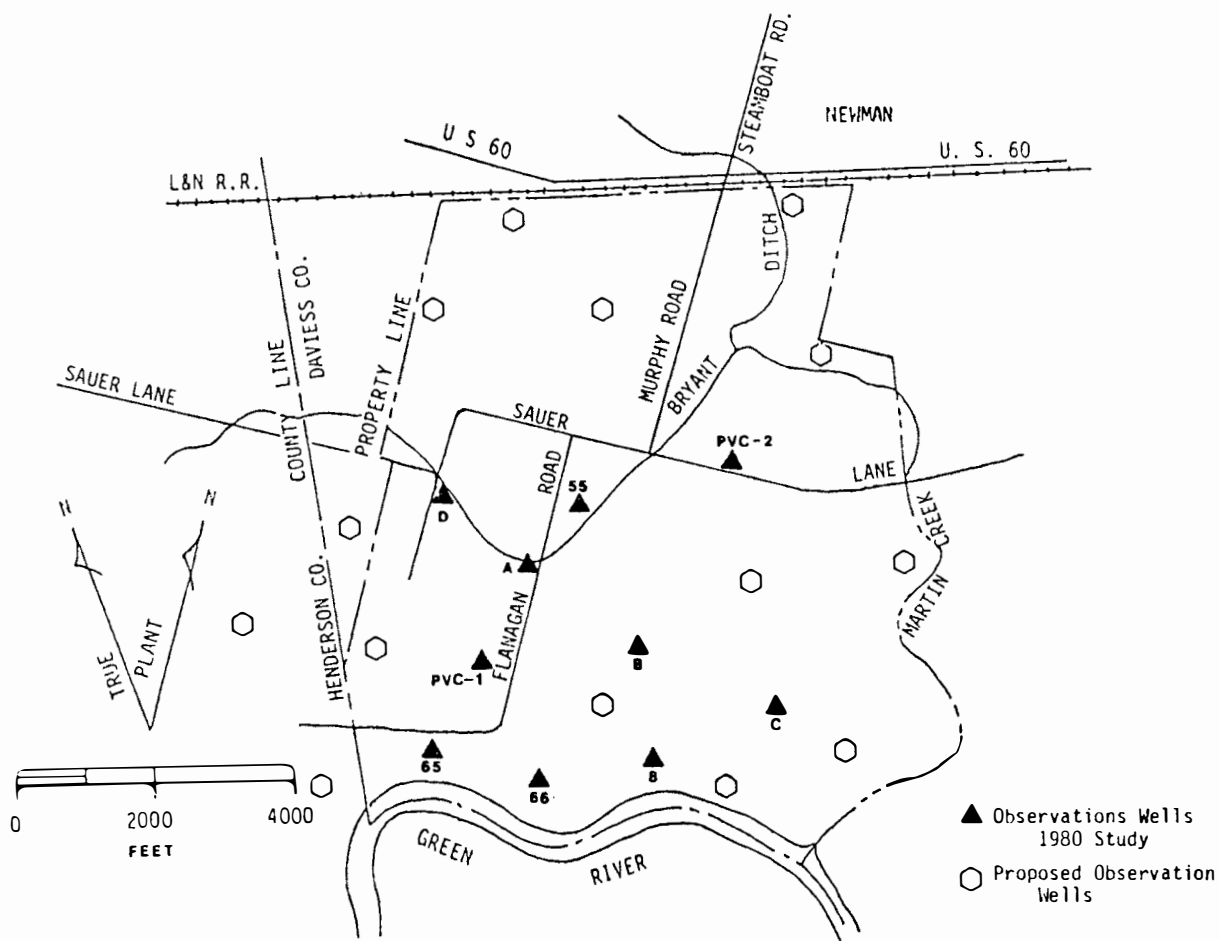


Fig. M.6. Proposed and existing observation well locations.

To identify the areal extent of the impermeable clay boundary, about 14 shallow auger borings will be drilled on the current floodplain parallel to the river. These borings, which are not envisioned to be deeper than 15.2 m (50 ft), will be drilled in two rows at intervals of about 305 m (1000 ft).

M.2.3.3 Aquifer characterization

Once the wells are installed and properly developed to ensure that all drilling sediments have been cleared, a slug test and a falling head permeability test will be performed to measure local flow rates.

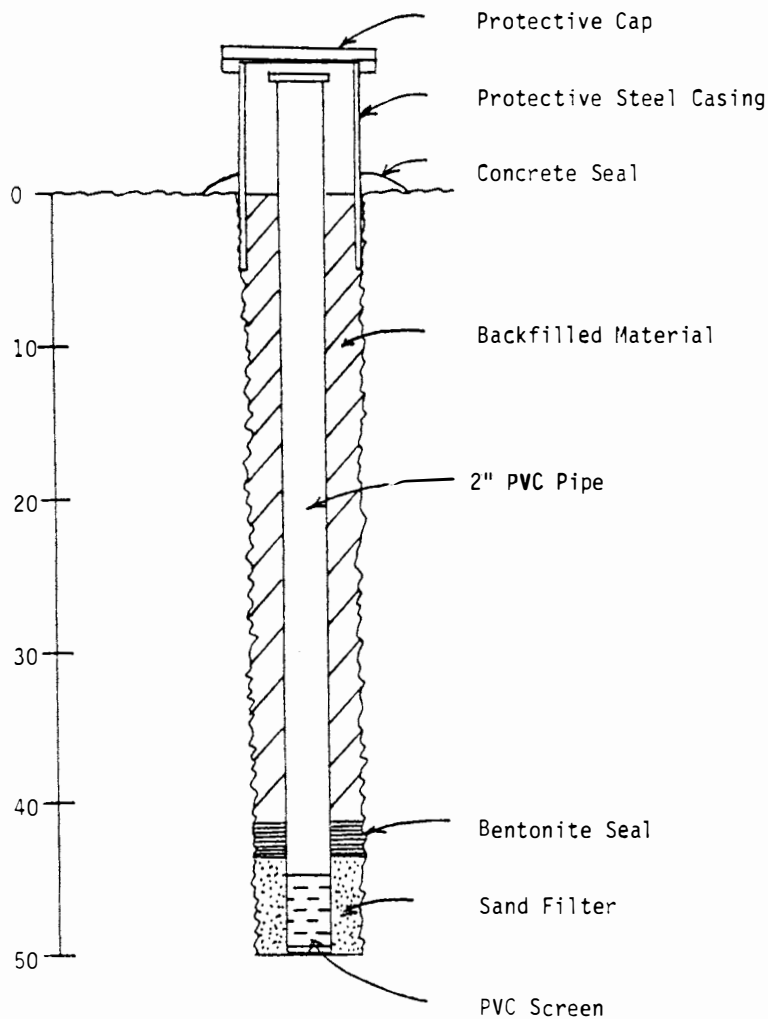


Fig. M.7. Typical observation well installation.

A pump test is necessary to clarify the discrepancies between published values for aquifer parameters and in situ field determinations. Values obtained during a proposed Rust Engineering water supply pump test investigation will be incorporated into this study if the results become available within the time frame of this investigation. If the Rust test is not available, a separate pump test will be performed because of the importance of the resulting calculations on groundwater rates. Calculations of permeability, transmissivity, storage coefficients, and porosity will be performed from the results of the pump test. All of the observation wells shown on Fig. M.5 will be used as observation points during the tests. Additional wells close to an installed pumping well will be needed if pump test results are not available from Rust Engineering.

M.2.3.4 Groundwater sampling

To achieve representative values for groundwater quality in the vicinity of the site, groundwater will be monitored quarterly for one year using the installed and proposed observation wells. Background water quality parameters for groundwater that will be monitored are shown in Table M.2. Each observation well sampled will be pumped to flush a minimum of three volumes of water from the well casing before a water sample is obtained. This will be done to ensure that any stagnant water in the well casing is removed. Sample handling and analysis will be in accordance with EPA regulations.¹⁰

**Table M.2. Recommended parameters
for groundwater monitoring^a**

Physical	Inorganic (continued)
Temperature	Nitrate (as N) ^a
Density	Alkalinity
Odor	Ammonia
Turbidity ^a	Cyanide
Color	Fluoride ^a
Taste	Phosphate
Specific conductance ^a	Total dissolved solids
	Total suspended solids
Inorganic	Sulfate ^a
Aluminum	Chloride ^a
Arsenic ^a	Alkalinity
Boron	pH ^a
Barium ^a	Hardness, as CaCO ₃
Beryllium	Sodium ^a
Bismuth	
Bromine	Organic
Cadmium ^a	Total organic carbon or chemical oxygen demand ^a
Cobalt	Phenols ^a
Chromium ^a	Arylamines
Copper	Aliphatic hydrocarbons
Iron ^a	Mono and polycyclic hydrocarbons
Germanium	Sulfur compounds
Mercury ^a	Chlororganics and chloramines
Lanthanum	Endrin ^a
Magnesium	Lindane ^a
Manganese ^a	Methoxychlor ^a
Molybdenum	Toxaphene ^a
Nickel	2, 4-D ^a
Lead ^a	2, 4, 5-TP Silvex ^a
Rubidium	Total organic halogens ^a
Antimony	
Selenium ^a	
Tin	
Titanium	Other
Vanadium	Total coliform ^a
Tungsten	Fecal coliform ^a
Zinc	Uranium
Zirconium	Thorium
Silver ^a	Radium ^a
Total nitrogen	Gross alpha ^a
	Gross beta ^a

^aIncludes parameters necessary to meet interim RCRA requirements (May 19, 1980).

M.2.3.5 Summary of groundwater studies

Table M.3 summarizes the groundwater studies that will be conducted, as discussed in the preceding descriptions.

Table M.3. Summary of groundwater studies

Study component	Frequency for one year
Observation well installation	Once
Auger boring investigation	Once
Aquifer characterization	Once
Pumping test (if necessary - see text)	Once
Permeability tests	Once
Groundwater quality sampling	Quarterly
Groundwater level measurement	Quarterly

M.2.4 Schedule

All study efforts will be initiated as soon as practicable in 1981 after the installation of the observation wells. Water level measurements and water quality analyses will be performed quarterly on all observation wells.

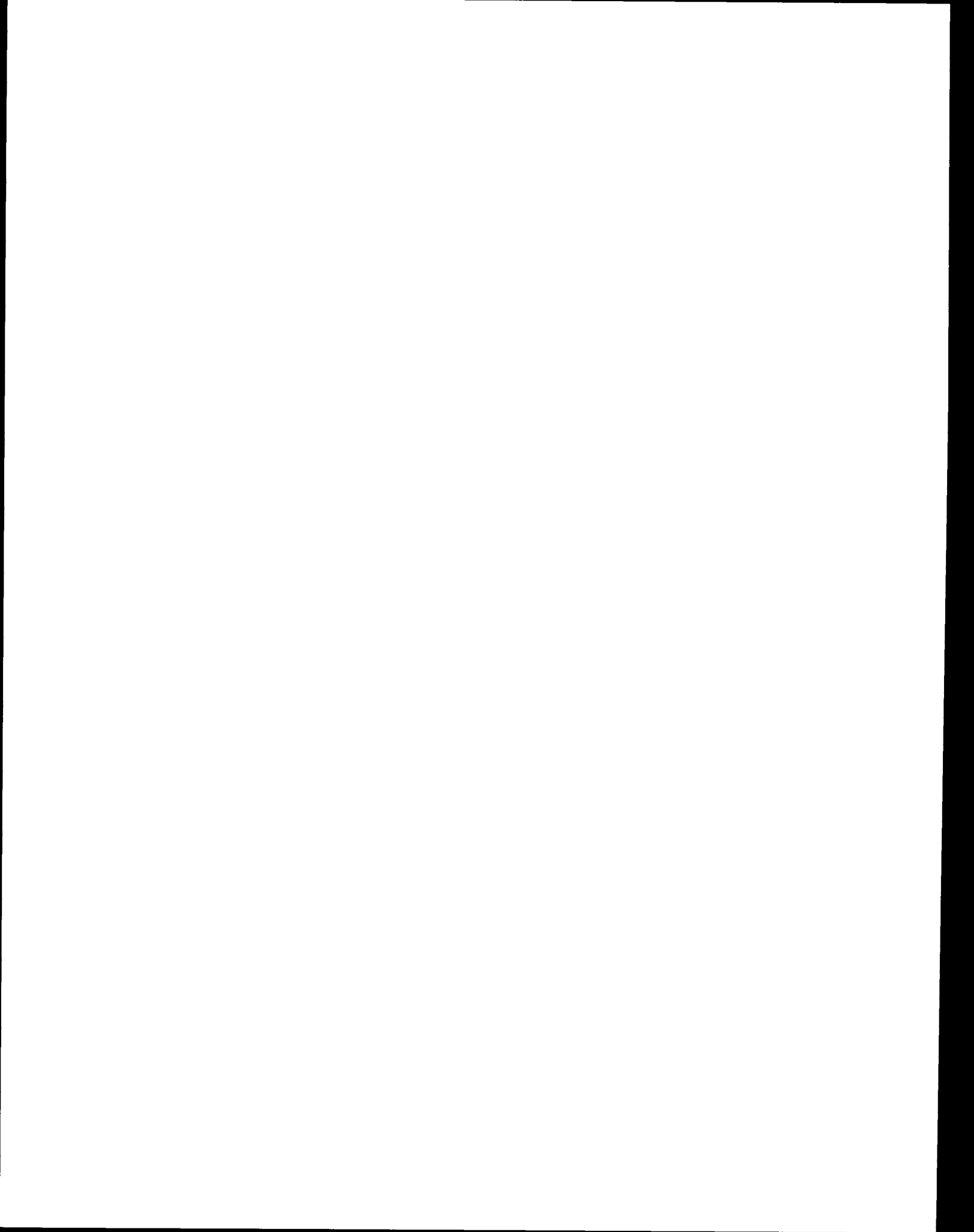
M.2.5 Deliverables

The following reports will be provided:

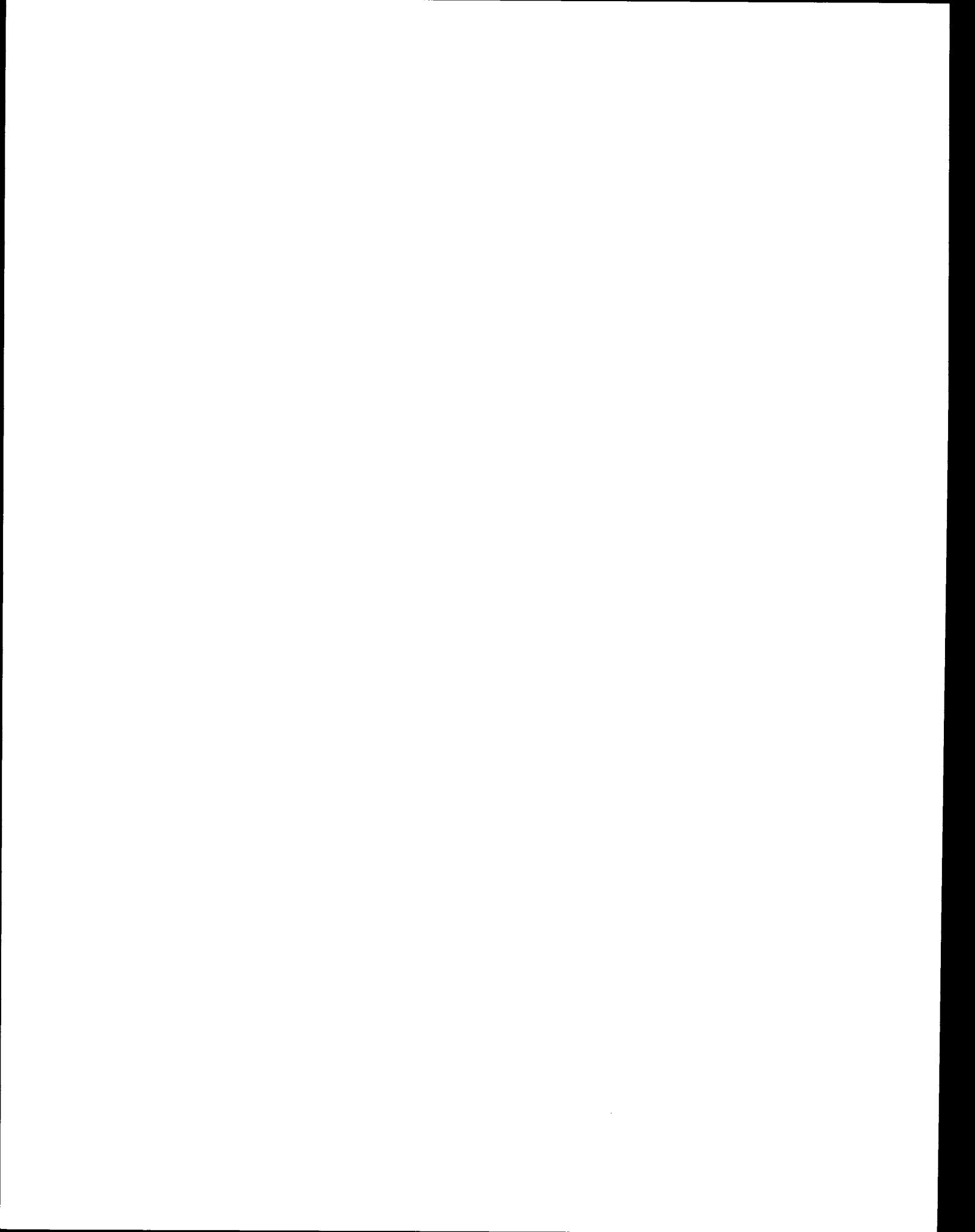
1. A quarterly written report will be made at the completion of each water quality sampling and groundwater level measurement, including any necessary deviations from the investigations.
2. A preliminary report on the results of the initial aquifer characteristics will be provided upon completion of the observation well installation and permeability tests.
3. A final report will be furnished within 30 d after the completion of all work (i.e., after all installations and characterization are complete and all observation well sampling is complete). This report should include:
 - a. the study plan, including a statement of the study objective and a description of all sampling and analysis methods and procedures,
 - b. all data obtained,
 - c. the conclusions drawn from the data in pursuit of the study objectives outlined in questions 1 through 5,
 - d. a discussion of the implications of the study, conclusions concerning plant design, construction, operation, and expansion to commercial scale, and
 - e. recommendations for studies of potential plant impact on the groundwater during construction and operation.

REFERENCES FOR APPENDIX M

1. P. D. Ryder, "Groundwater in the Alluvium along the Green River Between Its Mouth and Woodbury, Ky.," U.S. Geological Survey Open File Report WRI-53-73, 1974.
2. D. V. Whitesides and P. D. Ryder, "Effects of Pumping from the Ohio River Valley Alluvium between Carrollton and Ghent," *K. Geol. Surv., Ser. 10, Inf. Cir.* 28, 1969.
3. ATEC Associates, *Preliminary Geotechnical Engineering Study, 2000 TPD Solvent Refined Coal Facility*, prepared for Wheelabrator Cleanfuel Corporation and Kentucky Center for Energy Research, 1977.
4. J. T. Gallaher and W. E. Price, "Hydrology of the Alluvial Deposits of the Ohio River Valley in Kentucky," *U.S. Geol. Surv. Water-Supply Pap.* 1818, 1966.
5. H. T. Hopkins, *Fresh-Saline Water Interface Map of Kentucky*, Kentucky Geological Survey, 1966.
6. Southern Company Services, Inc., et al., 1980.
7. Dames and Moore, pending A.
8. Dames and Moore, pending B.
9. ATEC, 1979.
10. *Fed. Regist.*, Dec. 18, 1979, amended 40 CFR 136.



Appendix N
GROUNDWATER QUALITY



Appendix N

GROUNDWATER QUALITY

N.1 ALLUVIAL AQUIFER

Groundwater in the alluvial aquifers of the Ohio and Green rivers is variable in composition but is generally characterized as a calcium bicarbonate type with varying amounts of sodium and magnesium. The alluvial water is hard to very hard and the total dissolved solids (TDS) content is high. Iron and manganese content may be objectionably high in some areas. The pH is generally near neutral to slightly alkaline. Table N.1 includes analyses of alluvial water from seven wells located between Curdsville, Kentucky, and Woodbury, Kentucky, along the Green River. Table N.2 includes analyses of alluvial groundwater taken from the Ohio River alluvium in the Owensboro area.

Well water samples were collected from wells on and adjacent to the site during the baseline environmental monitoring program. Well locations are shown on Fig. M.2 of the previous appendix. Wells No. 1 through 3 are abandoned domestic wells which were sampled using a bailer. The bailer was lowered to approximately the mid-point of water depth in each well. Wells Nos. 4 through 10 and No. 23 are in use as domestic suppliers, and samples were obtained from valves at the pump where possible. Drinking water standards are used as a reference for interpreting groundwater quality (Table N.3). Table N.4 is a summary table of water analyses obtained from the site investigations. Federal and State drinking water standards are included in this table. Tables N.5, N.6 and N.7 include results of individual groundwater analyses.

Fluorine, mercury, lead, selenium, and nitrate were present in excess of standards in one or more of the analyses but were not consistently high. Manganese, on the other hand, was present in excess of recommended quantities in all samples from wells No. 8 and 9 and was in excess of recommended levels in one sample from four other wells. No polynuclear aromatics (PNAs) were detected in groundwater samples.

N.2 BEDROCK AQUIFERS

Bedrock underlying the site consists of interbedded shales, siltstones, sandstones, and coals of the Carbondale formation. The sandstones locally contain fresh water aquifers which have lower yields than the alluvial aquifers. Connate waters of the Pennsylvanian strata in the Illinois Basin are saline and the saline/fresh water interface has been mapped.¹ The saline/fresh water interface is defined as the depth or elevation at which the TDS content of groundwater is greater than 1000 mg/liter. Water samples taken above the interface show a gradual increase in dissolved solids with increasing depth. The major dissolved constituents of groundwater in the Carbondale formation are bicarbonate, calcium, sodium, and magnesium, with varying amounts of chloride.² Brines from Devonian age rocks penetrated at a depth of 1350 m (4384 ft) in Henderson County contained over 100,000 ppm chloride, 50,000 ppm sodium, with less than 10,000 ppm calcium and magnesium, and less than 800 ppm bicarbonate.² Table N.8 includes analyses of groundwater samples obtained from bedrock of the Carbondale formation. Most of the wells are located in the vicinity of Henderson; however, the last analysis in the table is of a sample obtained from a well in Owensboro. Data in Table N.8 reflect the wide range of variability of water from aquifers in the Carbondale formation. The water ranges from soft to very hard; bicarbonate is the dominant anion; locally, chloride concentrations are high; and dissolved solids content is variable.

No analyses are available for water samples taken from bedrock beneath the site. Experience of local drillers indicates that in western Daviess County, water encountered below 26 to 47 m (88 to 153 ft) has objectionable salinity. Electric logs from exploratory oil wells on the site show a rapid increase in dissolved solids of connate waters at elevations slightly below

Table N.1. Analyses of water from wells in the Green River alluvium

Dissolved constituents and hardness in mg/liter

Well No.	Depth (ft)	Date of collection	Temperature (°C)	SiO ₂	Fe	Mn	Ca	Mg	Na	K	HCO ₃	SO ₄	Cl	F	NO ₃	Dis-solved solids (residue at 180°C)	Hardness as CaCO ₃		Specific conductance (µmhos at 25°C)	pH	Color	Analyst ^a
																	Ca	Non-carbonate				
1	132	8/14 1970		15	6.1	0.06	97	37	35	1.5	555	23	3.5	0.2	0.3	449	394	0	819	7.4	5	1
2	85	10/21 1970	15.5	18	23	.65	85	25	74	1.6	234	180	54	1.0	40	584	190	130	934	6.8	5	1
3	102	8/11 1971		14	5.1	.09	80	33	36	2.4	392	60	31	.4	.0	449	340	18	774	7.5	1	1
4	96	1/28 1971		21	31	.45	69	21	39	1.1	288	50	32	.2	10	450	236	24	647	7.3	5	1
5	86	6/19 1967			6.2	.05	88	34	87 ^b	5.1	629	10	16	.4	.09	540	358	0		7.3		2
6	85	10/22 1970	14.5	15	24	.27	220	73	70	2.8	690	200	190	.3	.2	1,130	570	280	1,830	7.2	5	1
7	73	10/23 1970	14.0	14	8.9	.33	22	3.5	220	7.4	230	28	220	.4	18	649	70	0	1,190	7.1	80	1
Maximum				21	31	.65	220	73	220	7.4	690	200	220	1.0	40	1,130	570	280	1,830	7.5	80	
Minimum				14	5.1	.05	22	3.5	35	1.1	230	10	3.5	.2	.0	449	70	0	647	6.8	1	
Median				15	8.9	.27	85	33	70	2.4	392	50	32	.4	.3	540	340	18	876	7.3	5	

^a 1. U.S. Geological Survey. 2. Kentucky State Department of Health.^b Estimated from ionic balance and Na/K ratio considerations.Source: P. D. Ryder, *Groundwater in the Alluvium Along the Green River Between Its Mouth and Woodbury, Kentucky*, U.S. Geological Survey Water Resources Investigation 53-73, 1974.

Table N.2. Analyses of water from Ohio River alluvial aquifer

Date of collection	Type of water	SiO ₂	Fe	Mn	Ca	Mg	Na	K	HCO ₃	CO ₃	SO ₄	Cl	F	NO ₃	Dis-solved solids (residue at 180°C)	Hardness as CaCO ₃		Specific conductance (μmhos at 25°C)	pH	Analyst
																Ca, Mg	Non-carbonate			
Sept. 23, 1969	R	11	0.86	0.60	61	13	21	3.3	144	0	81	39	0.4	1.8	321	206	88	505	7.4	GS
May 22, 1968	R	23	0.33	0.15	52	24	13	0.6	274	0	20	9.0	0.4	3.1	268	238	1	170	7.7	GS

Source: D. S. Mull, R. V. Cushman, and T. W. Lambert, *Public and Industrial Water Supplies of Kentucky 1968-69*, Kentucky Geological Survey Information Circular No. 20, 1971.

Table N.3. U.S. EPA and Kentucky drinking water standards^a

Parameter	U.S.EPA ^b	Kentucky ^c
Arsenic	0.05	0.05
Bacteria, coliform, No. per 100 ml	1	5000
Barium	1.0	1.0
Cadmium	0.01	0.01
Chloride	250	
Chromium, VI	0.05	0.05
Color, units	15	
Copper	1	
Corrosivity	noncorrosive	
Cyanide		0.025
Endrin	0.002	
Fluoride	1.4–2.4	1.0
Foaming agents	0.5	
Hydrogen sulfide	0.05	
Iron	0.3	
Lead	0.05	0.05
Lindane	0.004	
Manganese	0.05	
Mercury	0.002	
Methoxychlor	0.1	
Nitrate, as N	10	
Odor, threshold odor number	3	3
pH range	6.5–8.5	
Radioactivity		
Gross alpha, pCi/liter	15	
Gross beta, millirem/year	4	
Radium, pCi/liter	5	
Dissolved alpha, pCi/liter		3
Gross beta, pCi/liter		1000
Dissolved Sr-90, pCi/liter		10
Selenium	0.01	0.01
Silver	0.05	0.05
Sulfate	250	
Total dissolved solids	500	500,750 ^d
Toxaphene	0.005	
Turbidity (units)	1	
2,4-D	0.01	
2,4,5-TP, or silvex	0.01	
Zinc	5	

^aValues in mg/liter unless otherwise noted.^bPrimary and proposed secondary standards.^cStandards for public water supply and food processing.^dNot to exceed 500 mg/liter monthly av or 750 mg/liter max.

sea level. Water from bedrock wells at the site is expected to exceed proposed secondary drinking water standards for dissolved solids and chloride — 500 and 250 mg/liter, respectively, at depths ranging from 56 to 135 m (188 to 450 ft) below the surface.

N.3 GROUNDWATER QUALITY

N.3.1 Background

Groundwater quality was assessed twice in 1977 and twice in 1979 for a total of four samples during the baseline monitoring. Ten domestic wells were sampled in 1977, seven in September

Table N.4. Summary of significant onsite water quality analyses, 1977 and 1979^a

Parameter	Drinking water std		Maximum value	Minimum value	Mean	Standard deviation	Number of samples ^d
	USEPA ^b	Kentucky ^c					
Alkalinity			321	102	265	78	10
Arsenic	0.05	0.05	0.012	<0.002	0.0057	0.0034	20
Barium	1.0	1.0	0.31	0.07	0.17	0.08	10
Boron			1.49	<0.001	0.54	0.563	20
Cadmium	0.01	0.01	0.0069	0.0005	0.0019	0.0015	20
Calcium			80	20	60	22	10
Chloride	250		36	0	8.6	14	10
Chromium, total	0.05	0.05	0.0051	<0.0010	0.0016	0.0010	20
Fluoride	1.4-2.4	1.0	1.78 ^e	0.26	0.57	0.45	10
Hardness, total			368	142	297	72	10
Iron, soluble	0.3		0.233	0.014	0.024	0.069	20
Lead	0.05	0.05	0.344 ^e	<0.001	0.038	0.077	20
Magnesium			38	7.5	32	10	10
Manganese	0.05		0.335 ^e	0.001	0.096 ^e	0.106 ^e	20
Mercury	0.002		0.0036 ^e	<0.0001	0.0013	0.0027	20
Nitrate, as N	10		8.6	0.3	4.4	5.6	10
pH	6.5-8.5		7.78	6.89	7.4	0.25	10
Selenium	0.01	0.01	0.0194 ^e	<0.0005	0.005	0.005	20
Silver	0.05	0.05	0.0037	0.0003	0.0014	0.0010	10
Sodium			59	16	32	14	10
Sulfate	250		60	20	43	12	10
Total dissolved solids	500	500,750 ^f	484	162	384	88	10

^a Values in mg/liter unless otherwise noted. Values from ER, Appendix F, Tables F.3, F.4, and F.5.

^b Primary and proposed secondary standards.

^c Standards for public water supply and food processing.

^d Samples from 11 wells (Nos. 1 through 10 and 23 on Fig. F.3, ER, Appendix F).

^e Value exceeding standard.

^f Not to exceed 500 mg/liter monthly av or 750 mg/liter maximum.

Source: ER, Appendix F.

and three in October. Five wells were sampled twice, once in April and once in September of 1979.

Sampling of the five wells was continued in 1980 for preconstruction monitoring. Data were collected in April, July, and November, 1980, for all wells except one, which was abandoned.

N.3.2 Methodology

The domestic wells that were sampled (Fig. N.1) are driven domestic wells with depths rarely exceeding 12.2 m (40 ft). These wells are in the alluvium, which extends to an average depth of 36.6 m (120 ft).

Samples were taken from valves at the pump. Appropriate samples were preserved using U.S. Environmental Protection Agency (EPA) procedures and sent to Howard Laboratories, Inc., on the same day they were collected.

N.3.3 Results and discussion

Groundwater sampled during preconstruction monitoring was found to have moderate to high levels of dissolved solids, nitrates, and manganese (Tables N.9 through N.12). Except for several

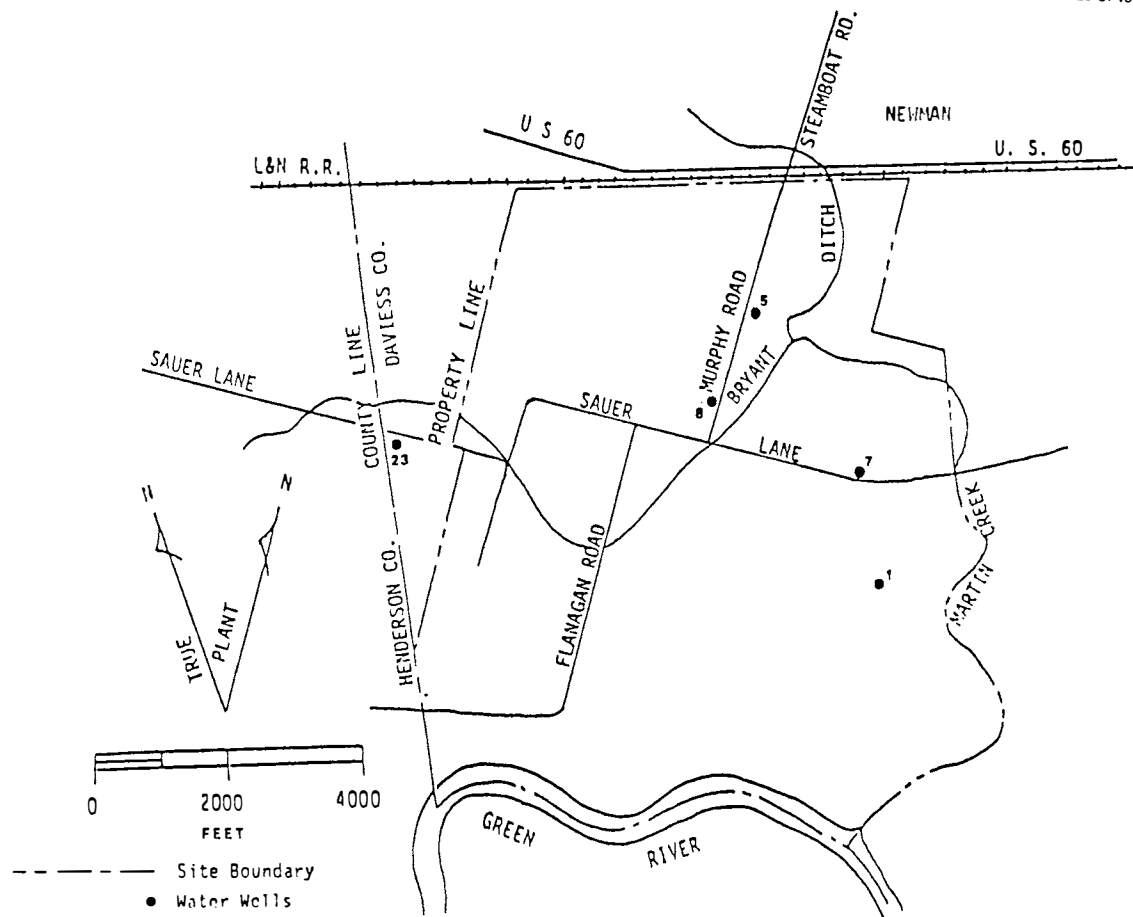


Fig. N.1. Well water quality sampling locations.

Table N.5. List of water wells and analyses of water samples, 1977^a

Parameter	WW1	WW2	WW3	WW4	WW5	WW6	WW7	WW8	WW9	WW10
Date of field investigations	10/27	10/27	10/27	9/28	9/28	9/28	9/28	9/28	9/28	9/28
Status ^b	A	A	A	D	D	D	D	D	D	D
Water depth in m (ft) below land surface	6.1 (22)	7.0 (22.8)	8.0 (26.1)		5.8 (19)	7.6 (25)		7.6 (25)		
Total well depth in m (ft) below land surface	10.4 (34.2)	12.1 (41.7)	10.3 (33.7)			9.8 (32)		10.7 (35)		9.1–10.8 (30–36)
Source of depth data	D&M ^c	D&M ^c	D&M ^c		Owner	Owner		Owner		Owner
Alkalinity	313.20	329.44	146.16	285	289	262	321	102	292	315
Arsenic	<0.008	<0.008	<0.008	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Barium	0.280	0.170	0.137	0.089	0.093	0.184	0.170	0.192	0.305	0.072
Boron	<0.10	<0.10	<0.10	<1.00	<1.00	<1.00	1.08	1.49	1.22	<1.00
Cadmium	0.0008	0.0041	0.0069	0.0028	0.0005	0.0020	0.0025	0.0028	0.0028	0.0025
Calcium	34.9	43.0	20.3	78.8	74.9	69.9	79.9	45.3	79.5	72.5
Chloride	35.75	14.59	3.41	<0.025	<0.025	<0.025	<0.025	32.49	<0.025	<0.025
Chromium, total	0.0030	0.0051	0.0025	0.0014	0.0014	0.0012	0.0017	0.0022	0.0018	0.0010
Fluoride	0.63	0.35	0.30	0.69	1.78 ^d	0.52	0.44	0.31	0.26	0.39
Hardness, total	346.0	368.0	142.0	297.6	301.6	313.5	347.2	198.4	335.3	319.5
Iron, soluble	0.048	0.074	0.014	0.230	0.050	0.036	0.034	0.035	0.036	0.029
Lead	0.048	0.111 ^d	0.344 ^d	0.031	0.053 ^d	0.037	0.027	0.040	0.026	0.025
Magnesium	36.9	37.7	7.45	30.8	36.3	39.6	37.2	22.5	32.1	36.2
Manganese	0.054 ^d	0.335 ^d	0.194 ^d	0.091 ^d	0.011	0.038	0.048	0.321 ^d	0.136 ^d	0.024
Mercury	0.0023 ^d	0.0021 ^d	0.0036 ^d	0.0002	<0.0001	<0.0001	0.0002	0.0001	<0.0001	0.0003
Nitrate	8.63	0.33	0.73	1.05	14.20 ^d	1.42	1.72	13.88 ^d	1.50	0.94
pH	7.62	7.78	7.10	7.35	7.39	7.50	7.25	6.89	7.30	7.40
Selenium	<0.0005	<0.0005	<0.0005	0.0072	0.0194 ^d	0.0051	0.0043	0.0083	0.0071	0.0044
Silver	0.0013	0.0004	0.0037	0.0012	0.0013	0.0011	0.0015	0.0008	0.0019	0.0003
Sodium	53.4	28.5	58.9	34.8	31.2	19.3	23.6	25.0	16.2	26.7
Sulfate	44.3	59.6	35.8	53.1	29.6	49.0	37.4	55.8	43.3	19.8
Total dissolved solids	484	428	162	418	456	366	380	366	408	370

^a Values in mg/liter unless otherwise noted.^b A = abandoned; D = domestic water supply sampled from faucets.^c Depths measured by Dames & Moore personnel in the field.^d Value exceeding standard.

Sources: Dames & Moore field data, 1977; Howard Laboratories, Inc., analytical results, 1977.

Table N.6. List of water wells and analyses of water samples, April 1979^a

Parameter	WW5	WW7	WW8	WW9	WW23
Date of field investigations	4/25	4/25	4/25	4/25	4/25
Status ^b	D	D	D	D	D
Antimony	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	<0.010	<0.010	<0.010	0.012	<0.010
Beryllium	<0.001	<0.001	<0.001	<0.001	<0.001
Boron	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	0.001	<0.001	<0.001	0.001	<0.001
Chromium, total	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	0.002	0.002	0.001	<0.001	0.006
Cyanide	<0.002	<0.002	<0.002	<0.002	<0.002
Iron	0.061	0.045	0.042	0.135	0.200
Lead	0.001	0.003	<0.001	<0.001	0.001
Manganese	<0.013	0.001	0.269 ^c	0.129 ^c	0.007
Mercury	<0.001	0.012 ^c	<0.001	<0.001	<0.001
Nickel	0.033	0.002	0.003	0.002	0.010
Polycyclic aromatic hydrocarbons	<i>d</i>	<i>d</i>	<i>d</i>	<i>d</i>	<i>d</i>
Selenium	<0.001	<0.001	<0.001	<0.001	<0.001
Trihalomethanes	<0.010	<0.010	<0.010	<0.010	<0.010
Vanadium	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	0.295	0.050	0.039	0.315	0.545

^a Values shown in mg/liter unless otherwise noted.^b A = abandoned; D = domestic water supply sampled from faucets.^c Value exceeding standard.^d None detected at the levels shown in ER, Appendix F, Table F.7.

Source: ER, Appendix F.

observations of manganese and one each involving nitrate and iron (Table N.13), concentrations were usually within EPA interim primary and proposed secondary drinking water standards. Manganese and iron, which were found in high levels in water and sediments, probably are derived from natural geologic formations of the region. High levels of nitrates were also found in the groundwater. Although their origin is not known, the fairly high levels of nitrates may result from extensive farming in the site area.

Other trace elements were present in low amounts, and no polynuclear aromatic hydrocarbon (PAH) compounds were detected in any of the 14 samples collected throughout the year. This constituted a slight improvement for trace metals over the baseline program, when at least one observation of mercury and selenium (in addition to lead and manganese) was in excess of recommended concentrations. The absence of PAHs agrees with the results of the baseline program.

Table N.7. List of water wells and analyses of water samples, September 1979^a

Parameter	WW5	WW7	WW8	WW9	WW23
Date of field investigations	9/18	9/18	9/18	9/18	9/18
Status ^b	D	D	D	D	D
Antimony	<0.001	<0.001	<0.001	0.001	<0.001
Arsenic	<0.002	<0.002	<0.002	0.002	<0.002
Beryllium	<0.001	<0.001	<0.001	<0.001	<0.001
Boron	0.003	0.006	0.008	0.007	0.001
Cadmium	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium, total	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	<0.001	<0.001	0.003	0.008	0.006
Cyanide	<0.002	<0.002	<0.002	<0.002	<0.002
Iron	0.233	0.153	0.101	0.076	0.049
Lead	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	0.012	0.024	0.109 ^c	0.103 ^c	0.005
Mercury	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel	<0.001	<0.001	<0.001	<0.001	<0.001
Polycyclic aromatic hydrocarbons	<i>d</i>	<i>d</i>	<i>d</i>	<i>d</i>	<i>d</i>
Selenium	0.010	0.005	<0.005	<0.005	0.005
Trihalomethanes	<0.010	<0.010	0.010	0.010	0.010
Vanadium	0.004	0.005	0.010	0.005	0.010
Zinc	0.250	0.035	0.055	0.195	0.370

^a Values shown in mg/liter unless otherwise noted.^b A = abandoned; D = domestic water supply sampled from faucets.^c Value exceeding standard.^d None detected at the levels shown in Table F.7 ER, Appendix F.

Source: ER, Appendix F.

Table N.8. Analyses of groundwater from the Carbondale formation, Henderson and Daviess counties

Date of collection	Temp. (°F)	SiO ₂	Fe	Mn	Ca	Mg	Na	K	HCO ₃	CO ₃	SO ₄	Cl	F	NO ₃	Dissolved solids	Hardness as CaCO ₃		Specific conductance at 25°C	pH
																Ca—Mg	Noncarbonate		
Henderson County																			
Jan. 21, 1953									1220			118	4.2	0.1				2040	
Mar. 30, 1950	55		0.15						1110	19	15	34	1.1	0.0		61		1730	
Dec. 22, 1952									1110			34	1.1	3.8				1700	
Mar. 30, 1950	55		0.16						1320	18	6	308	6.4	0.3		29		2860	
Mar. 30, 1950	57	5.6	0.37		74	13	24		326	0	2.6	6.8	0.3	13	308	238	0	527	7.9
Dec. 22, 1952	58								765	14		10	1.2	1.5				1290	
Dec. 22, 1952	57								1395	74		272	5.6	1.2				2850	
Dec. 29, 1949			0.24						1330	59	13	181		2.6		8		2600	
July 26, 1952									1420	30			4.6						
Mar. 30, 1950	58	7.5	0.69		30	9.2	190		618	0	2.3	9.8	0.5	1.5	555	113	0	889	8.0
Dec. 29, 1949	55		0.33						548		1.0	41		0.2		306		972	
Dec. 22, 1952									805	103		51	3.4	1.8				1730	
Dec. 22, 1952			0.59						827	19	14	94		7.2		128		1550	
Dec. 29, 1949			0.31								12	68		1.4		96		1550	
Dec. 22, 1952									998			85	3.0	0.8				1720	
Dec. 22, 1952									1140	69		130	4.8	2.0				2170	
Mar. 30, 1950		9.6	4.4		86	32	15		398	0	45	4.4	0.2	0.0	388	346	20	739	7.6
July 18, 1951	57		2.7						421		40	5	0.1	0.2		378		751	
Dec. 28, 1949	57		1.0						554		10	23		1.2		237		871	
Dec. 22, 1952	58								550			26	0.6	1.1				923	
Mar. 30, 1950			2.1						364		59	6	0.1	0.0		351		642	
Mar. 30, 1950		6.5	0.32		13	3.7	301		780	22	2.9	14	1.0	0.5	742	48	0	1200	8.2
Dec. 22, 1952	56								1100	69		146	4.0	2.0				2210	
Dec. 22, 1952	55		0.98						25		5	4	0.2	3.7		13		59	
Dec. 22, 1952			0.24						1410	33	7	198		8.5		44		2650	
July 26, 1952									1305	25			4.2						
Dec. 28, 1949		9.5	0.20		10	2.4	283		604	41	25	41	0.6	1.2	711	35	0	1170	8.0
Dec. 29, 1949	58		5.1						352		16	4		0.2		280		558	
Dec. 29, 1949	56		0.23						464		300	86		57		670		1490	
Mar. 29, 1950	56	4.0	1.5		84	27	94		599	0	6.0	18	0.9	0.4	530	321	0	897	7.3
Dec. 29, 1949	56								430		2	6		0.0		248		640	
Jan. 15, 1953	57								379			15	0.3	2.8				1020	
Mar. 29, 1950	58	27	0.39		30	18	12		177	0	1.0	2.4	0.4	29	197	149	4	325	7.7
July 18, 1951		8.8	2.2		8.8	7.3	909	9.2	1044	10	0.7	830	1.2	5.8	2270	52	0	3913	8.1
July 18, 1951	54		5.3						629		1	4	0.3	0.4		486		874	
Daviess County																			
May 22, 1968		31	2.8	0.20	83	29	29	0.7	444	0	4.0	10	0.2	1.4	406	326	0	706	7.4

Sources: Henderson County -- E. J. Harvey, *Geology and Groundwater Resources of the Henderson Area, Kentucky*, Geological Survey Water-Supply Paper 1356, 1956; Daviess County -- D. S. Mull, R. V. Cushman, and T. W. Lambert, *Public and Industrial Water Supplies in Kentucky, 1968-69*, Kentucky Geological Survey Information Circular No. 20, 1971.

Table N.9. Summary of groundwater samples collected from five wells on April 29, July 31, and November 12, 1980^{a,b,c}

	Mean ^d	Range
pH		5.93–7.15
Conductivity (μmhos)	607.5	260–745
Cyanide (mg/liter)		<0.002
Total dissolved solids (mg/liter)	364.3	140–472
Phosphorus (mg/liter)		<0.01–0.10
Ammonia as N (mg/liter)		0.04–0.15
Nitrate (mg/liter)	5.63	0.86–11.88
Phenols (mg/liter)		<0.001–0.006
Trace Elements		
Antimony		<1
Arsenic		<2.5–6.3
Beryllium		<1
Boron	29.8	3–170
Cadmium		<1–2
Chromium		<1–2
Copper		<1–21
Iron		<1–500
Lead		<1–18
Manganese	98.9	3–329
Mercury		<0.1–0.4
Nickel		<1–10
Selenium		<2.5
Vanadium		<1–<10
Zinc	280.1	35–800
Organics		
Trihalomethanes ^e		<1.0–<5.0
PAH Compounds		
2-methylnapthalene		<0.01
Fluoranthene		<0.01
Pyrene		<0.01
Benzo(c)phenanthrene		<0.01
Benzo(a)anthracene		<0.02
Chrysene		<0.02
5-methyl chrysene		<0.06
Benzo(b)fluoranthene		<0.01
Benzo(j)fluoranthene		<0.03
Benzo(g)pyrene		<0.02
Orthophenylene pyrene		<0.01
Dibenzo(a,c)anthracene		<0.01
Dibenzo(a,h)anthracene		<0.01
Benzo(g,h,i)perylene		<0.03
Dibenzo thiophene		<0.01

^aResults expressed as μg/liter unless noted otherwise.

^bBased on 14 total observations; each of 5 wells samples three times, except well No. 8, which was inoperable in November.

^cSee Figure for well locations.

^dNot determined when one or more observations reported as a less than (<) value.

^eBased on 28 observations because of duplicate samples.

Table N.10. Summary of groundwater samples exceeding EPA interim primary and proposed secondary drinking water standards

Parameter	Location	Date	Concentration (mg/liter)	Proposed standard	Percentage of total samples exceeding proposed standard ^a
Manganese	WW1	Spring ^b	0.272	0.050	
	WW8	Spring ^b	0.306		
	WW1	Summer ^c	0.193		
	WW8	Summer ^c	0.329		
	WW1	Fall ^d	0.177		
Nitrate	WW2	Fall ^d	11.88	10	7
Iron	WW3	Fall ^d	0.5	0.3	14
	WW23	Spring ^b	0.387		

^aTotal observations: 14

^bApril 29, 1980

^cJuly 31, 1980

^dNovember 12, 1980

Table N.11. Groundwater samples collected April 29, 1980

	WW 23	WW 1	WW 5	WW 7	WW 8
pH, S.U.	6.15	6.80	6.92	6.90	6.70
Conductivity, μ mhos	339	700	745	705	585
Cyanide, mg/liter	<0.002	<0.002	<0.002	<0.002	<0.002
Total dissolved solids, mg/liter	184	408	452	392	344
Phosphorus, mg/liter	0.10	0.06	0.07	0.05	0.10
Ammonia as N, mg/liter	<0.10	0.15	<0.10	<0.10	<0.10
Nitrate, mg/liter	3.13	3.69	9.63	0.86	8.05
Phenols, mg/liter	<0.001	0.006	0.005	0.003	<0.001
Trace Metals, mg/liter					
Arsenic	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025
Beryllium	<0.001	<0.001	<0.001	<0.001	<0.001
Boron	0.019	0.004	0.008	0.025	0.006
Cadmium	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	0.002	<0.001	<0.001	<0.001	0.004
Iron	0.387	0.035	0.026	0.014	0.009
Lead	<0.001	0.003	<0.001	<0.001	<0.001
Manganese	0.020	0.272	0.032	0.003	0.306
Mercury	<0.0001	<0.0001	0.0004	0.0002	<0.0001
Nickel	<0.001	<0.001	<0.001	<0.001	0.001
Selenium	<0.002	<0.002	<0.002	<0.002	<0.002
Vanadium	<0.010	<0.010	<0.010	<0.010	<0.010
Zinc	0.200	0.190	0.330	0.100	0.050
Antimony	<0.001	<0.001	<0.001	<0.001	<0.001
Trihalomethanes (Run 1)	<5.0	<5.0	<5.0	<5.0	<5.0
Trihalomethanes (Run 2)	<5.0	<5.0	<5.0	<5.0	<5.0
Trihalomethanes (Blanks, <5.0)					
2-methylnaphthalene, mg/liter	<0.01	<0.01	<0.01	<0.01	<0.01
Fluoranthene, mg/liter	<0.01	<0.01	<0.01	<0.01	<0.01
2-methyl fluoranthene, mg/liter	^a	^a	^a	^a	^a
Pyrene, mg/liter	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(c)phenanthrene, mg/liter	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(a)anthracene, mg/liter	<0.02	<0.02	<0.02	<0.02	<0.02
Chrysene, mg/liter	<0.02	<0.02	<0.02	<0.02	<0.02
5-methyl chrysene, mg/liter	<0.06	<0.06	<0.06	<0.06	<0.06
Benzo(b)fluoranthene, mg/liter	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(j)fluoranthene, mg/liter	<0.03	<0.03	<0.03	<0.03	<0.03
Benzo(a)pyrene, mg/liter	<0.02	<0.02	<0.02	<0.02	<0.02
Orthophenylene pyrene, mg/liter	<0.01	<0.01	<0.01	<0.01	<0.01
Dibenzo(a,c)anthracene, mg/liter	<0.01	<0.01	<0.01	<0.01	<0.01
Dibenzo(a,h)anthracene, mg/liter	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(g,h,i)perylene, mg/liter	<0.03	<0.03	<0.03	<0.03	<0.03
Dibenzo thiophene, mg/liter	<0.01	<0.01	<0.01	<0.01	<0.01

^aNo standard available.

Table N.12. Groundwater samples collected July 31, 1980
(as $\mu\text{g/liter}$ unless indicated otherwise)

	WW 23	WW 1	WW 5	WW 7	WW 8
pH, S.U.	6.20	6.85	6.90	6.93	6.90
Conductivity, μmhos	310	740	710	725	610
Cyanide, mg/liter	<0.002	<0.002	<0.002	<0.002	<0.002
Total dissolved solids, mg/liter	140	472	440	428	372
Phosphorus	0.06	0.04	<0.01	0.06	0.08
Ammonia as N, mg/liter	<0.1	0.14	0.11	<0.1	<0.1
Nitrate, mg/liter	8.10	3.55	7.30	1.20	8.77
Phenols, mg/liter	<0.002	<0.002	<0.002	<0.002	<0.002
Metals, mg/liter					
Arsenic	0.0063	<0.0025	<0.0025	0.0048	0.0048
Beryllium	<0.001	<0.001	<0.001	<0.001	<0.001
Boron	0.010	0.003	0.005	0.083	0.004
Cadmium	0.002	<0.001	<0.001	<0.001	<0.001
Chromium	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	0.021	<0.001	0.007	0.010	0.004
Iron	0.152	0.013	0.015	0.011	0.003
Lead	<0.001	<0.001	0.018	0.004	<0.001
Manganese	0.006	0.193	0.014	0.003	0.329
Mercury	<0.0001	<0.0001	<0.0001	0.0001	<0.0001
Nickel	<0.001	<0.001	<0.001	0.010	<0.001
Selenium	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025
Vanadium	<0.001	0.001	<0.001	<0.001	<0.001
Zinc	0.800	0.126	0.216	0.067	0.067
Antimony	<0.001	<0.001	<0.001	<0.001	<0.001
Trihalomethanes (Run 1)	<5.0	<5.0	<5.0	<5.0	<5.0
Trihalomethanes (Run 2)	<5.0	<5.0	<5.0	<5.0	<5.0
Trihalomethanes (Blanks, <5.0)					
2-methylnaphthalene	<0.01	<0.01	<0.01	<0.01	<0.01
Fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01
2-methyl fluoranthene	^a	^a	^a	^a	^a
Pyrene	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(c)phenanthrene	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(a)anthracene	<0.02	<0.02	<0.02	<0.02	<0.02
Chrysene	<0.02	<0.02	<0.02	<0.02	<0.02
5-methyl chrysene	<0.06	<0.06	<0.06	<0.06	<0.06
Benzo(b)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(j)fluoranthene	<0.03	<0.03	<0.03	<0.03	<0.03
Benzo(a)pyrene	<0.02	<0.02	<0.02	<0.02	<0.02
Orthophenylene pyrene	<0.01	<0.01	<0.01	<0.01	<0.01
Dibenzo(a,c)anthracene	<0.01	<0.01	<0.01	<0.01	<0.01
Dibenzo(a,h)anthracene	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(g,h,i)perylene	<0.03	<0.03	<0.03	<0.03	<0.03
Dibenzo thiophene	<0.01	<0.01	<0.01	<0.01	<0.01

^a No standard available.

Table N. 13. Groundwater samples collected November 12, 1980
(as µg/liter unless otherwise indicated)

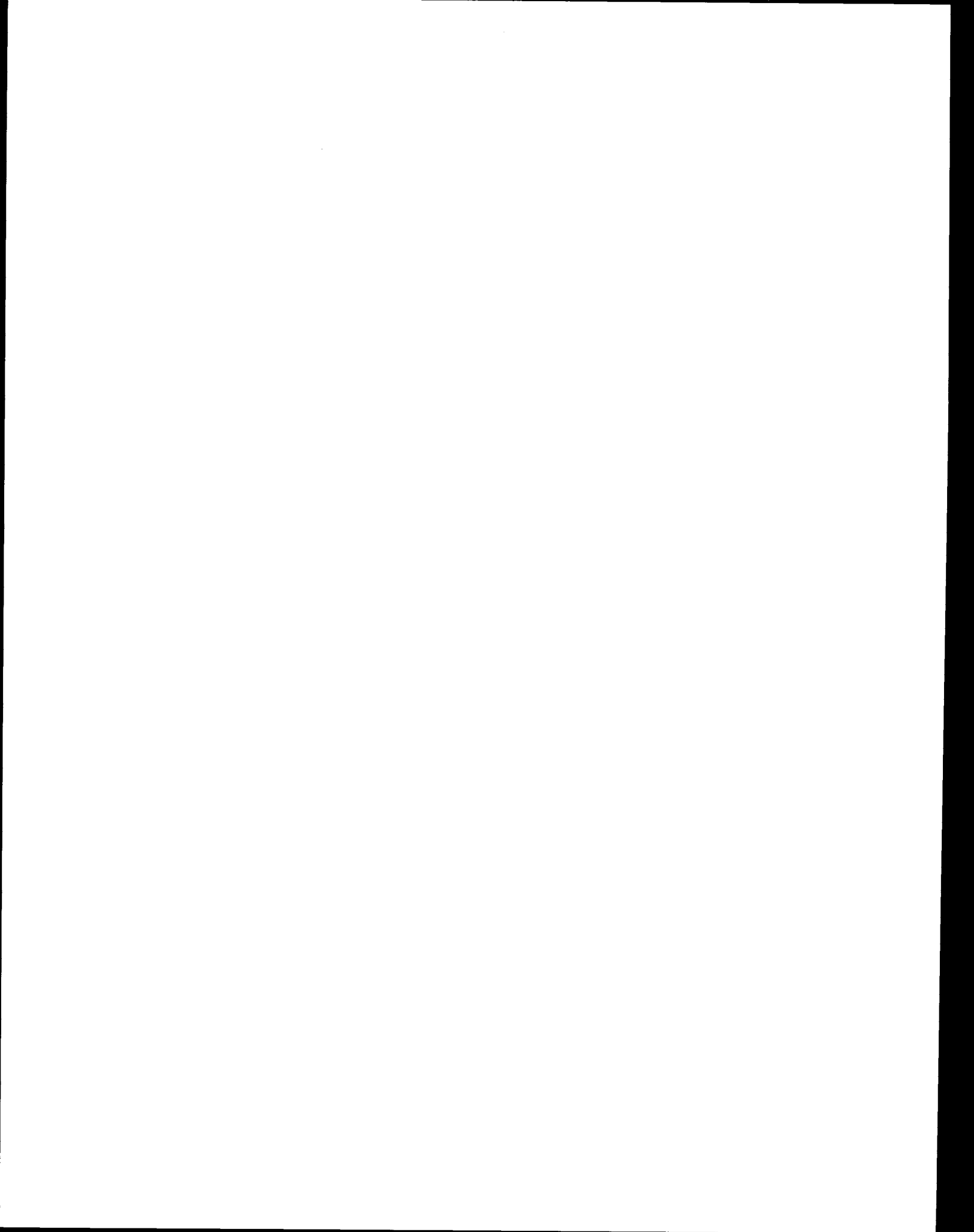
	WW1	WW5	WW23	WW7
pH, S.U.	6.72	7.15	5.93	7.12
Conductivity, µmhos	648	739	260	689
Cyanide, mg/liter	<0.002	<0.002	<0.002	<0.002
Total dissolved solids, mg/liter	404.0	472.0	152.0	440.0
Phosphorus, mg/liter	<0.01	<0.01	<0.01	<0.01
Ammonia as N, mg/liter	0.06	0.05	0.07	0.04
Nitrate, mg/liter	1.96	11.88	9.52	1.23
Phenols, mg/liter	<0.001	0.021	<0.001	<0.001
Metals, mg/liter				
Arsenic	<0.0025	<0.0025	<0.0025	<0.0025
Beryllium	<0.001	<0.001	<0.001	<0.001
Boron	<0.005	<0.005	0.170	0.070
Cadmium	<0.001	<0.001	<0.001	<0.001
Chromium	0.002	<0.001	<0.001	<0.001
Copper	<0.001	<0.001	<0.001	<0.001
Iron	<0.001	<0.001	0.500	<0.001
Lead	<0.001	0.002	<0.001	<0.001
Manganese	0.177	<0.010	<0.010	<0.010
Mercury	0.0001	<0.0001	<0.0001	<0.0001
Nickel	<0.001	<0.001	<0.001	<0.001
Selenium	<0.0025	<0.0025	<0.0025	<0.0025
Vanadium	0.002	0.003	0.002	0.005
Zinc	0.615	0.375	0.750	0.035
Antimony	<0.001	<0.001	<0.001	<0.001
Trihalomethanes (Run 1)	<1.0	<1.0	<1.0	<1.0
Trihalomethanes (Run 2)	<1.0	<1.0	<1.0	<1.0
Trihalomethanes (Blanks, <1.0)				
2-methylnapthalene	<0.01	<0.01	<0.01	<0.01
Fluoranthene	<0.01	<0.01	<0.01	<0.01
2-methyl fluoranthene	^a	^a	^a	^a
Pyrene	<0.01	<0.01	<0.01	<0.01
Benzo(c)phenanthrene	<0.01	<0.01	<0.01	<0.01
Benzo(a)anthracene	<0.02	<0.02	<0.02	<0.02
Chrysene	<0.02	<0.02	<0.02	<0.02
5-methyl chrysene	<0.06	<0.06	<0.06	<0.06
Benzo(b)fluoranthene	<0.01	<0.01	<0.01	<0.01
Benzo(j)fluoranthene	<0.03	<0.03	<0.03	<0.03
Benzo(a)pyrene	<0.02	<0.02	<0.02	<0.02
Orthophenylene pyrene	<0.01	<0.01	<0.01	<0.01
Dibenzo(a,c)anthracene	<0.01	<0.01	<0.01	<0.01
Dibenzo(a,h)anthracene	<0.01	<0.01	<0.01	<0.01
Benzo(g,h,i)perylene	<0.03	<0.03	<0.03	<0.03
Dibenzo thiophene	<0.01	<0.01	<0.01	<0.01

^aNo standard available.

REFERENCES FOR APPENDIX N

1. H. T. Hopkins, *Fresh-Saline Water Interface Map of Kentucky*, Kentucky Geological Survey, 1966.
2. E. J. Harvey, "Geology and Groundwater Resources of the Henderson Area Kentucky," *U.S. Geol. Surv. Water-Supply Pap.* 1356, 1956.

Appendix 0
GROUNDWATER AVAILABILITY



Appendix 0

GROUNDWATER AVAILABILITY

0.1 GROUNDWATER SUPPLY

No significant impact is anticipated as a result of water withdrawal from the aquifer during plant operation. For drinking and sanitary purposes, the SRC-I facility will use potable groundwater from a well adjacent to the water treatment plant and approximately 244 m (800 ft) from the Green River. The well will be approximately 30 m (100 ft) deep and will penetrate 24 m (80 ft) of saturated sand and gravel. The average expected withdrawal of groundwater from the well will be 18.1 liters/min (4.8 gpm); the maximum withdrawal will be 360 liters/min (100 gpm).

0.2 AQUIFER RECHARGE MODEL

Aquifer recharge beneath the proposed site has been simulated by means of a simple model. The aquifer is interpreted as being unconfined, based on borings logs and water level measurements at the site; its thickness for this simulation is taken to be 27 m (89 ft), using the midpoints of the observed bedrock and water table elevations. The location of the simulated well was placed 91 m (300 ft) from borehole 8 and on a line with borehole 7 (Fig. 0.1), in order to place it in the approximate location of the water supply well proposed for the facility.

Borehole 10 (Fig. 0.1) showed a thick clay deposit next to the Green River. Because the thickness and areal extent of this barrier to groundwater flow is unknown, it is uncertain what effect this deposit will have on river recharge to the aquifer. If the clay deposit is wide and continuous, recharge will be inhibited to a greater extent than if it were localized or not continuous. Therefore, the well simulation was modeled for two extreme cases — complete connection with the river and no connection with the river.

A storage coefficient of 0.2 was used, based on an examination of aquifer samples from borings on the site (ATEC 1977) and on the findings of Whitesides and Ryder (1969) for the Ohio River alluvium. A hydraulic conductivity of 15 m (49 ft) per day and an aquifer thickness of 27 m (89 ft) were the other elements of the calculations, which were done at points along a line extending away from the river.

0.3 MODELING RESULTS

The results of the modeling are shown in Fig. 0.2 and Table 0.1. The calculations indicate that the aquifer is fairly insensitive to the nature of the recharge from the Green River and that little effect may be expected on the local groundwater table at withdrawal rates up to 63 liters/s (1000 gpm).

If the maximum planned withdrawal of 360 liters/min (100 gpm) were to be continuously pumped from the site well, the drawdown at the nearest domestic well [approximately 1829 m (6000 ft) northeast of the proposed well] would be less than 0.3 m (1 ft) after 10 years.

In calculating this drawdown it was conservatively assumed that the well would be pumped continuously at the maximum anticipated rate and that no aquifer recharge would occur. These assumptions represent a worst-case estimate of the local impact on groundwater availability, because the well is not expected to be pumped continuously, and some recharge to the aquifer is expected. Thus, the drawdown at the nearest domestic well is expected to be less than the calculated amount.

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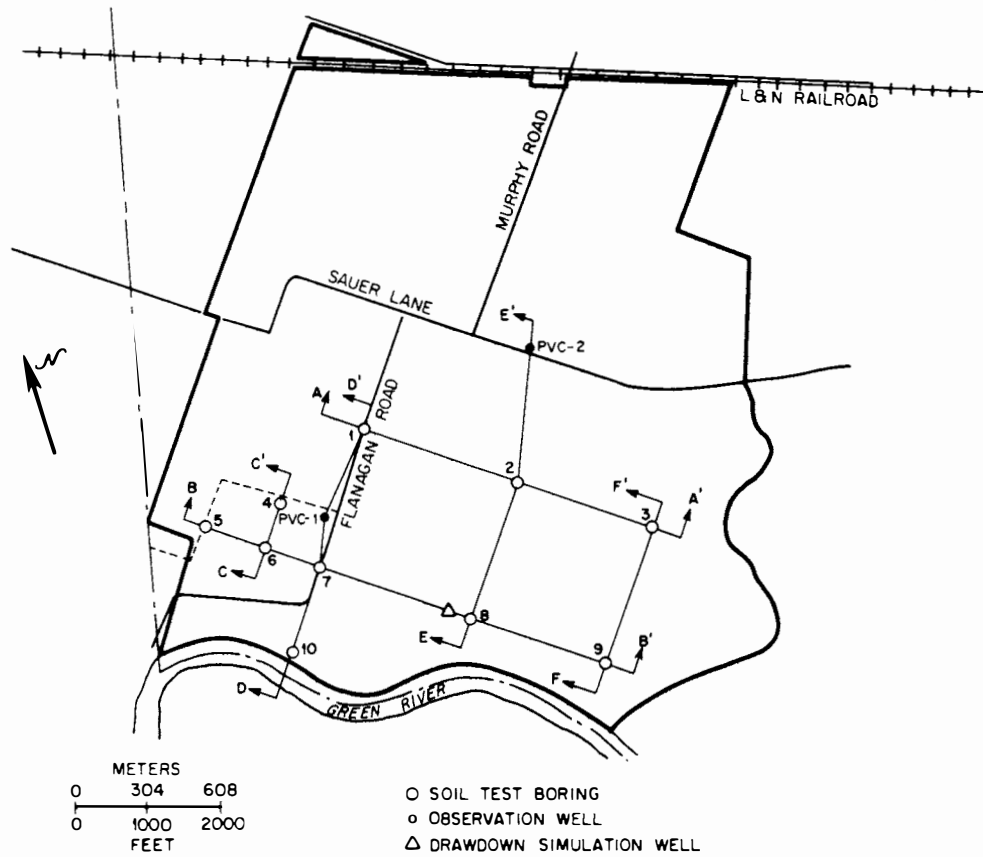


Fig. 0.1. Locations of test wells and drawdown simulation well.

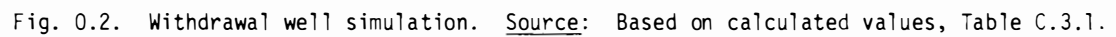


Fig. 0.2. Withdrawal well simulation. Source: Based on calculated values, Table C.3.1.

Table 0.1. Drawdowns in m (ft) resulting from well pumping^a

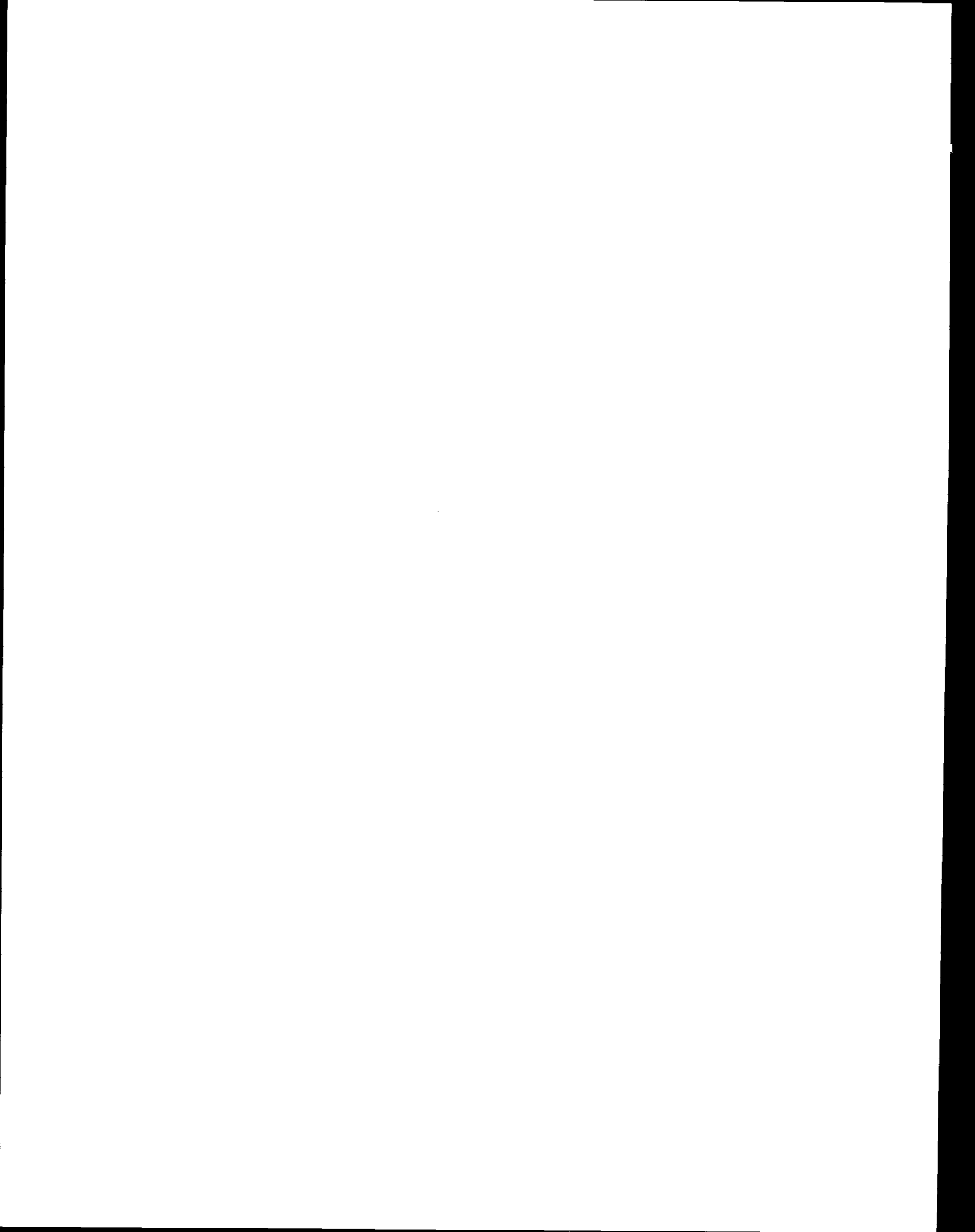
Distance from well	Drawdown for 1 year			Drawdown for 10 years		
	No river recharge	Complete river recharge	Difference	No river recharge	Complete river recharge	Difference
Case A. Continuously pumping 6.3 liters/s (100 gpm)						
3.0 (10)	0.87 (2.9)	0.85 (2.8)	0.023 (0.08)	1.3 (4.2)	1.0 (3.4)	0.24 (0.84)
152 (500)	0.06 (0.20)	0.06 (0.20)	0 (0)	0.36 (1.2)	0.23 (0.76)	0.13 (0.43)
305 (1000)	0.01 (0.02)	0.01 (0.02)	0 (0)	0.18 (0.59)	0.11 (0.35)	0.072 (0.23)
1838 (6000)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Case B. Continuously pumping 12.6 liters/s (200 gpm)						
3.0 (10)	1.7 (5.7)	1.7 (5.6)	0.047 (0.15)	2.6 (8.5)	2.1 (6.8)	0.51 (1.7)
152 (500)	0.12 (0.40)	0.12 (0.40)	0.003 (0.01)	0.72 (2.4)	0.47 (1.5)	0.26 (0.85)
305 (1000)	0.01 (0.03)	0.01 (0.03)	0 (0)	0 (0)	0.21 (0.70)	0.14 (0.47)
1838 (6000)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Case C. Continuously pumping 63.1 liters/s (1000 gpm)						
3.0 (10)	8.7 (29)	8.5 (28)	0.24 (0.77)	13 (42)	10 (34)	2.6 (8.4)
152 (500)	0.61 (2.0)	0.60 (2.0)	0.014 (0.05)	3.6 (12)	2.3 (7.6)	1.3 (4.3)
305 (1000)	0.05 (0.17)	0.05 (0.17)	0 (0)	1.8 (5.9)	1.1 (3.5)	0.72 (2.3)
1838 (6000)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

^a Values less than 0.003 m (0.01 ft) are shown as 0.

Source: ER, Appendix F, Table F.7.

REFERENCE FOR APPENDIX O

1. ATEC Associates, *Preliminary Geotechnical Engineering Study, 2000 TPD Solvent Refined Coal Facility*, prepared for Wheelabrator Cleanfuel Corporation and Kentucky Center for Energy Research, 1977.



Appendix P

COAL, SLAG, AND SRC SOLID PRODUCT LEACHING TESTS

Appendix P

COAL, SLAG, AND SRC SOLID PRODUCT LEACHING TESTS

P.1 COAL LEACHATE TESTING

Field leach testing of five proposed feedstock coals has been performed at Oak Ridge National Laboratory (ORNL).¹ Coal samples were placed in lysimeters and were exposed to natural rainfall events during a three-month period. Leachate samples were collected during and after each rainfall event and were analyzed for potentially hazardous metal content.

Results of field leaching tests performed on the Kentucky No. 9 and Illinois No. 6 coals are presented in Tables P.1 and P.2 respectively. Mean concentrations of each parameter were compared with Primary² and proposed Secondary³ Drinking Water Standards of the U.S. Environmental Protection Agency (EPA). Leachate from both coals exceeds the Primary Drinking Water Standards for the elements As, Cd, Cr, and Se. Leachate from both coals also exceeds proposed Secondary Drinking Water Standards for pH, iron, and sulfate content. The amount by which measured parameters exceed the standards is shown in the table. It is clear from these data that special handling of coal pile leachate is required to avoid contamination of surface water and groundwater.

Table P.1. Summary of leachate data collected from Kentucky No. 9 coal

Parameter	Observations	Mean	Standard deviation	Minimum	Maximum	Mean exceeds DW std by
Runoff, % of rainfall	8	71	29.5	65	100	
Percent transmission before filter	20	32.5	21.6	0.9	86.3	
Percent transmission after filter	19	48.0	21.6	13.3	87.1	
pH	20	2.1	0.2	1.8	2.5	4.4
Acidity, mg/liter as CaCO ₃	15	33,100	22,400	7,760	78,200	
Electrical conductivity, μ mhos/cm	20	10,500	4,650	4,480	20,000	
Sulfate, mg/liter	20	27,300	18,100	5,820	72,600	109X
Iron, mg/liter	20	9,850	7,250	1,780	26,200	32,833X
Arsenic, μ g/liter	8	9,050	6,130	2,040	17,500	181X
Barium, mg/liter	8	<0.2	a			0
Cadmium, μ g/liter	8	166	106	47	386	16.6X
Chromium, μ g/liter	8	724	296	330	1,220	14.4X
Lead, μ g/liter	8	12	10	7.2	35	0
Selenium, μ g/liter	8	829	1,000	56	3,000	82.9X
Silver, μ g/liter	8	0.05	b			
Mercury, μ g/liter	8	0.20	0.20	0.05	0.60	0

^aBarium concentration <0.2 mg/liter for all samples.

^bSilver concentration <0.05 g/liter for all samples.

Source: E. C. Davis, *A Laboratory and Field Analysis of Factors Affecting Quality of Leachate from Coal Storage Piles*, Ph.D. dissertation, Dept. of Environmental and Water Resources Engineering, Vanderbilt University, Nashville, Tenn., 1980.

Table P.2. Summary of leachate data collected from Illinois No. 6 coal

Parameter	Observations	Mean	Standard deviation	Minimum	Maximum	Mean exceeds DW std by
Runoff, % of rainfall	6	73	6.7	65	83	
Percent transmission before filter	11	80.1	20.8	19.1	94.2	
Percent transmission after filter	11	88.6	6.2	81.9	97.9	
pH	11	2.2	0.1	2.1	2.4	4.3
Acidity, mg/liter as CaCO ₃	6	21,200	7,270	6,500	25,400	
Electrical conductivity, μ mhos/cm	11	15,200	5,640	6,500	21,700	
Sulfate, mg/liter	11	21,500	10,900	5,850	37,200	86X
Iron, mg/liter	11	7,710	3,870	2,090	12,000	25,700X
Arsenic, μ g/liter	5	147	90.8	9.4	258	2.94X
Barium, mg/liter	5	0.2	^a			0
Cadmium, μ g/liter	5	268	165			26.8X
Chromium, μ g/liter	5	438	234	21	560	8.7X
Lead, μ g/liter	5	14	5.6	7.2	21	0
Selenium, μ g/liter	5	438	370	19	908	43.8X
Silver, μ g/liter	5	0.35	0.31	<0.05	0.81	0
Mercury, μ g/liter	5	0.12	0.12	0.03	0.30	0

^aBarium concentration <0.2 mg/liter for all samples.

Source: E. C. Davis, *A Laboratory and Field Analysis of Factors Affecting Quality of Leachate from Coal Storage Piles*, Ph.D. dissertation, Dept. of Environmental and Water Resources Engineering, Vanderbilt University, Nashville, Tenn., 1980.

P.2 SLAG LEACHATE TESTING

(These are preliminary data on SRC-I waste, as of April 25, 1980.)

P.2.1 Slag/flydust waste acquisition

Mineral residues from the SRC-I Pilot Plant at Wilsonville, Alabama, were shipped to Germany for gasification in a Koppers-Totzek Gasifier. Feed coal for the pilot run (run 179) was Kentucky No. 9 coal. Mineral ash residue (MAR) from the Kerr-McGee unit and Kentucky No. 9 coal were fed into the Koppers-Totzek Gasifier in a mixture of 90% MAR and 10% Kentucky No. 9 coal. Approximately 1.4 kg (3 lb) of gasified waste from run 179 were shipped from Germany to ORNL in plastic bags and were received Feb. 15, 1980. After gasification, the waste consists of flydust and slag in proportions of nearly 1:1.

P.2.2 Results of batch leaching

Slag and flydust were subjected to the extraction procedure recommended for identification of hazardous wastes by EPA in the proposed Resource Conservation and Recovery Act (RCRA). Results of leachate analysis for the eight trace elements included in the Primary Drinking Water Standards, and RCRA Standards are included in Table P.3. In addition to the eight priority trace elements, Cu, Ni, V, and Zn were analyzed because they are of environmental importance and may be added to the list of hazardous trace elements in future regulations.

P.2.3 Discussion of preliminary results

Batch leach testing using the EPA extraction procedures and proposed RCRA hazardous waste designations (May 19, 1980) indicates that the gasified mineral residue would not be classified as a

Table P.3. EPA extraction procedure results for ash and flydust produced by GKT gasifier on SRC-I residue

Element	Slag run 179	Flydust run 179	RCRA standard ^a
Arsenic, ppb	4	4	5,000
Barium, ppb	3.3	73	100,000
Cadmium, ppb	0.098	45	1,000
Chromium, ppb	0.46	8.5	5,000
Lead, ppb	1.1	78.5	5,000
Mercury, ppb	0.022	0.047	200
Selenium, ppb	<5	<5	1,000
Silver, ppb	<0.01	0.01	5,000
Copper, ppm	0.0013	1.53	<i>b</i>
Nickel, ppm	0.10	3.71	<i>b</i>
Zinc, ppm	0.012	7.9	<i>b</i>
Vanadium, ppm	9.27	1.6	<i>b</i>

^a RCRA standard equals 100 times the EPA "Interim Primary Drinking Water Standard."

^b Elements not listed in the "Interim Primary Drinking Water Standard."

hazardous waste. Priority pollutant trace elements are leachable in quantities much lower than those specified by hazardous waste regulations. Fly dust, the finest fraction of waste generated, releases more soluble trace elements than does coarse slag. Cadmium and lead concentrations in the fly dust exceeded primary drinking water standards; but, all other trace element concentrations were within drinking water standards.

P.3 SRC SOLID PRODUCT LEACHING TESTS

Leaching tests were performed on two samples of SRC-I product which were crushed to pass through a 3/8-in. sieve. The American Society for Testing and Materials (ASTM) leaching Method A, using deionized water, was used since this method most nearly simulates exposure of stored product to natural precipitation.

The shaking procedure calls for a liquid to solid ratio of 4:1, and a shaking period of 48 h. The leachate is then filtered through a 0.45- μ membrane filter and preserved for analysis.

For our samples, 200 g of SRC-I product were contacted with 800 ml of the extractant fluid for 48 h.

Primary and proposed secondary drinking water standards are included in Table P.4 for comparison. Leachate concentrations are well below the recommended levels for all the primary standards. The leachate exceeds the proposed secondary drinking water standard for manganese and is more acid than the pH range recommended in the secondary standard. Organic constituents of the leachate are under study and will be reported at a later date.

The SRC solid product does not appear to present a hazard to water quality, based on testing and analyses performed to date. Upon completion of the leaching tests, which involved agitation of the sample, the leachate remained black and opaque. The coloration was caused by fine particulates which remained in suspension but were retained on 0.45- μ membrane filters. Runoff from the SRC storage area will be collected and routed through the wastewater treatment facility. Due to the brittle nature of the product, shipping and handling activities are expected to generate dust which may cause local surface water quality impacts if the product is stored without dust suppression. The proposed design includes dust suppression and leachate collection and treatment.

Table P.4. Chemical analysis of leachates produced from SRC-I product using the ASTM Type "A" leaching procedure

Constituent	Sample No.		Drinking water standards ^a
	1	2	
Arsenic, ppb	0.5	0.1	50
Barium, ppm	0.10	0.03	1
Cadmium, ppb	0.07	0.33	10
Chromium, ppb	0.22	0.18	50
Lead, ppb	17	0.7	50
Mercury, ppb	0.024	0.001	2
Selenium, ppb	3	3	10
Silver, ppb	0.02	0.02	50
Copper, ppb	4.0	1.8	1000
Nickel, ppb	3.4	1.2	NS ^b
Zinc, ppb	5.0	0.44	5000
Calcium, ppm	0.54	0.44	NS
Chloride, ppm	1.1	6.6	250
Iron, ppm	0.012	0.0012	0.3
Magnesium, ppm	0.12	0.06	NS
Manganese, ppm	0.1	0.1	0.05
Potassium, ppm	0.5	0.5	NS
Sodium, ppm	2.05	1.62	NS
Sulfate, ppm	1.5	1.0	250
pH (final)	5.5	5.6	6.5-8.5
Electrical Conductivity (μ mhos/cm)	1.6	2.0	NS
Alkalinity, ppm	4	3.75	NS
Total dissolved solids, ppm	64	68	500
Total filterable residue, ppm	2440	2520	NS
Total organic carbon, ppm	7.5	6.3	NS
Chemical oxygen demand, ppm	23	21	NS

^aEnvironmental Protection Agency primary and secondary drinking water standards.

^bNS—no standard promulgated or proposed.

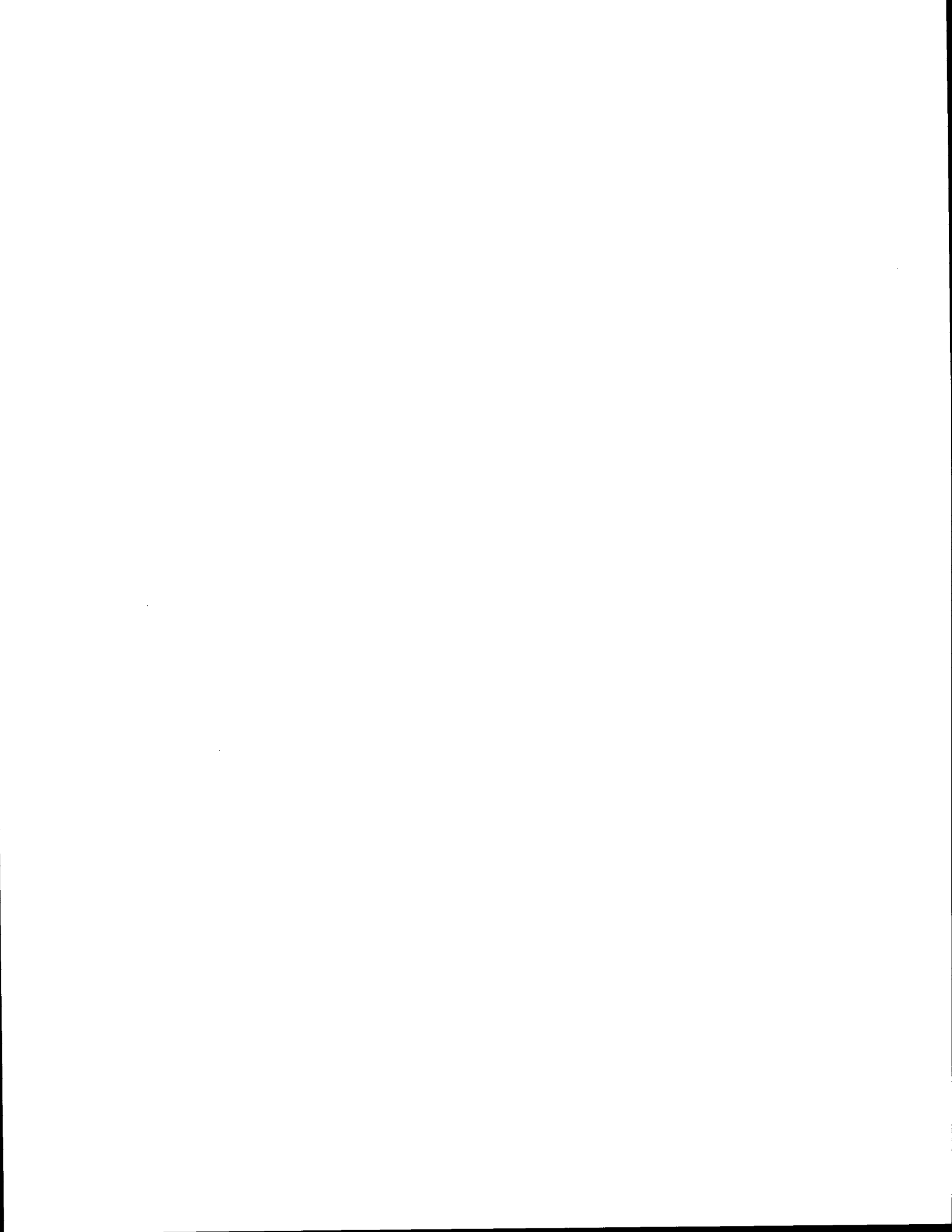
Source: Written communication from W. J. Boegly, Environmental Sciences Division, ORNL, June 2, 1980.

REFERENCES FOR APPENDIX P

1. E. C. Davis, *A Laboratory and Field Analysis of Factors Affecting Quality of Leachate from Coal Storage Piles*, Ph.D. dissertation, Dept. of Environmental and Water Resources Engineering, Vanderbilt University, Nashville, Tenn., 1980.
2. *National Interim Primary Drinking Water Regulations*, U.S. Environmental Protection Agency, Office of Water Supply EPA-570/9-76-003, 1976.
3. "National Secondary Drinking Water Regulations," 40 CFR Part 143, March 31, 1977.

Appendix Q

PROJECT ENVIRONMENTAL PLAN FOR THE SRC-I DEMONSTRATION PLANT



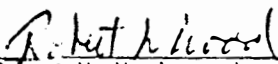
Appendix Q

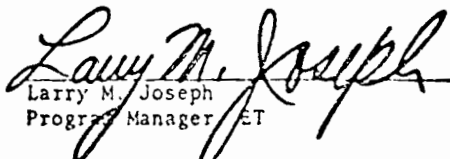
PROJECT ENVIRONMENTAL PLAN

FOR THE

SRC I DEMONSTRATION PLANT

MAY 2, 1979


Robert W. Wood, and
Paul Duhamel
Project Environmental Officers, EV


Larry M. Joseph
Program Manager, ET

PROJECT ENVIRONMENTAL PLAN (PEP) - SRC II. INTRODUCTION

This plan outlines the environmental (including health and safety) research and development activities to be performed in support of environmental compliance activity for the SRC-I demonstration plant and in support of future SRC I commercialization decisions. This plan identifies environmental project activities to be conducted cooperatively by ET and EV. Environmental research and development activities of other government agencies which are applicable to the SRC I process have been considered in its development.

The demonstration plant design includes provisions to meet legislative and regulatory environmental requirements promulgated by those agencies with that responsibility. In addition, the demonstration projects will incorporate design criteria specified by DOE and the industrial partner which in the absence of unforeseen events are likely to permit construction of commercialization plants using the same design.

In addition, DOE/EV will undertake studies and evaluations to obtain data required to recommend design improvements for the commercial plant and to assess the environmental risks and benefits of commercialization of the process.

II. OBJECTIVES

The primary environmental program objective is to have the reference process meet, at commercial scale, the mandatory requirements of the applicable Federal, state, and local environmental regulations. The objectives of this planning activity are to formulate a RD&D program which addresses the principal environmental concerns as recently highlighted in the Coal Liquefaction Environmental Readiness Document (ERD), September 1978 and the Coal Liquefaction Environmental Development Plan (EDP), in September 1977.

In prelude to major programmatic and siting activities, Environmental Impact Statements (EIS) as specified by the National Environmental Policy Act (NEPA), and water resource analyses have to be prepared and reviewed. The key concerns to be addressed in the environmental program are: worker protection; siting; potential public health risks from process products, by products, and emissions; and management of solid wastes. Other uncertainties that need to be resolved are the potential impacts of projected and/or proposed regulations on the environmental control technology, the ultimate environmental acceptability, and implications for commercialization. Because of the potential hazards associated with the materials involved, a specific concern that has to be addressed where SRC I is produced and used is the development and implementation of an industrial hygiene and epidemiology program early enough to protect workers and the public from harmful exposures to the product.

The specific objectives of the environmental program are:

1. Compliance -

Develop plans and conduct operations that comply with applicable environmental regulations and required permits providing necessary NEPA documentation for the construction, operation, and ultimate fate of the SRC I demonstration facility, and water resource data. Prepare and implement a joint EV-ET environmental characterization plan to assure environmental acceptability of the SRC I process when eventually commercialized under projected EPA and OSHA coal liquefaction guidelines.

2. Controls -

Evaluate current and apply as necessary state-of-the-art pollution controls and mitigation procedures for compliance with existing regulations for the demonstration plant. Assess the efficacy of these controls for compliance with proposed and projected emission, effluent, solid waste and health effect regulations at commercial scale. Identify the resultant additional environmental control technology development programs if any, needed to ensure that the technology, when commercialized, will be environmentally acceptable and cost-effective.

3. Characterization and Monitoring -

Determine the chemical and physical characteristics of the demonstration plant process materials, emissions, and solid wastes. Establish composition and fate of leachates from the process wastes and residues. Work done here will be continuation of the current and planned work with the pilot plant samples.

4. Safety -

Develop, assess, and implement an industrial hygiene and safety program for the operation phase of the demonstration facility. Assess the applicability of this program to the potential commercialization facilities.

5. Health and Ecological Effects -

Identify the occupational and public health effects and probability of exposure to the products, effluents, and the solid wastes and their leachates. Identify ecological effects of the same exposures. This work done at the demonstration facility will form the basis for a health and ecological assessment for a mature SRC I industry.

6. Assessments -

Perform an assessment to determine the overall environmental impact of the SRC-I coal liquefaction demonstration plant. The results from this assessment will be used for an integral assessment of a projected, mature SRC I industry to determine the overall environmental benefits and risks of the SRC I coal liquefaction process and/or technology.

III. TASKS AND SCHEDULES

ET initiated environmental work at the SRC Pilot Plant site in 1973 and EV initiated work in 1976. A coordinated ET-EV SRC I environmental implementation plan to assess the environmental acceptability of the process when commercialized is in preparation. Phase I of the plan for work at Pilot Plant site is to be implemented in 1979 and Phase II of the plan for work at the demonstration site is to be prepared and implemented in CY 1980.

Table 1 shows the current ET-EV coordinated environmental work initiated and planned for the SRC I process including work at the pilot and demonstration plant sites. This effort includes the collection of the environmental baseline and operating data and synthesis of this information to assure environmental acceptability of the SRC I process for future commercialization. The EV funding shown reflects the planned funding for this work and is subject to changes in budget and priorities. The EV sponsored work will generate information which will enable an optimum environmental design. FY 79 and FY 80 EV funding is for work done at the Takoma SRC Pilot Plant and includes SRC I and SRC II modes of operation. The TEC data shown includes cost on the basis of construction and operation at one demonstration plant using either SRC I or SRC II process. If two demonstration plants are built to evaluate SRC I and SRC II process respectively then the EV cost will be less than double the cost shown which apply to a single demonstration plant. Better cost estimates for both situations will be developed after the environmental work at the pilot plant has been completed. The ET budget will fund the project work in the tasks given in Table 1; however, they are difficult to separate from the overall technology budget and therefore estimated cost figures are given in the Table. Respective budget commitments of ET and EV for FY 79 are reflected in Table 1. Other figures shown in Table 1 will be more accurately estimated as information is generated.

Table 2 shows the schedules for the environmental activities and highlights the relationship with the project phases.

TABLE I
ENVIRONMENTAL TASKS/FUNDING OFFICE/COSTS

PROJECT TITLE: SRC I

Specific Objective ^{1/}	Required Task	Funding Office	Costs ^{5/} (\$ thousands)			Comments
			FY79 ^{2/}	FY80 ^{3/}	TEC ^{4/}	
1. NEPA Regulatory Compliance for the SRC II Demonstration Plant	1.1 Prepare required documents (NEPA, water resources etc.) for construction and operation of the SRC I facility.	ET				
		EV				
		ET				
		ET				
		ET				
2. Environmental Controls ^{6/}	1.2 Determine requirements of applicable environmental, health, safety and water use regulations, assign necessary control equipment and obtain necessary permits for the SRC I facility.	ET				FY 79 effort focused on Fort Lewis, Wash., pilot facility. Needs for demo plant to be determined.
		EV				
		ET				
		EV				
		ET				
	1.3 Maintain compliance with applicable regulations (permit requirements) during operation of the SRC I demo plant.	ET				EV will focus on anticipating compliance needs and implications on mature commercial industry. EV cost shown is process specific in 30% and 70% of the funding is for the study of unit operations integral to all liquefaction systems. FY 79-80 general assessment activity (SRC - Texaco Gasifier)
		EV				
		ET				
		EV				
		ET				
	1.4 Prepare a detailed joint environmental implementation plan for the SRC I facility.	ET				
		EV				
	2.1 Assess the atmospheric emission and particulate control needs.	ET				
		EV				

- ^{1/} Number relates to specific environmental objectives listed in Section 2.
^{2/} FY 79 Actual for Ongoing R&D. FY 79 EV funding is for work done at the Takoma SRC pilot plant and includes SRC I and SRC II modes of operation.
^{3/} FY 80 Estimated Budget Allocation. FY 80 EV funding is for work done at the Takoma SRC pilot plant and includes SRC I and SRC II modes of operation.
^{4/} Total Estimated Cost for Task Element; all years through demonstration project completion for one SRC plant. Availability of funds contingent upon competing project/technology priorities.
^{5/} All costs are preliminary estimates. ET funds for environmental related activities are part of the demonstration project budget; EV funding is to be requested and justified separately from ET funding.
^{6/} Environmental control development and demonstration not budgeted by EV.

TABLE 1
ENVIRONMENTAL TASKS/FUNDING OFFICE/COSTS

PROJECT TITLE: SRC I

Specific Objective ^{1/}	Required Task	Funding Office	Costs ^{5/} (\$ thousands)			Comments
			FY79 ^{2/}	FY80 ^{3/}	TEC ^{4/}	
2. Environmental Controls ^{6/} (cont'd)	2.2 Evaluate the effectiveness of contaminated water clean-up, management, and disposal procedures for the SRC I process.	ET EV				FY 79 effort directed at PHA control options & concentration of wastewater.
	2.3 Identify control needs necessary to mitigate trace material leaching from process solid wastes from the SRC I facility.	ET EV				FY 79-80 effort focused on determining RCRA implications (solids and sludges).
	2.4 Determine and-use environmental control technology and safety requirements for the SRC I demo facility.	ET EV				Evaluating Mitchelville and subsequent burn test results.
	2.5 Develop if necessary environmental controls to mitigate environmental, health, and safety impacts of commercial operations for the SRC I demo facility.	ET				
	2.6 Develop SRC I waste management procedures and conduct monitoring of baseline, operational, and post-operational soil and water systems.	ET				
	2.7 Estimate by experimental methods the hydrologic cycle relative to SRC I fuel waste sites.	ET				
	2.8 Define state-of-the-art procedures for management of SRC I fuel wastes which minimize adverse environmental impacts to ecosystems.	ET				

^{1/} Number relates to specific environmental objectives listed in Section 2.

^{2/} FY 79 Actual for Ongoing R&D. FY 79 EV funding is for work done at the Takoma SRC pilot plant and includes SRC I and SRC II modes of operation.

^{3/} FY 80 Estimated Budget Allocation. FY 80 EV funding is for work done at the Takoma SRC pilot plant and includes SRC I and SRC II modes of operation.

^{4/} Total Estimated Cost for Task Element; all years through demonstration project completion for one SRC plant. Availability of funds contingent upon competing project/technology priorities.

^{5/} All costs are preliminary estimates. ET funds for environmental related activities are part of the demonstration project budget; EV funding is to be requested and justified separately from ET funding.

^{6/} Environmental control development and demonstration not budgeted by EV.

TABLE 1
ENVIRONMENTAL TASKS/FUNDING OFFICE/COSTS

PROJECT TITLE: SRC I

Specific Objective ^{1/}	Required Task	Funding Office	Costs ^{5/} (\$ thousands)			Comments
			FY79 ^{2/}	FY80 ^{3/}	TEC ^{4/}	
3. Characterization and Monitoring		ET				
		EV				
	3.1 Assess current information on air quality surface to substrate water supplies in the regions where SRC I development is anticipated.	ET				
	3.2 Develop (if necessary, methodologies for measuring and monitoring of air and water pollutants from the SRC I facility which may adversely effect man and the environment.	EV				Specific needs to be defined. Generic measurement science currently being funded.
	3.3 Accumulate baseline operational and post operational air and water quality data at the proposed SRC I site.	ET				Three years at demo level.
		EV				
	3.4 Characterize and quantify the materials in SRC I process samples of planned and fugitive releases, products, byproducts, effluents, leachates and emissions from the end use.	ET				Work planned thru FY 1986.
		EV				
	3.5 Characterize chemical transformation of atmospheric release; supply samples of reaction products for screening studies from SRC I process.	EV				Needed studies to be defined.
	3.6 Quantify consumption water use and determine the effects on surface and groundwater supplies availability, and quality at the proposed SRC I site.	ET				

- 1/ Number relates to specific environmental objectives listed in Section 2.
^{2/} FY 79 Actual for Ongoing R&D. FY 79 EV funding is for work done at the Takoma SRC pilot plant and includes SRC I and SRC II modes of operation.
^{3/} FY 80 Estimated Budget Allocation. FY 80 EV funding is for work done at the Takoma SRC pilot plant and includes SRC I and SRC II modes of operation.
^{4/} Total Estimated Cost for Task Element; all years through demonstration project completion for one SRC plant. Availability of funds contingent upon competing project/technology priorities.
^{5/} All costs are preliminary estimates. ET funds for environmental related activities are part of the demonstration project budget; EV funding is to be requested and justified separately from ET funding.
^{6/} Environmental control development and demonstration not budgeted by EV.

TABLE 1
ENVIRONMENTAL TASKS/FUNDING OFFICE/COSTS

PROJECT TITLE: SRC I

Specific Objective ^{1/}	Required Task	Funding Office	Costs ^{5/} (\$ thousands)			Comments
			FY79 ^{2/}	FY80 ^{3/}	TEC ^{4/}	
3. Characterization and Monitoring (cont'd)	3.7 Determine the extent of geological disturbances to be expected at SRC I fuel waste sites and the effect on groundwater movement; analyse control methods.	ET EV				ET will conduct the ET-EV studies required for the demonstration site. EV studies will be commercial applications of the process.
	3.8 Characterize and determine the extent of land impacted by ash, residue, and other wastes following conversion, and assess the need for controls and reclamation efforts at the SRC I site.	ET EV				ET responsible for impacts at demonstration site. EV responsible for examining implications for commercialization.
	3.9 Define the degrees of mobilization and fate of trace metals and organic residuals present in synthetic fuel waste disposal sites for the SRC I process.	ET EV				Studies primarily pilot plant effort. Minimal studies planned at demonstration plant.
	3.10 Evaluate the tendency for trace contaminants in waste sites to become biologically available, and characterize significant food chain transfers for SRC I process.	EV				Needed studies to be defined.
	3.11 Characterize chemical and microbiological transformations of residuals which proceed within SRC demonstration plant waste sites or in fresh water and soil systems to which they are transferred, provide environmental reaction products for screening studies.	EV				Generic program on chemical and microbiological aspects of liquid and solid wastes is underway. Specific needs for SRC I to be defined.

^{1/} Number relates to specific environmental objectives listed in Section 2.

^{2/} FY 79 Actual for Ongoing R&D. FY 79 EV funding is for work done at the Tacoma SRC pilot plant and includes SRC I and SRC II modes of operation.

^{3/} FY 80 Estimated Budget Allocation. FY 80 EV funding is for work done at the Tacoma SRC pilot plant and includes SRC I and SRC II modes of operation.

^{4/} Total Estimated Cost for Task Element; all years through demonstration project completion for one SRC plant. Availability of funds contingent upon competing project/technology priorities.

^{5/} All costs are preliminary estimates. ET funds for environmental related activities are part of the demonstration project budget; EV funding is to be requested and justified separately from ET funding.

^{6/} Environmental control development and demonstration not budgeted by EV.

TABLE 1
ENVIRONMENTAL TASKS/FUNDING OFFICE/COSTS

Specific Objective ^{1/}	Required Task	Funding Office	Costs ^{5/} (\$ thousands)			Comments
			FY79 ^{2/}	FY80 ^{3/}	TCC ^{4/}	
c. Occupational Safety and Health		ET				
		EV				
	4.1 Develop if necessary, measuring and monitoring systems for SRC I work areas.	EV				Specific needs to be defined, generic measurement science program currently being funded.
	4.2 Develop if necessary, individual dose monitoring systems for evaluating exposure to hazardous systems at the SRC I site.	EV				Specific needs to be defined, generic measurement science program currently being funded.
	4.3 Develop and implement program for medical surveillance of workers in the SRC I demonstration plant.	ET				
	4.4 Develop and implement SRC I industrial hygiene and safety programs.	ET				
	4.5 Assess data from biological screening and toxicity studies for possible application to SRC I demonstration plant industrial hygiene procedures.	ET				
		EV				ET responsible for demonstration operations. EV responsible for implications for commercialization. Funding included under 6.1.

^{1/} Number relates to specific environmental objectives listed in Section 2.

^{2/} FY 79 Actual for Ongoing R&D. FY 79 EV funding is for work done at the Takoma SRC pilot plant and includes SRC I and SRC II modes of operation.

^{3/} FY 80 Estimated Budget Allocation. FY 80 EV funding is for work done at the Takoma SRC pilot plant and includes SRC I and SRC II modes of operation.

^{4/} Total Estimated Cost for Task Element; all years through demonstration project completion for one SRC plant. Availability of funds contingent upon competing project/technology priorities.

^{5/} All costs are preliminary estimates. ET funds for environmental related activities are part of the demonstration project budget; EV funding is to be requested and justified separately from ET funding.

^{6/} Environmental control development and demonstration not budgeted by EV.

TABLE 1
ENVIRONMENTAL TASKS/FUNDING OFFICE/COSTS

PROJECT TITLE: SRC I

Specific Objective ^{1/}	Required Task	Funding Office	Costs ^{5/} (\$ thousands)			Comments
			FY79 ^{2/}	FY80 ^{3/}	TEC ^{4/}	
4. Occupational Safety and Health (Cont'd)	4.6 Conduct epidemiology studies of workers and environmentally exposed populace in the SRC I coal liquids industry.	ET EV				Two years.
	4.7 Develop capability for responses to major accidental releases for the SRC I process.	ET EV				ET responsibility.
5. Health and Ecological Effects		ET EV				
	5.1 Characterize by short-term methods, the biological activity in SRC I samples of planned and fugitive process releases, products, byproducts, effluents, solid leachates and emissions from the end use of the products and the byproducts.	EV				
	5.2 Establish dose-response relationships for carcinogenic potential and other delayed effects for chronic low level exposures to SRC I process effluents defined by toxicity studies.	EV				
	5.3 Using ecological systems capable of quantitative response in short time periods, determine potential ecological impact of the SRC I process materials.	EV				Needed studies to be defined.

^{1/} Number relates to specific environmental objectives listed in Section 2.

^{2/} FY 79 Actual for Ongoing R&D. FY 79 EV funding is for work done at the Takoma SRC pilot plant and includes SRC I and SRC II modes of operation.

^{3/} FY 80 Estimated Budget Allocation. FY 80 EV funding is for work done at the Takoma SRC pilot plant and includes SRC I and SRC II modes of operation.

^{4/} Total Estimated Cost for Task Element; all years through demonstration project completion for one SRC plant. Availability of funds contingent upon competing project/technology priorities.

^{5/} All costs are preliminary estimates. ET funds for environmental related activities are part of the demonstration project budget; EV funding is to be requested and justified separately from ET funding.

^{6/} Environmental control development and demonstration not budgeted by EV.

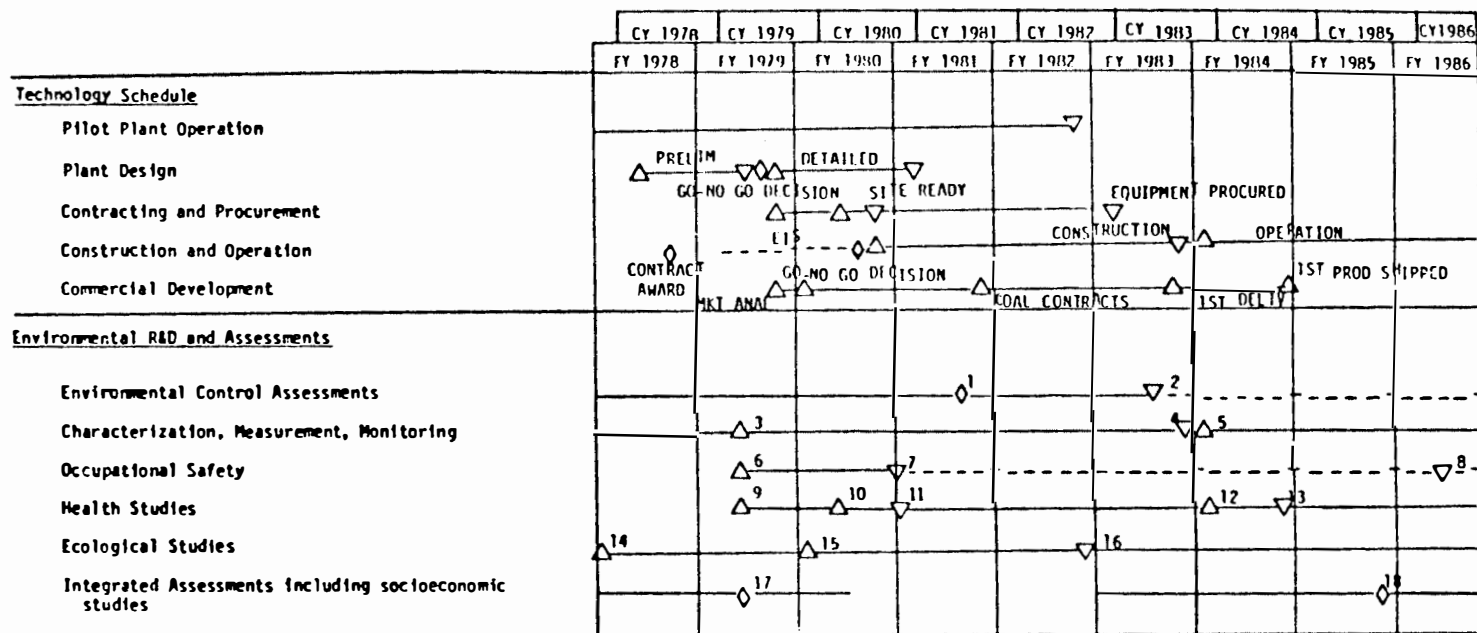
TABLE 1
ENVIRONMENTAL TASKS/FUNDING OFFICE/COSTS

PROJECT TITLE: SRC I

Specific Objective ^{1/}	Required Task	Funding Office	Costs ^{b/} (\$ thousands)			Comments
			FY79 ^{2/}	FY80 ^{3/}	TEC ^{4/}	
5. Health and Ecological Effects (cont'd)	5.4 With appropriate ecological systems, determine long-term chronic and sublethal effects of SRC I coal liquefaction effluents. Analyze synergism of these substances with selected chemical, biological, and physical stresses.	EV				Generic program on measurement and methods development is underway. Specific needs for SRC II to be defined.
	5.5 Develop if necessary, appropriate measurement, monitoring, and sampling methods for SRC I process.	EV				
	5.6 Quantitatively evaluate in experimental animals acute and delayed toxicity, carcinogenicity, mutagenicity, and systems damage of chemical agents and mixtures identified in process waste streams for SRC I process for which required dose-effects data are inadequate or nonexistent.	EV				
6. Assessments	6.1 Prepare overall environmental assessment of production, transport and use of SRC I fuel including socioeconomic, health, and ecological impacts.	ET EV				ET will emphasize the assessments of the demonstration plant and EV will concentrate on the commercialization assessments.

- 1/ Number relates to specific environmental objectives listed in Section 2.
2/ FY 79 Actual for Ongoing R&D. FY 79 EV funding is for work done at the Takoma SRC pilot plant and includes SRC I and SRC II modes of operation.
3/ FY 80 Estimated Budget Allocation. FY 80 EV funding is for work done at the Takoma SRC pilot plant and includes SRC I and SRC II modes of operation.
4/ Total Estimated Cost for Task Element; all years through demonstration project completion for one SRC plant. Availability of funds contingent upon competing project/technology priorities.
5/ All costs are preliminary estimates. ET funds for environmental related activities are part of the demonstration project budget; EV funding is to be requested and justified separately from ET funding.
6/ Environmental control development and demonstration not budgeted by EV.

TABLE 2
TECHNOLOGY/ENVIRONMENTAL MILESTONE SCHEDULE
FOR SRC I ENVIRONMENTAL PLAN



▲ Milestone - Initiation
 ▼ Milestone - Completion
 ○ Decision Point
 — Activity Bar
 - - - - - Continuing

- 1/ Assessment of Adequacy of Environmental Control Technology
- 2/ Evaluate Adequacy of Plant Control Technology and Future Needs as required
- 3/ Initiate Process Chemical and Residuals Characterization (Pilot Plant)
- 4/ Complete Process Chemicals and Residuals Characterization (Pilot Plant)
- 5/ Initiate Process Chemical & Residual Characterization (Demo Plant)
- 6/ Initiate Safety Procedures Assessment
- 7/ Decision on Adequacy of Occupational Health and Safety Medical Surveillance Plan
- 8/ Complete Assessment of Operational Safety Procedures and Surveillance
- 9/ Initiate Health Screening (Pilot Plant)

- 10/ Initiate Chronic Toxicity (Pilot Plant)
- 11/ Complete Health Screening (Pilot Plant)
- 12/ Initiate Confirmatory Health Evaluations (Demo Plant)
- 13/ Complete Chronic Toxicity (Pilot Plant)
- 14/ Initiate Ecological Screening (Pilot Plant)
- 15/ Initiate Ecological Effect Related Studies (Demo Plant)
- 16/ Complete Ecological Screening (Pilot Plant)
- 17/ Decision on SRC I Process Demo Based on Environmental Assessment
- 18/ Assessment after Demo Plant Operation and Prior to Shipment of First Product

Appendix R

MOBILITY OF POTENTIAL CONTAMINANTS IN SITE SOILS

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Appendix R

MOBILITY OF POTENTIAL CONTAMINANTS IN SITE SOILS

R.1 INTRODUCTION

Site areas that could be subjected to infiltration of dissolved contaminants include the ash ponds, the coal storage areas, the metal sludge landfill, the wastewater treatment area, and solvent storage areas. These contaminant source areas are located on both lower and upper terrace portions of the site. Predominant soils on both terraces in the area to be developed during the demonstration phase are Elk, Ginat, Otwell, Weinbach, and Jacob. These soils are silt loams and clay loams with variable permeabilities and local fragipans. Thicknesses of silty and clayey soils on the upper terrace are about 2.5 m (8 ft) and on the lower terrace about 4.6 m (15 ft). Surficial soils of the upper terrace overlie a lens of loose sand (Appendix L), and on the lower terrace, surficial soils overlie fairly dense sand.

Soil permeability data from the soil survey for Daviess and Hancock counties¹ were used to estimate the period of residency of leachates in surficial soils. Permeability beneath measured profiles, to the top of the underlying sand, was assumed to be the same as that at the base of the measured zone. Table R.1 gives the ranges of time (in hours) required for water to pass through soil types, assuming percolation at the published rate. The Elk soil is most permeable, and the Ginat and Jacob soils are least permeable.

The infiltration estimates were prepared using the design parameters of the ash disposal ponds: a 15-cm (6-in.) compacted clay liner having hydraulic conductivity of 10^{-7} cm/s and a 6.2-m (20-ft) hydraulic head on the liner. Darcy's law was used to estimate the volume of seepage through the liner which is approximately 4.1×10^{-2} cm³/s/m². Hydraulic conductivities of existing soil horizons range from 4×10^{-3} cm/s to 4×10^{-5} cm/s, which is equivalent to infiltration of 0.4 cm³/s/m² to 4 cm³/s/m² under zero head conditions. Comparisons of the seepage volume through the liner with the infiltration capacities of underlying soil horizons indicate that as leachate soaks through the clay liner its velocity will increase in underlying soils. The ranges of time required for leachate to penetrate the soil profile assume vertical migration, and Darcy's law was used to compute the travel time. Travel times through surficial soils only are included because leachate migration in the underlying sands is expected to be more rapid than in silty clays and will be strongly influenced by water table fluctuations and flow patterns in the alluvial aquifer. Upon reaching the water table, leachate is expected to migrate with the predominant groundwater movements.

The infiltration conditions assumed in the preparation of Table R.1 are an oversimplification of the known conditions. The Otwell and Weinbach soils typically have a fragipan in the subsoil, and the Ginat soil has a poorly developed fragipan in some areas. Permeabilities of the fragipan zones are about one order of magnitude lower than for overlying and underlying zones. In the event of liner failure, which results in infiltration of a large volume of liquid above a fragipan, lateral migration at the top of the low permeability zone would result, and a lesser amount of the liquid would infiltrate the fragipan. Fluids migrating laterally could travel to areas where downward migration is less inhibited or, if sufficient hydraulic head exists, could saturate surface soils outside of diked areas and break out at the surface. The probability of either of these conditions occurring depends on local conditions, the location of a leak, and the amount of fluid involved in a leak. Residence times given in Table R.1 represent a case of vertical infiltration and lateral migration in greater residence times for liquids in the surface soils.

The significance of the residence period of potential contaminants in surficial soils is that toxic trace metals may be prevented from reaching the groundwater system by ion exchange near the surface. Samples of Elk and Ginat B-horizon soils collected on the site had cation exchange capacities of 18 to 20 milliequivalents per 100 grams of soil. This exchange capacity, though

Table R.1. Leachate residence time^a in surficial soils

Soil Series	Soil horizon thickness		Range of hydraulic conductivity		Time required to penetrate soil column			
	Upper terrace ^b	Lower terrace ^c	Min (cm/s)	Max (cm/s)	Upper terrace		Lower terrace	
	(cm)	(cm)			Min (hours)	Max (hours)	Min (hours)	Max (hours)
Elk	76 ^d	76 ^d	4.4E-4	1.4E-3	15	48	15	48
	152	366	1.4E-3	4.4E-3	10	30	23	73
	Total				25	78	38	121
Otwell	51 ^d	NP ^e	4.4E-4	1.4E-3	10	32	NP	NP
	36 ^f		4.2E-5	1.4E-4	71	238		
	143		4.4E-4	1.4E-3	28	90		
Total					136	643	179	1067
Melvin	229 ^d	442 ^d	4.4E-4	1.4E-3	45	145	279	877
Weinbach	46 ^d	46 ^d	4.4E-4	1.4E-3	9	29	9	29
	41 ^f	41	4.2E-5	1.4E-4	81	271	81	271
	Total				128	390	161	525
Jacob	NP	442 ^d	1.4E-4	4.4E-4	NP	NP	279	877

^aResidence time is the number of hours required for leachate to penetrate the total thickness of fine grained surficial soils, assuming vertical movement through the entire profile.

^bSurficial silts and clays on the upper terrace are approximately 2.5 m (8ft) thick.

^cSurficial silts and clays on the lower terrace are approximately 4.6 m (15 ft) thick.

^dThickness of surface soil horizon is assumed to be 15 cm (6 in.) less than published value since site preparation includes removal of this soil.

^eNot present.

^fData for fragipan layer.

Source: Soil horizon thicknesses and permeabilities were obtained from *Soil Survey of Daviess and Hancock counties, Kentucky*, U.S. Dept. of Agriculture, Soil Conservation Service, Washington, D.C., 1974.

not especially high, reflects the good ability of these soils to attenuate trace metals under favorable conditions. Under strongly acidic and/or reducing conditions, the attenuating capacity of the soils is expected to diminish. Even under favorable conditions, oversaturation of the soil with contaminants would result in migration of leachates into the underlying sands which contain the alluvial aquifer.

R.2 DISCUSSION OF ASSUMPTIONS USED IN SRC-I GROUNDWATER TRANSPORT MODELLING: METAL SLUDGE LANDFILL*

Several assumptions have, of necessity, been made concerning the properties of the soils at the Newman site and the behavior of the chemical species being transported. These may be summarized as follows:

1. The permeability of the silty clay and silt layer immediately below the landfill had to be estimated because no permeability data were available for this soil type at the site. The silty clay was estimated to be three orders of magnitude less permeable than the dense sand. Because this silty clay layer determines the rate of vertical flow through the unsaturated zone beneath the landfill (at least, in the worst case, in which the synthetic and clay liners are assumed to have ruptured), the value selected for permeability is critical. Runs were performed using values of 1×10^{-6} cm/s (typical value for clays) and 1×10^{-5} cm/s as obtained from laboratory results of recompacted site material.
2. A minimum relative permeability was imposed on the unsaturated soils because the relationships supplied for the variation of permeability with suction pressure (refer to assumption 3) are unrealistic for high suction pressures. This minimum value selected, which is from ref. 2, is 0.005.

*This section was supplied by ICRC and Dames & Moore.

3. Because characteristics of permeability vs suction pressure and degree of saturation vs suction pressure have not been determined for the site, the relationships developed by Van Genuchten,³ for two general soil types were used.
4. Distribution coefficients for adsorption of the various chemical species onto the soil particles have been extracted from various field programs conducted by Dames & Moore. Specifically, the Freundlich adsorption expression was used:

$$C_s = K_d C^m,$$

where

C_s is the concentration on the soil (mg/g),

K_d is the adsorption distribution coefficient [$\text{mg}^{(1-m)} / \text{g}$],

C is the concentration in the groundwater (mg/l),

m is the exponent of C .

The values of K_d and m used in the study are listed in Table 1. They are based on adsorption characteristics of arsenic, cadmium, and selenium as observed in a calcareous soil.

Table 1. Summary of data used in SRC-I groundwater and leaching chemical species transport modelling — hydrodynamic parameters

Soil unit	Parameter	Value	Source
Moisture content			
Sludge and leachate		40%	Data on moisture content of the various soils and the dry density were obtained various bore holes, but particularly hole No. 5, which was nearest to the landfill site (Atec Assoc., Geotechnical Engineering Study, October 1979)
Clay liner		20%	
Silty clay		20%	
Loose sand		25%	
Dense sand		25%	
Dry density			
Sludge and leachate		110 pcf ^a	Data on sludge and clay liner is partially based field data obtained by Dames & Moore at a uranium sludge pond site (Gas Hills, Wyo.) ^a
Clay liner		120 pcf ^a	
Silty clay		100 pcf	
Loose sand		102 pcf	
Dense sand		110 pcf	
Porosity and unconfined storage coefficient			
Sludge		0.40 ^a	
Clay liner		0.30 ^a	
Silty clay		0.38	
Loose sand		0.44	
Dense sand		0.41	
Saturated permeability			
Sludge		2.835×10^{-4} ft/day ^a	Environmental Report, p. F-33
Clay liner		2.835×10^{-4} ft/day	
Silty clay		1) 2.835×10^{-3} ft/day 2) 2.835×10^{-2} ft/day	
Loose sand		2.835 ft/day	Estimate, Atec Assoc., Geotechnical Engineering Study, October 1979, p. 16
Dense sand		2.835×10^{-1} ft/day	

Adsorption distribution coefficients are a function of the local pH of the groundwater. Because the pH in the landfill is expected to be very high because of the treatment that the sludge will have undergone, pH will decrease in proportion to distance from the landfill. In general, K_d has been experimentally observed to increase with pH; thus, the metals would be less mobile in the neighborhood of the landfill than at average pH levels. Similarly, the solubility of the metals will decrease in proportion to distance from the landfill because of the variation in pH. Both of these factors make probable an overestimation of transport in the region adjacent to the pond, in which pH levels are affected by pond seepage and before the soil has completely buffered the pH. That is, the predicted results will be conservative.

5. Based on numerous laboratory and field measurements of thermal plumes in surface waters, Shirazi and Davis⁴ have developed a series of graphs of plume trajectories that depend on jet vs ambient current velocities. Because the unsaturated one-dimensional analysis resulted in a prediction of vertical fluid velocities at the water table and because the ambient groundwater velocities may be estimated from observation well data, the depth to which the concentration plume will penetrate may be analogously determined. In this way, it was established that the maximum depth of plume penetration would be 9.8 m (32 ft); 4.9 m (16 ft) was taken as an average value.

The sludge landfill was modelled numerically by means of two Dames & Moore computer programs. One program modelled the landfill and underlying soils during the time required for the metals of concern to reach the water table (i.e., an unsaturated flow model in one, vertical space domain was used). The second program was used to model the transport of the chemical species after they have reached the water table. This model is applicable to saturated flow conditions and was applied in the two-dimensional horizontal plane.

- a. The unsaturated model predicted the following results:

A one-dimensional vertical model of the landfill and underlying soils was used to predict (1) the flow velocities and (2) the time necessary for the cadmium and arsenic fronts to reach the current water table. During the initial modeling, selenium, which is very immobile in a calcareous soil, was found to take more than 50 years to reach the water table; hence, selenium was not modelled in any detail.

A column of 40 finite-difference cells was used to represent the 13.9-m (45.5-ft) column size between the top of the landfill and the water table. The pressure heads within the landfill were modelled at hydrostatic pressures (i.e., the pressure on the liner was 2.4 m (8 ft) of water (assuming that the landfill is continuously filled to its maximum permissible depth). The pressure head at the water table was set to zero (relative to atmospheric pressure).

The results of the one-dimensional predictions showed that after two years the pore pressures reached steady state and did not change thereafter. The soil column under the landfill never becomes completely saturated beneath the silty clay layer because the silty clay unit cannot transmit moisture rapidly enough to saturate the sands beneath.

The chemical species front travels slowly down to the water table; their rate of travel depends on the local concentration gradient, groundwater flow velocity, and rate of adsorption into the soil. For a case in which the landfill liner is assumed to rupture completely, it was found that it took 10 years for cadmium concentrations of half that found in the landfill itself to reach the water table. The corresponding time for arsenic is 11 years. A second run, in which the permeability of the silty clay was reduced by an order of magnitude, reduced the time of passage to the water table by half for each of the selected metals (5 and 6 years, respectively).

- b. The saturated model predicted the following results:

A two-dimensional horizontal model of the saturated sand unit below the landfill was used to predict the transport of chemical species of concern after they had reached the water table.

A finite-difference grid of 29 by 33 cells of variable size, covering 305 m² (100 ft²) was used in this analysis. A groundwater gradient of 0.00085 m/m (0.0028 ft/ft) in a direction N to S, deduced from the observation well data at the site, was input to the model. The head in the Green River was fixed at a summer low-flow level of 106 m (349 ft). This gradient was used because of limited data on flow characteristics to the west of the site. Preliminary data indicates flow is not to the south but to the SW and SE; so, a worst-case assumption of flow directly to the river was used.

The flow is averaged with depths in the vertical direction. Because the bedrock is almost 30.5 m (100 ft) beneath the water table, it is very unlikely that the concentration plume will mix through that entire depth. Thus, some assumptions, based on the flow of jets into ambient currents and documented elsewhere, have been used to arrive at maximum and minimum probable plume depths.

Predictions of the concentration distributions of cadmium and arsenic, which are based on assumptions that the landfill is a continuous source for 100 years and that the plume depth is the minimum likely to occur, show that even after 100 years the plumes do not reach the Green River. The silty clay unit that borders the river tends to deflect the plume parallel to the river, as may be observed in the arsenic plume at a time of 100 years after the start of disposal operations.

The second run resulted in a more rapid transport of metals to the water table but reduced each two-dimensional flow concentration by only the respective 5 years. This results in the 50-year concentrations on the graph to be those after 45 years for the second run.

Table 2 is a summary of the chemical species data and reaction parameters used in the transport modelling.

Table 2. Summary of data used in SRC-1 groundwater and leaching chemical species transport modelling - chemical species and reaction parameters

Chemical species	Parameter	Value	Source
Adsorption coefficient			
Arsenic		0.015	K_d and m data have been extracted from tests conducted by Dames Moore on a calcareous type soil Exxon-Crandon, EIS, Dames & M 1980
Cadmium		0.002	
Selenium		3457	
m (exponent in Freundlich adsorption expression)			
Arsenic		0.877	
Cadmium		0.31	
Selenium		3.01	
Background concentrations			
Arsenic		0.0057 mg/liter	Background concentrations are taken from p. N-7 of the Draft EIS for SRC-I, January 1981
Cadmium		0.0019 mg/liter	
Selenium		0.005 mg/liter	
Landfill concentrations			
Arsenic		9.05 mg/liter	Landfill concentrations are taken from p. P-3 of the Draft EIS SRC-I, January 1981
Cadmium		0.166 mg/liter	
Selenium		0.829/liter	

Concentrations of arsenic and cadmium in an unlined landfill are shown in Figs. R.1 and R.2 respectively.

The cases illustrated in Figs. R.3 through R.6 represent a worst-case situation:

1. The permeability of the dense sand (below the water table) was taken to be 10^{-3} cm/s (The range quoted in ref. 5 is 10^{-3} to 10^{-4} cm/s).

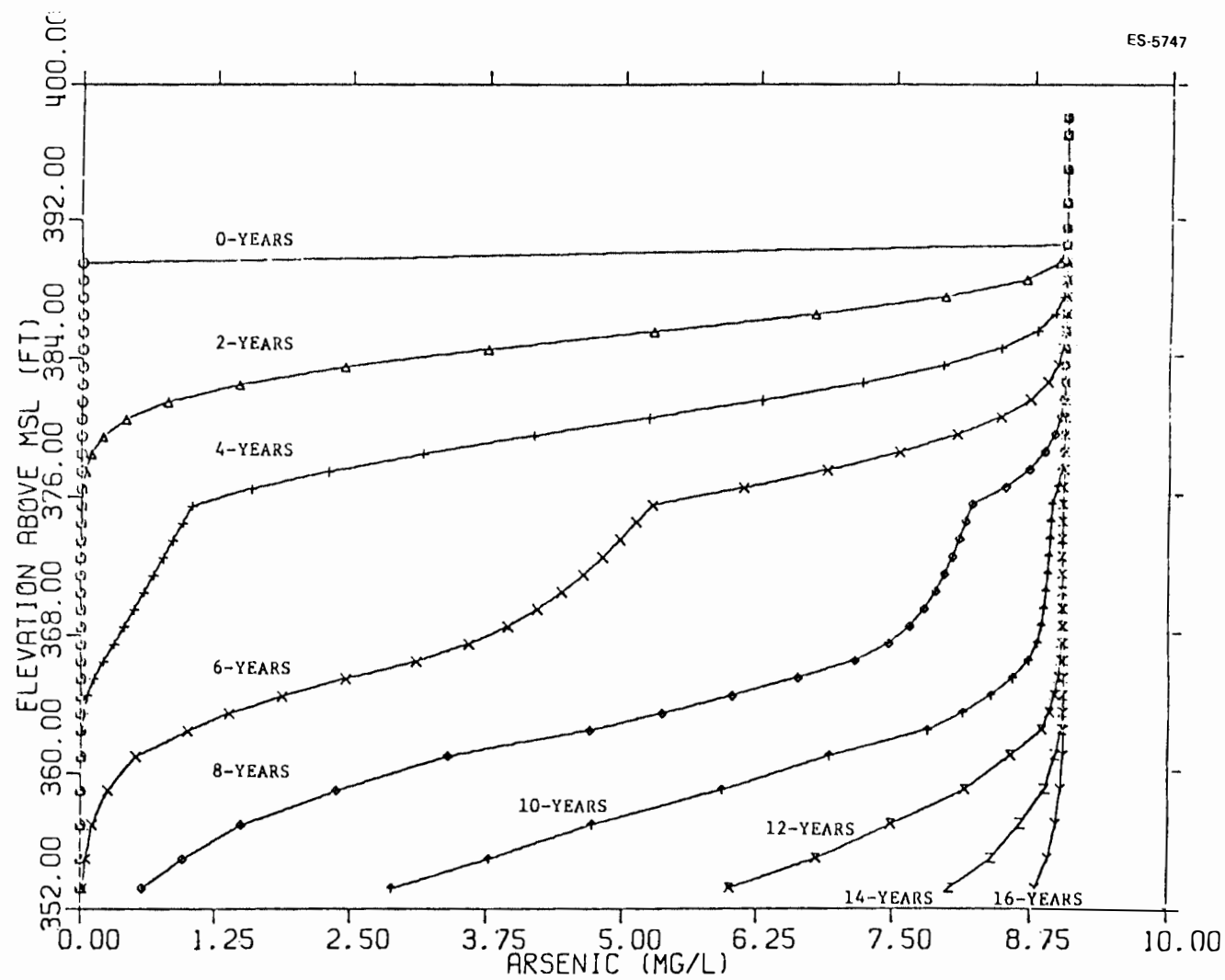


Fig. R.1. Concentrations of arsenic (unlined landfill) $K = 1 \times 10^{-6}$ cm/sec for silty clay.

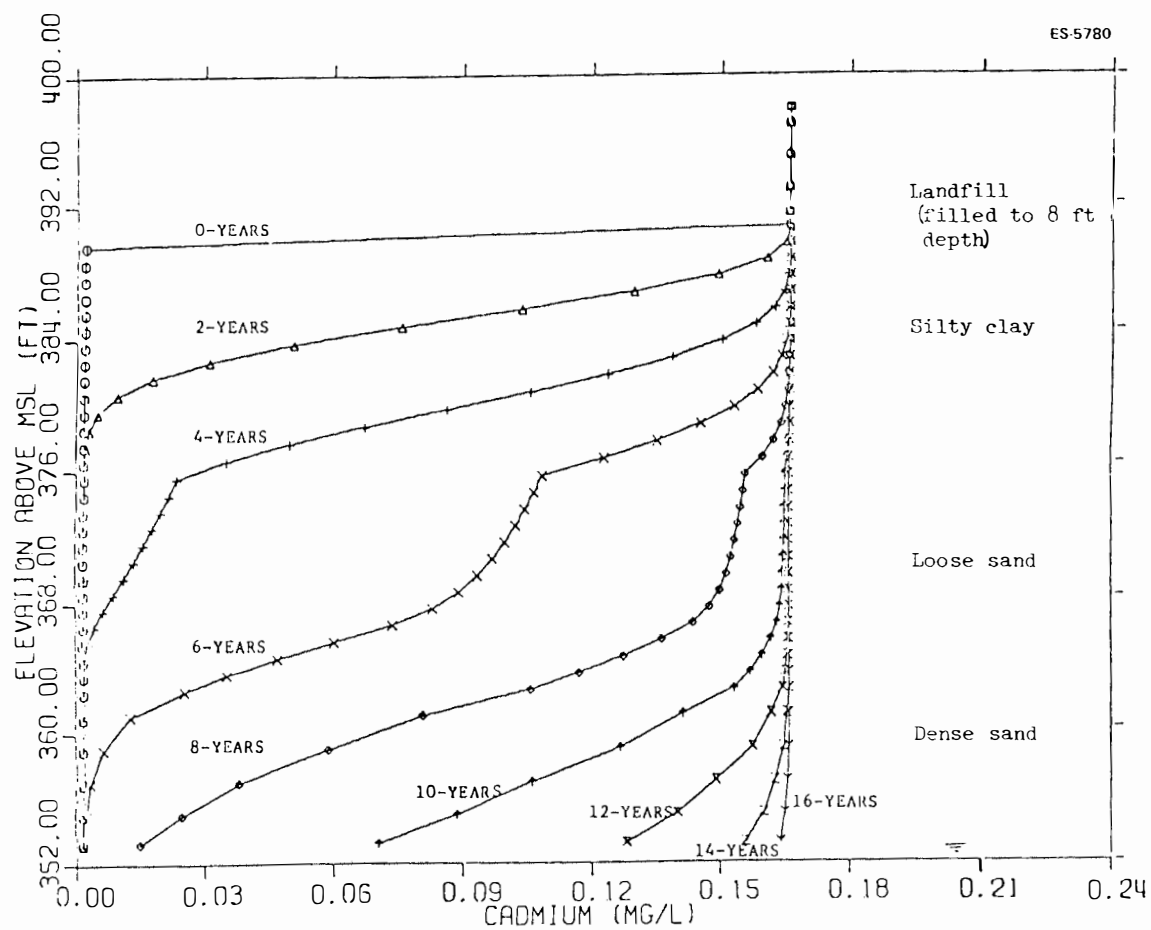
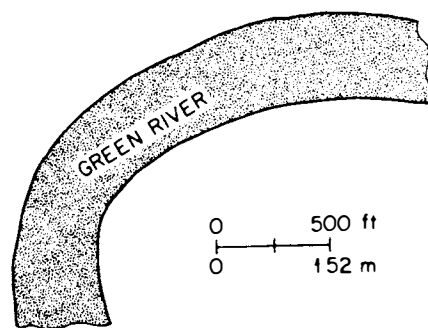
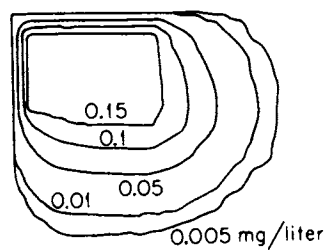


Fig. R.2. Concentrations of cadmium (unlined landfill).

R-10

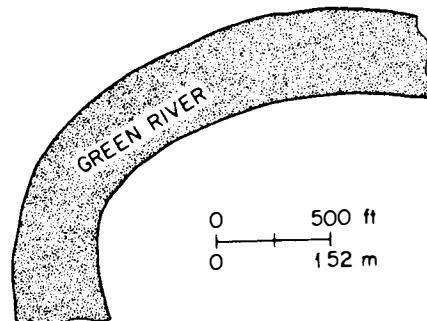
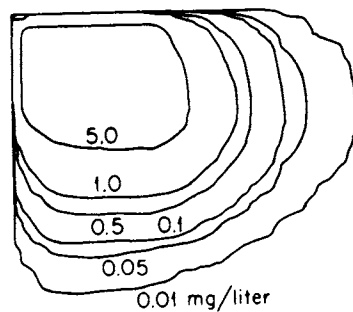
ES-5752



CADMIUM: 50 years

Fig. R.3. Concentrations of cadmium in an unlined landfill (50 years).

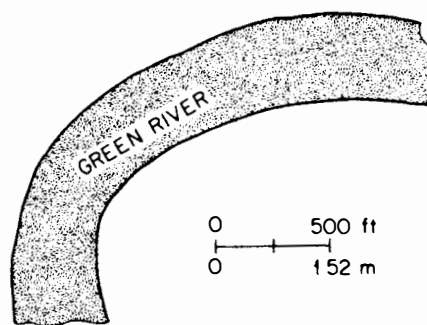
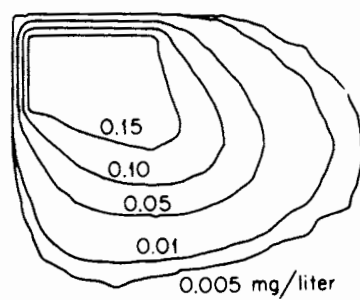
ES-5758



ARSENIC: 50 years

Fig. R.4. Concentrations of arsenic in an unlined landfill (50 years).

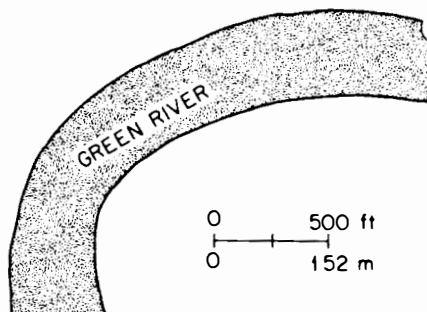
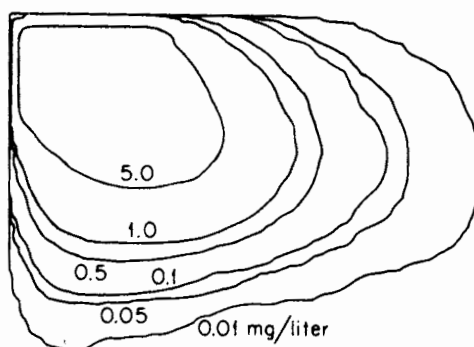
ES-5753



CADMIUM: 100 years

Fig. R.5. Concentrations of cadmium in an unlined landfill (100 years).

ES-5754



ARSENIC: 100 years

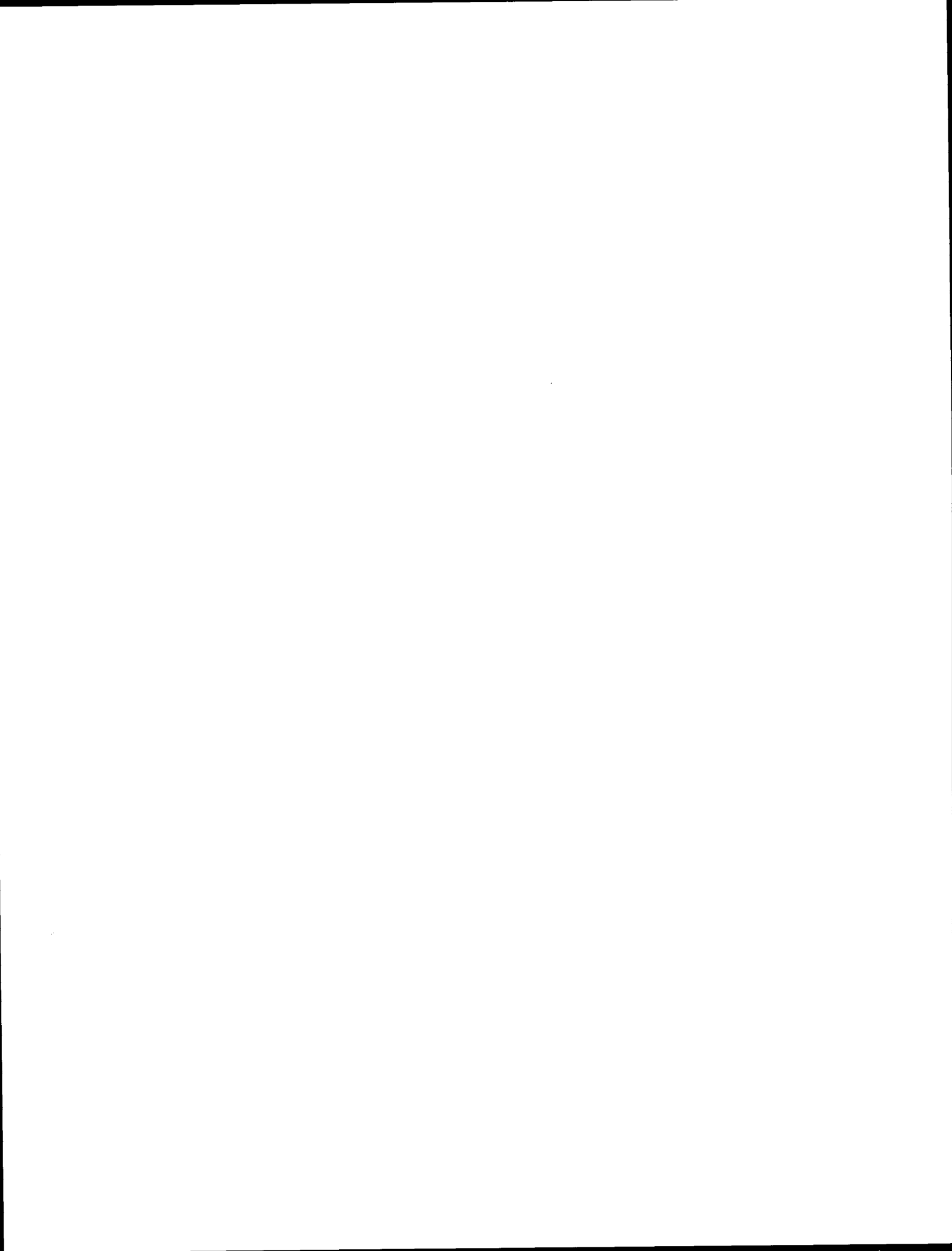
Fig. R.6. Concentrations of arsenic in an unlined landfill (100 years).

2. The landfill is assumed to have no lining system and to be in continuous active service throughout the period of prediction. (Active life of the landfill will be considerably less than 50 to 100 years.)
3. The depth of plume penetration is assumed to be a minimum value [4.9 m (16 ft) below the water table]. The minimum is 4.9 m (16 ft), and the maximum is 9.8 m (32 ft).

REFERENCE FOR APPENDIX R

1. F. R. Cox, *Soil Survey of Daviess and Hancock Counties, Kentucky*, U.S. Dept. of Agriculture, Soil Conservation Service, Washington, D.C., 1974.
2. Bower.
3. Van Genuchten, 1977.
4. Shirazi and Davis, 1974.
5. ATEC Associates, p. 5.

Appendix S
AIR QUALITY



Appendix S

AIR QUALITY

The results given in Table 4.16 were derived from air quality modeling of the SRC-I demonstration plant using the Industrial Source Complex (ISC) model. The ISC model is the U.S. Environmental Protection Agency's (EPA) updating of their CRSTER (single source) model. The ISC model has the capability of calculating pollutant concentrations on a grid from many different sources at different locations. It also handles both area sources and point sources and lends itself well to a project such as SRC-I with (1) large area sources in its coal piles and (2) many point sources.

The ISC model actually consists of two computer programs: the ISCST (ST = short term) and ISCLT (LT = long term). The ISCST uses sequential hourly meteorological data of the format used by its EPA predecessor program CRSTER, and the ISCLT uses a STAR meteorological data input — a wind frequency distribution program classified according to six air stability categories.

This ISC model is expected to be placed on EPA's "Guideline on Air Quality" list of recommended models when the Guideline is updated in early 1981.

S.1 SELECTION OF BASELINE MONITORING SITE BY MODELING

Air quality and meteorological monitoring has been conducted on a site selected for the construction of a proposed solvent refined coal (SRC-I) processing facility. The objective of this monitoring has been to document the baseline conditions prior to construction of the facility to be able to assess the air quality impact of its construction and operation.

Monitoring was initially conducted on site for one year from October 12, 1977, to October 20, 1978. A report of the findings of that initial year of monitoring is in Ref. 1. Following a redefinition of the SRC-I project, an expanded monitoring program was begun on the same site on April 30, 1979, and continued to April 30, 1980.

The proposed SRC-I facility site is located on the Green River in Daviess County near Newman, Kentucky, 19 km (12 miles) west of Owensboro, Kentucky. This is a rural, agricultural area. The nearest major point sources are power generating facilities on the Ohio River, 11 km (7 miles) north-northwest of the site.

Air quality dispersion modeling was used to select the location of the monitoring site. The parameters to be monitored were selected in consultation with the U.S. Department of Energy (DOE) and the Kentucky Division of Air Pollution Control.

The basic numerical model used to simulate the air quality in the area near the proposed site and the impact of the proposed facility was EPA's CRSTER. The formulation and assumptions of this model are described in the User's Manual (EPA 1977). A modification was made to the original model to allow multiple sources to be located at different points within the polar grid (MLTCRS). This change allows each facility to be treated independently while the predicted pollutant concentrations at each receptor reflect the influence of all sources. The terrain in the study area was assumed to be uniform.

The polar grid used in the model (MLTCRS) was centered on the proposed SRC plant site. The receptors were located every 10 degrees radially around the site at 1, 3, 6, 10, and 15 km from the site. This configuration produces a denser network of receptors (close to the site), which is of prime interest in this project. It also includes the probable impact area of the proposed site.

The MLTCRS output is identical to the CRSTER output format. The annual average, as well as the highest and second highest 24- and 3-h concentrations are given at each of the 180 receptors. The 24- and 3-h concentrations are not concurrent but are the highest (or second highest) to occur at each of the receptors during the meteorological year modeled. Meteorological data from the Rockport generating station, under construction, were utilized as input to MLTCRS.

S.2 RESULTS

S.2.1 Sulfur dioxide modeling before monitoring

The modeled concentrations of SO₂ showed a uniform distribution in the area of the proposed SRC plant site with maximums nearer the existing major sources near Newburgh, Indiana, and in Owensboro, Kentucky.

The results of the modeling analysis are summarized in Table S.1 for comparison with the results of the onsite monitoring conducted from October 1977 to October 1978 and the Kentucky Ambient Quality Standards.

Table S.1. Summary of modeled and measured maximum SO₂ concentrations
Concentrations given in $\mu\text{g}/\text{m}^3$

	Location: 230° 5 km			Location: 50° 10 km		Location: 340° 10 km	
	Annual	Highest 24-h	Second-highest 24-h	Highest 3-h		Second-highest 3-h	
Modeled for 1975 using MLTCRS ^a	25	243	157	760		591	
Measured on site 1977-1978	19	173	138	586		568	
Kentucky primary SO ₂ standard	80		365 ^b				
Kentucky secondary SO ₂ standard	60					1300 ^b	

^a MLTCRS — a version developed by Dames and Moore of the EPA-approved CRSTER dispersion model.

^b Not to be exceeded more than once per year.

Source: ER, Appendix I.

Table S.1 indicates that the annual highest 24-h and second highest 24-h concentrations occur at 230 degrees and 15 km from the proposed plant site. The meteorological conditions contributing to the 24-h maximums include winds from the south and south-southwest, suggesting the sources of these maximums are the manufacturing and power generation plants located 25 to 26 km southwest of the proposed plant.

S.2.2 Particulate matter modeling before monitoring

As with SO₂, the modeled total suspended particulates (TSP) concentrations around the proposed plant site showed a relatively uniform distribution. The concentrations predicted from the model are not very high because it included only the contributions of the point sources listed in Sect. 4.2.3. Most of the TSP measured in the atmosphere comes from fugitive sources.

The results of the TSP modeling analysis and onsite measurements are summarized in Table S.2, while Figs. 4.4 and 4.5 depict the distribution of annual average and second highest TSP concentrations as calculated by MLTCRS.

Table S.2. Summary of modeled and measured maximum total suspended particulate (TSP) concentrations

Concentrations given in $\mu\text{g}/\text{m}^3$; measured at location of 330° 15 km

	Annual	Highest 24-h	Second highest 24-h
Modeled for 1975 by MLTCRS ^a	2.2	23	20
Measured on site 1977-1978	48	189	146
Kentucky primary TSP standard	75		260 ^b
Kentucky secondary TSP standard	60		150

^aMLTCRS — a version developed by Dames and Moore of the EPA-approved CRSTER dispersion model.

^bNot to be exceeded more than once per year.

Source: ER, Appendix I.

Concentrations of nitrogen dioxide were predicted in a similar fashion, utilizing the MLTCRS model. No atmospheric reactions were assumed, so the results listed in Table 4.13 represent conservative estimates of pollutant concentrations.

S.3 ATMOSPHERIC EFFECTS OF COOLING TOWER OPERATION

The primary heat rejection system for the proposed SRC-I processing facility at the Newman, Kentucky, site will be a wet-type mechanical-draft cooling tower. In the cooling tower, most of the heat is transferred to the atmosphere by evaporation, with the remaining cooling accomplished by sensible heat transfer. Potential atmospheric effects of cooling tower generation include visible plume, ground fogging and icing, and drift deposition (drift deposition is discussed in Sect. S.4). These effects and their relative severity on the local environment depend on the type and size of the cooling tower and the prevailing meteorological conditions.

The purpose of the following study is to assess the range and magnitude of these potential atmospheric effects associated with the operation of a mechanical-draft cooling tower at the proposed Newman site. Appropriate mathematical models were utilized to estimate the frequency of occurrence of visible plume length, ground-level fogging and icing, and increases in ground-level relative humidity and temperature, as well as rates of drift deposition.

S.3.1 Description of cooling tower

The cooling tower for the Newman site is assumed to be a rectangular, wet-type mechanical-draft tower. It will be 55 m (180 ft) long, 21.6 m (71 ft) wide, and 16.5 m (54 ft) tall, and will consist of five cells, each with a diameter of 7.46 m (24.5 ft). Additional data and cooling tower operating parameters are presented in Table S.3.

S.3.2 Meteorological data

Specific meteorological data for the cooling tower analysis were obtained from hourly surface weather observations at the National Weather Service (NWS), Evansville, Indiana, station. The hourly wind speed, wind direction, atmospheric stability, dry-bulb and dew-point temperatures, and other surface data for the entire one-year period of 1975 were used to assess cooling tower plume characteristics. The annual meteorological joint frequency distribution of wind speed, wind direction, atmospheric stability, and relative humidity was used to estimate drift deposition rates.

Table S.3. Cooling tower characteristics used for dispersion modeling

Characteristics	Measurement	
Tower height, m (ft)	16.5	(54)
Tower dimensions, m (ft)	55 X 22	(180 X 71)
Tower base elevation, m (ft)	118	(390)
Number of cells		5
Cell diameter, m (ft)	7.5	(24.5)
Exit velocity, m/s (ft/s)	10	(32.7)
Total heat dissipation rate, J, MMBtu/h	7.20E11	(682.3)
Total water circulation rate, m ³ /s, gal/min	4.3	(68,233)
Blowdown rate, m ³ /s, gal/min	.022	(350)
Total water drift rate, percentage		0.05

S.3.3 Model description

A cooling tower plume model developed by Dames & Moore was used to estimate the frequency of occurrence of the following phenomena as a function of direction and distance from the tower: (1) visible plume length, (2) ground-level fogging, (3) ground-level icing, (4) increase in ground-level relative humidity, and (5) increase in ground-level ambient temperature. The model is based on the steady-state Gaussian plume dispersion equation. A brief description of the model is presented below.

A power law is used to adjust wind speed to tower height:

$$U_h = U_0 \left(\frac{h}{h_0} \right)^s$$

where

U_h = wind speed (m/s) at height h of cooling tower exit

U_0 = wind speed (m/s) at height h_0 of wind sensor

h = height of cooling tower exit (m)

h_0 = height of wind sensor (m)

s = 0.25 for unstable and neutral conditions, or 0.50 for stable conditions (stability classes E & F).

The buoyant rise of the plume above tower height is computed by Briggs¹ as:

$$h = 1.6 F^{1/3} U^{-1} X^{2/3}$$

where

h = plume rise (m)

F = buoyancy flux parameter (m⁴/s³)

U = wind speed at tower height (m/s)

X = downwind distance (m)

The buoyancy flux parameter F is given by Briggs¹ as:

$$F \approx 3.7 \times 10^{-5} \times \frac{\text{m}^4/\text{s}^3}{\text{cal/s}} \times Q_H$$

where

Q_H = heat emission rate (cal/s) and 3.7×10^{-5} is an approximation to $g/\pi c_p \rho \gamma$ for air.

To calculate adjustments to horizontal and vertical dispersion coefficients, an effective initial plume size (m^2) is first computed:

$$\begin{aligned} d_e &= 2\sqrt{(\pi d^2/4) (n/\pi)} \\ &= d\sqrt{n} \end{aligned}$$

where

d_e = effective diameter

d = cell diameter

n = number of cells per bank

The initial dispersion coefficients σ_{y_0} and σ_{z_0} are then calculated:

$$\sigma_{z_0} = d_e/4.3$$

$$\sigma_{y_0} = d(n - 2) + 2d/4.3$$

These initial values of the dispersion coefficients are added to those corresponding to values previously derived.²

The Gaussian dispersion equation is used to compute the water vapor concentration at the plume centerline:

$$x_i = [Q/(2\pi\sigma_y\sigma_z u)] \{1 + \exp[-2(H/\sigma_z)^2]\}$$

$$x_G = [Q/(2\pi\sigma_y\sigma_z u)] \exp[-1/2(H/\sigma_z)^2]$$

where

x = water vapor concentration (specific humidity) (g/m^3)

Q = water vapor emission rate (g/s)

u = mean wind speed through vertical extent of plume (m/s) (approximated by wind speed at tower height)

σ_y, σ_z = horizontal and vertical dispersion coefficients at distance x (adjusted to account for the effective initial plume size)

H = effective source height (m) (sum of tower height and plume rise)

It is assumed that the exit temperature and relative humidity of the plume linearly approach ambient temperature and moisture density; the visible plume is therefore predicted to terminate at the distance at which the plume (centerline) and ambient moisture densities agree within 0.001 g/m^3 . Ground-level moisture densities are used to predict ground-level fogging, icing, and relative humidity increases.

After water vapor concentrations downwind of the tower have been computed, they are used to calculate downwind temperatures. A linear relationship between the two parameters is assumed:

$$T_G = (X_G - B)/A$$

where

$$A = (X_E - X_A)/(T_E - T_A)$$

$$B = X_A - AT_A$$

and the variables are defined as follows:

T = temperature ($^{\circ}\text{C}$)

X = water vapor concentration (specific humidity) (g/m^3),

with subscripts defined as follows:

A = ambient

G = ground level

E = plume exit

Ground-level temperatures are used to predict ground-level temperature increases.

S.3.4 Results of modeling analysis

The number and relative frequency of occurrence of visible plume length, ground-level fogging, icing, 1% relative humidity increases, and half-degree (Celsius) temperature increases were estimated for 16 wind-direction sectors for 20 downwind distances from the proposed cooling tower at 500-ft intervals. The results of the modeling analysis using this model indicate that:

1. The visible plume will extend farther than 1000 m (3500 ft) from the tower less than 50% of the time and farther than 3000 m (10,000 ft) 22% of the time. The plume will be visible at greater distances from October through March and at shorter distances from April through September, to the west during the first half of the year and to the north and northeast during the second half.
2. Ground-level fogging will occur 13% of the time, rarely (11 times during the year) farther than 3000 m (10,000 ft) from the tower and usually to the east through south and to the west of the tower. The highest frequencies of occurrence are predicted for January through March (30%) and for October through December (21%).
3. Ground-level icing will occur 6% of the time rarely (once during the year) farther than 3000 m (10,000 ft) from the tower and usually to the east and south of the tower. Of the 466 hourly incidences of icing, 292 are predicted to occur from January through March; one is predicted to occur from April through June; 208 are predicted to occur from October through December.
4. Relative humidity increases of 1% will occur beyond 500 m (1500 ft) less than 50% of the time. These increases will be primarily to the north of the tower.

5. Temperature increases of 0.5°C will occur less than 50% of the time, be within 500 m (1500 ft), and occur most frequently to the north and west of the tower.

S.4 COOLING TOWER DRIFT DEPOSITION

In addition to the visible plume emitted from the cooling tower, a small fraction of mechanically entrained water droplets from within the tower will be discharged directly into the air. These drift droplets contain essentially the same chemicals, dissolved salts, or minerals as the water circulating in the tower.

S.4.1 Model description

A cooling tower drift deposition model adapted by Dames & Moore from the Pennsylvania State Report on Salt Deposition (1972) was used to estimate drift deposition rates as a function of direction and distance from the tower. This model is based upon the assumption that a cooling tower plume has a Gaussian distribution and that, after the plume is exhausted from the cooling tower and elevated through thermal buoyancy, drift deposition causes it to tilt back toward the ground. In the model, the dry plume rise formula by Briggs is used to calculate the buoyant plume rise.

As drift droplets, which consist of dissolved particles, are transported by the wind, the liquid evaporates and the particles fall to the ground. Thus, a trajectory-type model is used to predict drift deposition. The length of time droplets spend in the air, traveling with the wind, depends upon their fall velocities, which decrease as the drops evaporate.

In order to determine the length of time a drop is airborne, and, therefore, the distance it travels, the model takes into consideration the initial concentration and size of the droplet, how quickly it reaches equilibrium size, and the extent of evaporation. The initial concentration is assumed to be identical to the concentration within the cooling tower, and an initial size distribution typical of the mechanical-draft cooling tower is assumed. The time required for a droplet to reach equilibrium size is computed as a function of the distance the droplet must fall in order to reach equilibrium size.

The extent of evaporation depends upon relative humidity. When the ambient relative humidity is 50% or less, it is assumed that all water is evaporated from the droplet, leaving only the previously dissolved particle as dry deposition. For ambient relative humidities exceeding 50%, wet deposition is assumed.

S.4.2 Results of modeling analysis

S.4.2.1 Dissolved particles

Drift deposition rates for dissolved particles from the cooling tower were estimated for 16 wind-direction sectors at 16 downward distances [0.5 to 30.0 km (0.3 to 18.6 miles)] from the proposed cooling tower. Table S.4 gives the size distribution of droplets used in the modeling analysis. An initial concentration of 1200 parts of dissolved particles per million parts of water was assumed. The predicted deposition rates for dissolved particles are presented in Table S.5. Approximately 640,000 gal of liquid droplets per month can be expected to drift to the ground within a 30-km (18.6-mile) radius of the proposed tower. These droplets consist of water and very dilute solutions of dissolved particles. Sixty-two percent of the liquid is expected to reach the ground within 0.5 km (0.3 miles) of the tower, where the average rate of deposition is predicted to be 10,650 gal/km² per month, or 0.024 in. of liquid per year. Rates of deposition would be highest to the north-northwest and lowest to the west-northwest of the cooling tower.

The drift deposition of dissolved particles primarily increases the amount of moisture at the surface, and, in cold weather, contributes to icing near the cooling tower. The cooling tower may be expected to slightly increase occurrences of icing in the immediate vicinity.

Table S.4. Size distribution of droplets from cooling tower, as used in drift deposition modeling analysis

Representative particle size (μm)	Mass function (% by weight)
25	0.426
50	0.254
75	0.107
100	0.058
125	0.039
150	0.024
175	0.014
200	0.0095
225	0.0071
250	0.006
275	0.004
300	0.004
325	0.004
350	0.004
375	0.0040000
400	0.0046000

S.4.2.2 Dry particles

The predicted deposition rates for dry particles are presented in Table S.6. Approximately 31 t of dry particles per year can be expected to drift to the ground within a 30-km (18.6-mile) radius of the proposed tower. Approximately 72.6% of this drift deposition is expected to occur within 0.5 km (0.3 miles) of the tower, where the average monthly rate of deposition is predicted to be 0.15 g/sq mile. Rates would be highest to the north-northwest of the tower and lowest to the west-northwest.

The major impact of the drift deposition of dry particles is to increase the corrosion rate of nearby structures. Deposition of solid particles would have a slight impact in the immediate vicinity of the cooling tower.

S.5 PARTICULATE MODELING

S.5.1 Consumption of PSD increments

The DEIS states that an estimated 73% of the PSD 24-h increment for particulates will be consumed by the demonstration plant. However, updated Industrial Source Complex (ISC) dispersion modeling analyses have reduced that figure to 21.8%. Earlier calculations predicted a maximum 24-h ground-level concentration of 26.9 $\mu\text{g}/\text{m}^3$; the new estimate is 6.74 $\mu\text{g}/\text{m}^3$ for the demonstration plant alone and 8.1 $\mu\text{g}/\text{m}^3$ for all PSD sources in the area. The new estimated average annual concentration for all PSD sources in the area is 1.26 $\mu\text{g}/\text{m}^3$.

Based on overly conservative emissions and modeling assumptions it was calculated that 20 of the 26.9 $\mu\text{g}/\text{m}^3$ maximum 24-h concentration was due to fugitive emissions alone. The new results have reduced this contribution to 2.41 of the 6.74 $\mu\text{g}/\text{m}^3$ total concentration.

The reduction in fugitive particulate air quality impact was achieved by considering three key factors — the effect of wind speed on SRC- and coal-pile wind erosion losses, the impact of scheduling SRC- and coal-loading and unloading operations for only 8 out of 24 h, and the effects of using prewashed coal. Each factor is discussed in more detail below.

Table S.5. Disposition rates for dissolved particles, gal/km²/month

Affected sector	Distances (km)															
	0.50	1.00	1.50	2.00	3.00	4.00	5.00	6.00	8.00	10.00	12.50	15.00	17.50	20.00	25.00	30.00
S	0.63E+04	0.30E+03	0.29E+03	0.29E+03	0.25E+03	0.21E+03	0.17E+03	0.16E+03	0.15E+03	0.15E+03	0.13E+03	0.94E+02	0.66E+02	0.48E+02	0.31E+02	0.23E+02
SSW	0.77E+04	0.39E+03	0.39E+03	0.40E+03	0.37E+03	0.33E+03	0.29E+03	0.27E+03	0.28E+03	0.30E+03	0.26E+03	0.19E+03	0.13E+03	0.91E+02	0.57E+02	0.41E+02
SW	0.11E+05	0.43E+03	0.43E+03	0.46E+03	0.47E+03	0.45E+03	0.43E+03	0.50E+03	0.83E+03	0.11E+04	0.10E+04	0.67E+03	0.40E+03	0.25E+03	0.14E+03	0.96E+02
WSW	0.15E+05	0.64E+03	0.65E+03	0.68E+03	0.68E+03	0.63E+03	0.58E+03	0.62E+03	0.95E+03	0.12E+04	0.11E+04	0.74E+03	0.44E+03	0.27E+03	0.15E+03	0.11E+03
W	0.72E+04	0.39E+03	0.39E+03	0.39E+03	0.36E+03	0.32E+03	0.29E+03	0.30E+03	0.42E+03	0.53E+03	0.47E+03	0.31E+03	0.18E+03	0.12E+03	0.64E+02	0.45E+02
WNW	0.44E+04	0.29E+03	0.29E+03	0.29E+03	0.26E+03	0.22E+03	0.19E+03	0.18E+03	0.18E+03	0.20E+03	0.17E+03	0.13E+03	0.92E+02	0.69E+02	0.46E+02	0.34E+02
NW	0.70E+04	0.39E+03	0.34E+03	0.34E+03	0.31E+03	0.28E+03	0.24E+03	0.23E+03	0.24E+03	0.26E+03	0.23E+03	0.18E+03	0.13E+03	0.10E+03	0.71E+02	0.52E+02
NNW	0.17E+05	0.13E+04	0.11E+04	0.11E+04	0.87E+03	0.73E+03	0.63E+03	0.62E+03	0.83E+03	0.10E+04	0.92E+03	0.61E+03	0.37E+03	0.24E+03	0.14E+03	0.10E+03
N	0.12E+05	0.11E+04	0.90E+03	0.84E+03	0.66E+03	0.53E+03	0.43E+03	0.39E+03	0.38E+03	0.39E+03	0.33E+03	0.24E+03	0.17E+03	0.12E+03	0.79E+02	0.58E+03
NNE	0.14E+05	0.12E+04	0.97E+03	0.86E+03	0.69E+03	0.57E+03	0.48E+03	0.44E+03	0.49E+03	0.55E+03	0.48E+03	0.34E+03	0.22E+03	0.15E+03	0.97E+02	0.70E+02
NE	0.99E+04	0.96E+03	0.74E+03	0.65E+03	0.51E+03	0.42E+03	0.35E+03	0.34E+03	0.46E+03	0.58E+03	0.52E+03	0.34E+03	0.20E+03	0.12E+03	0.69E+02	0.50E+02
ENE	0.89E+04	0.61E+03	0.57E+03	0.55E+03	0.49E+03	0.42E+03	0.37E+03	0.39E+03	0.56E+03	0.71E+03	0.63E+03	0.42E+03	0.25E+03	0.15E+03	0.84E+02	0.58E+02
E	0.11E+05	0.65E+03	0.62E+03	0.62E+03	0.54E+03	0.45E+03	0.40E+03	0.45E+03	0.79E+03	0.11E+04	0.99E+03	0.63E+03	0.34E+03	0.19E+03	0.94E+02	0.64E+02
ESE	0.11E+05	0.68E+03	0.65E+03	0.63E+03	0.54E+03	0.43E+03	0.43E+03	0.63E+03	0.16E+04	0.24E+04	0.23E+04	0.14E+04	0.70E+03	0.34E+03	0.14E+03	0.87E+02
SE	0.11E+05	0.59E+03	0.56E+03	0.56E+03	0.48E+03	0.39E+03	0.34E+03	0.36E+03	0.60E+03	0.80E+03	0.73E+03	0.47E+03	0.27E+03	0.16E+03	0.82E+02	0.56E+02
SSE	0.17E+05	0.10E+04	0.87E+03	0.83E+03	0.68E+03	0.54E+03	0.46E+03	0.44E+03	0.56E+03	0.69E+03	0.61E+03	0.40E+03	0.24E+03	0.15E+03	0.83E+02	0.59E+02

Table S.6. Disposition rates for dry particles, kg/km²/month

Affected sector	Distances (km)															
	0.50	1.00	1.50	2.00	3.00	4.00	5.00	6.00	8.00	10.00	12.50	15.00	17.50	20.00	25.00	30.00
S	0.73E+02	0.67E+01	0.33E+01	0.23E+01	0.17E+01	0.13E+01	0.92E+00	0.80E+00	0.69E+00	0.65E+00	0.54E+00	0.32E+00	0.23E+00	0.17E+00	0.11E+00	0.74E+01
SSW	0.11E+03	0.95E+01	0.53E+01	0.38E+01	0.30E+01	0.24E+01	0.15E+01	0.13E+01	0.12E+01	0.12E+01	0.99E+00	0.59E+00	0.42E+00	0.30E+00	0.18E+00	0.13E+00
SW	0.16E+03	0.13E+02	0.83E+01	0.61E+01	0.54E+01	0.37E+01	0.28E+01	0.27E+01	0.32E+01	0.35E+01	0.29E+01	0.18E+01	0.11E+01	0.71E+00	0.39E+00	0.26E+00
WSW	0.20E+03	0.18E+02	0.11E+02	0.83E+01	0.72E+01	0.49E+01	0.36E+01	0.34E+01	0.38E+01	0.41E+01	0.34E+01	0.20E+01	0.12E+01	0.81E+00	0.45E+00	0.31E+00
W	0.97E+02	0.10E+02	0.67E+01	0.45E+01	0.36E+01	0.27E+01	0.20E+01	0.19E+01	0.19E+01	0.19E+01	0.16E+01	0.91E+00	0.57E+00	0.38E+00	0.21E+00	0.14E+00
WNW	0.65E+02	0.67E+01	0.42E+01	0.28E+01	0.22E+01	0.17E+01	0.12E+01	0.10E+01	0.88E+00	0.84E+00	0.73E+00	0.44E+00	0.32E+00	0.24E+00	0.15E+00	0.11E+00
NW	0.94E+02	0.83E+01	0.46E+01	0.32E+01	0.25E+01	0.20E+01	0.13E+01	0.11E+01	0.10E+01	0.10E+01	0.87E+00	0.57E+00	0.43E+00	0.33E+00	0.21E+00	0.15E+00
NNW	0.25E+03	0.24E+02	0.13E+02	0.96E+01	0.75E+01	0.53E+01	0.38E+01	0.34E+01	0.36E+01	0.37E+01	0.29E+01	0.18E+01	0.11E+01	0.75E+00	0.43E+00	0.31E+00
N	0.18E+03	0.19E+02	0.94E+01	0.72E+01	0.51E+01	0.39E+01	0.27E+01	0.22E+01	0.19E+01	0.18E+01	0.14E+01	0.84E+00	0.57E+00	0.43E+00	0.26E+00	0.19E+00
NNE	0.20E+03	0.20E+02	0.11E+02	0.79E+01	0.58E+01	0.44E+01	0.30E+01	0.26E+01	0.23E+01	0.22E+01	0.18E+01	0.11E+01	0.72E+00	0.52E+00	0.31E+00	0.22E+00
NE	0.14E+03	0.16E+02	0.87E+01	0.61E+01	0.45E+01	0.31E+01	0.22E+01	0.20E+01	0.20E+01	0.20E+01	0.16E+01	0.97E+00	0.59E+00	0.39E+00	0.21E+00	0.15E+00
ENE	0.15E+03	0.16E+02	0.96E+01	0.72E+01	0.53E+01	0.37E+01	0.28E+01	0.25E+01	0.26E+01	0.27E+01	0.21E+01	0.12E+01	0.77E+00	0.51E+00	0.28E+00	0.19E+00
E	0.15E+03	0.15E+02	0.88E+01	0.70E+01	0.58E+01	0.35E+01	0.28E+01	0.27E+01	0.32E+01	0.35E+01	0.28E+01	0.16E+01	0.93E+00	0.55E+00	0.28E+00	0.19E+00
ESE	0.16E+03	0.19E+02	0.12E+02	0.98E+01	0.85E+01	0.42E+01	0.38E+01	0.42E+01	0.63E+01	0.74E+01	0.59E+01	0.34E+01	0.17E+01	0.90E+00	0.39E+00	0.25E+00
SE	0.13E+03	0.12E+02	0.63E+01	0.49E+01	0.41E+01	0.26E+01	0.20E+01	0.20E+01	0.24E+01	0.26E+01	0.20E+01	0.12E+01	0.72E+00	0.45E+00	0.24E+00	0.15E+00
SSE	0.19E+03	0.19E+02	0.94E+01	0.66E+01	0.51E+01	0.35E+01	0.26E+01	0.23E+01	0.23E+01	0.24E+01	0.20E+01	0.12E+01	0.70E+00	0.47E+00	0.26E+00	0.18E+00

The modeling results indicate that the commercial plant can be constructed within the 24-h and the annual increment restrictions based on a fourfold increase in point-source contributions and a conservatively estimated fivefold increase in fugitive emissions. Extensive ambient air quality modeling will be conducted during the demonstration phase to assess these ISC modeling predictions.

S.5.2 Basis for revised calculations

Unlike point-source emissions that are discharged from vents and stacks, fugitive particulates evolve from a wide variety of sources and are typically caused by wind erosion. Fugitive emissions in the demonstration plant include dusting from coal and solid SRC storage piles and particulates generated when coal is dumped from trucks or railcar hoppers. Estimation and impact analyses of these sources are required for the PSD permit, but to date EPA has provided no definitive guidelines for either their estimation or control. Most emission information that does exist is either based on small-scale testing of coal-dust sources under a distinct set of conditions or is obtained without any testing. Critical variables such as wind speed, silt content, and pile orientation with respect to wind direction are not considered in existing emission factors.

The new values derived are based on the same sources simulated with the EPA ISC model in the DEIS, but three additional effects were also considered.

- Pile wind losses, which were originally simulated for any prevailing wind-speed conditions, were not realistic because wind losses are not expected at wind velocities under 6 miles/h. The new modeling estimates assumed no pile losses at the lowest of six wind-speed classes (0.75 and 2.5 m/s).³
- The emissions expected from truck and railcar unloading have been recalculated by computing the amount for an 8-h intermittent unloading period rather than by averaging the emissions over 24 h.
- Finally, a 97% control efficiency was assumed due to the use of washed rather than run-of-mine coal in the new calculations. Pile wind-erosion emission factors are based on coal containing 6% silt, silt being the portion of coal particulates that may become airborne (<75 μ m). Washing coal has been predicted to reduce the silt concentration from 6 to 0.18%.

Washed coal is essentially stripped of coal fines, which create particulate emissions. Based on limited laboratory tests performed on washed coal samples of the eastern type, the following characteristics have been established:

Washed coal	Particle size		
	250-150 μ	150-45 μ	<45 μ
Dry-sieve analysis	2.95%	2.25%	0.75%
Wet-sieve analysis	0.058%	0.008%	Not measurable

Silt content (<74 μ) has been graphically determined to be 0.18% using the above data. The moisture content of the samples was 3.7%. Parameters used by one reference (ref. 4) to calculate emission factors from ROM coal operations are a 6% silt content and a 7% moisture content.

The recalculations reduced increment consumption to 21.8%, which is a more realistic estimate for a plant processing only 6000 tons of coal per day.

S.6 HYDROCARBON MODELING

S.6.1 Model selection

The short-term version (ISCST) of the U.S. EPA's Industrial Source Complex Model (ISC)⁵ was selected as the principal analytical tool for the assessment of the air quality impact of the

SRC-I plant's volatile organic compound (VOC) emissions. The use of ISC is approved in the latest revisions of the U.S. EPA's *Guideline on Air Quality Models*.⁶ The ISC model is appropriate for these analyses due to its ability to simulate volume sources of fugitive VOC emissions in addition to the numerous point sources of VOC in the proposed SRC-I plant design.

S.6.2 Modeling methodology

A full-year ISCST model simulation was conducted to assess the impact of heavy distillate VOC and total VOC emissions from the proposed plant using the meteorological data and VOC emissions data described in Sect. S.6.3. For purposes of modeling, all of the emissions of both heavy distillate VOC and total VOC were assumed to be gaseous and, thus, transported in the atmosphere. Fugitive emissions of both heavy distillate and total VOC originate from four plant process areas. Fugitive VOC sources are primarily leaks in valves and connections in the systems of pipes found in these four process areas. Because of the variability in the release height of the fugitive VOC emissions, it is appropriate to model fugitive VOC as emanating from volume sources rather than from area sources. Because of the high surface roughness created by SRC-I plant structures and the elevated emission temperatures and heat flux created by nearby piping systems conveying hot materials and/or other heat sources, the fugitive heavy distillate VOC and total VOC sources were modeled using the ISC Urban Mode 1 dispersion option rather than the Rural Mode. The 29 point sources of total VOC were also modeled, using ISC Urban Mode 1. The effect of Urban Mode 1 is that all occurrences of stable atmospheric dispersion conditions computed by the RAMMET program (see Sect. S.6.3) are shifted to neutral atmospheric dispersion conditions.⁵

Three classes of receptor locations were used in the heavy distillate VOC air quality impact analysis:

1. Receptors within the plant property;
2. Receptors along the plant fence line; and
3. Receptors beyond the fence line.

The Universal Transverse Mercator (UTM) coordinates of receptors used in the heavy distillate VOC modeling analyses are listed in Table S.7. Twenty-three receptors, labeled PLANT01 through PLANT23, are located at intervals of approximately 0.5 km throughout the plant property. Another receptor, labeled AIRSEP, is located at the UTM coordinates of the proposed plant's air separator. Receptors FENCE02 through FENCE36 are located at 20° intervals along the plant fence line. Beyond the property line, heavy distillate VOC air quality impact was predicted at five "sensitive receptor" locations, which are either communities or wildlife areas in the region around the plant. In addition, receptors outside the plant property are located at staggered 20° intervals in concentric circular rings 2.5 and 5.0 km from collocated SRC-I plant sources 11-VA-08 through 11-VA-18. The 18 fence-line receptors and the air separator receptor, listed in Table S.7, were also used in the air quality impact analysis for the proposed plant's total VOC emissions from both point and volume sources.

S.6.3 Meteorological data

The meteorological data base used in the modeling analysis consists of a full year of hourly surface weather observations and concurrent twice-daily upper air observations. The period of record is October 19, 1977 to October 18, 1978. Hourly wind direction, wind speed, and temperature at the 10-m level were provided by onsite monitoring data. Ten-meter wind data from a meteorological monitoring system operated by the Aluminum Company of America (Alcoa) at Newburgh, Indiana, approximately 16 km northwest of the SRC-I plant site, were used to fill in missing or invalid onsite data. Hourly ceiling height and opaque cloud-cover data were obtained from the Evansville, Indiana, National Weather Service (NWS) station, located about 30 km northwest of the plant site. Evansville NWS 10-m wind and temperature data were used to fill in the few hours for which valid data were unavailable from either the onsite or Alcoa monitors. Morning and afternoon mixing heights were provided by the Nashville, Tennessee, NWS station, situated some 200 km southeast of the plant site. The EPA's RAMMET meteorological processor program⁷ was used to combine the surface and upper air data, compute hourly atmospheric stability indices, and interpolate hourly mixing heights from twice-daily values.

Table S.7. Receptor locations for VOC modeling

Receptor	UTM Coordinates (m)		Receptor	UTM Coordinates (m)	
	East	North		East	North
Plant 01	472000	4185000	Fence 26	471810	4186020
Plant 02	472000	4186200	Fence 28	471790	4186300
Plant 03	472300	4185900	Fence 30	471970	4186520
Plant 04	472350	4186400	Fence 32	472130	4186720
Plant 05	472400	4185600	Fence 34	472310	4186930
Plant 06	472500	4186600	Fence 36	472590	4187380
Plant 07	472700	4185600	Hebbards	467000	4188000
Plant 08	472700	4186900	Blufcity	466500	4183500
Plant 09	472800	4186300	Stanley	478500	4186000
Plant 10	472800	4187300	Spotsvil	463500	4190000
Plant 11	473000	4186800	Sloughs	471000	4182500
Plant 12	473040	4185683	R 1/15	473233.0	4188574.3
Plant 13	473111	4185611	R 1/45	474353.8	4187927.8
Plant 14	473215	4185505	R 1/75	475000.8	4186807.0
Plant 15	473200	4185600	R 1/105	475000.8	4185513.0
Plant 16	473200	4186000	R 1/135	474353.8	4184392.2
Plant 17	473200	4186500	R 1/165	473233.0	4183745.2
Plant 18	473200	4187100	R 1/195	471939.0	4163745.2
Plant 19	473700	4185200	R 1/225	470818.2	4184392.2
Plant 20	473700	4185700	R 1/255	470171.2	4185513.0
Plant 21	473700	4186800	R 1/285	470171.2	4186807.0
Plant 22	473900	4186200	R 1/315	470318.2	4187927.3
Plant 23	472970	4185755	R 1/345	471939.0	4188574.8
Aireep	472176	4185855	R 2/30	475086.0	4190490.1
Fence 02	473150	4187660	R 2/60	476916.1	4188660.0
Fence 04	473730	4187490	R 2/90	477586.0	4186160.0
Fence 06	474070	4187010	R 2/120	476916.1	4183660.0
Fence 08	474340	4186460	R 2/150	475086.0	4181829.9
Fence 10	474280	4185350	R 2/180	472586.0	4181160.0
Fence 12	474050	4185300	R 2/210	470086.0	4181829.9
Fence 14	473620	4184900	R 2/240	468255.9	4183660.0
Fence 16	472960	4185100	R 2/270	467586.0	4186160.0
Fence 18	472590	4185260	R 2/300	468255.9	4183660.0
Fence 20	472270	4185310	R 2/330	470086.0	4190490.1
Fence 22	472020	4185500	R 2/360	472586.0	4191160.0
Fence 24	471720	4185660			

S.6.4 Results

The highest and second highest predicted heavy distillate VOC and total VOC concentrations for 1-, 3-, and 8-h averaging periods are presented in Table S.8. Heavy distillate VOC concentrations reported in this table are separated into values predicted inside the plant property and values outside the plant property. Concentrations predicted at receptors on the fence line are assumed to belong to both of these categories.

The predicted 1-h concentrations of heavy distillate VOC were analyzed to determine their range of concentrations off plant. Table S.9 summarizes these results at the fence line and 2.5 and 5.0 km from the center of the plant. Both the maximum and minimum concentrations predicted at 5.0 km are approximately 27% of the concentrations predicted at the fence line. At 5 km, the concentrations ranged from 3 to 13 $\mu\text{g}/\text{m}^3$, with the highest concentrations in the east and the southwest directions.

Table S.8. Predicted heavy distillate VOC and total VOC concentrations due to the proposed SRC-I plant

Averaging time (h)	Rank	Heavy distillate concentration		Total VOC concentration ($\mu\text{g}/\text{m}^3$)
		Inside plant boundaries ($\mu\text{g}/\text{m}^3$)	Outside plant boundaries ($\mu\text{g}/\text{m}^3$)	
1	highest	58	50	236
1	2nd highest	58	47	227
3	highest	57	46	218
3	2nd highest	52	44	210
8	highest	46	35	138
8	2nd highest	39	30	129

Table S.9. Highest 1-hour heavy distillate VOC predicted concentrations at and beyond the plant fence line^a

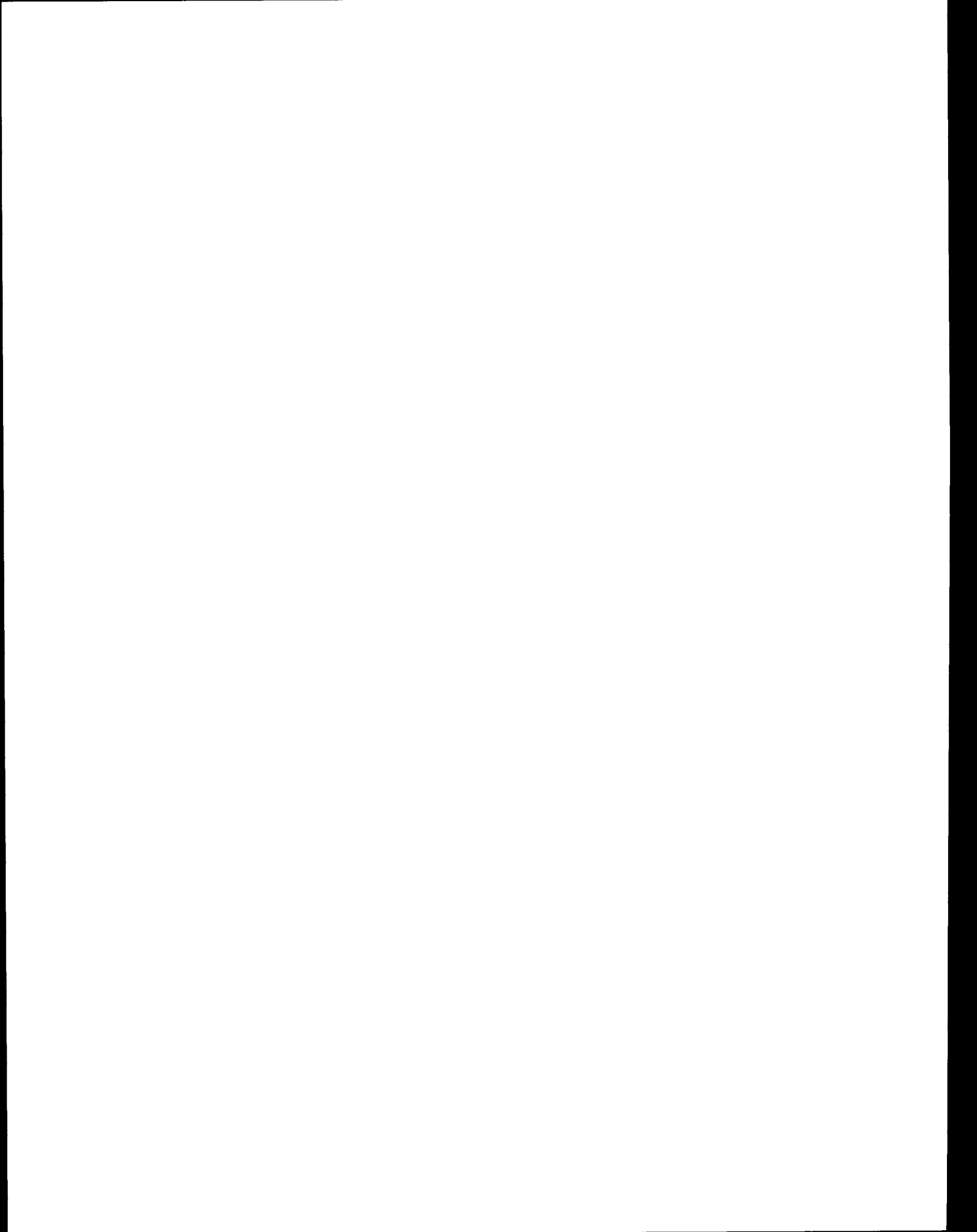
Distance	Maximum		Minimum	
	Concentration ($\mu\text{g}/\text{m}^3$)	Direction ($^{\circ}$)	Concentration ($\mu\text{g}/\text{m}^3$)	Direction ($^{\circ}$)
Fence line	50	300	11	40
2.5 km	26	225	8	45
5.0 km	13	90	3	30

^aDistance and direction data are with respect to collocated sources 11-VA-08 through 11-VA-18.

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Appendix T
SOCIOECONOMICS



T.1 SUPPLEMENTAL SOCIOECONOMIC TABLES

Table T.1. Craft availability through local labor unions

Craft categories	Location of local union	Requirement	Peak man-month	Enrollment in local union ^a	Comments
Boilermakers	Louisville, Ky.	294	April 1983	800	All locals in the surrounding area are interchangeable. Local has the ability to draw workers from Nashville, Tenn., no problems foreseen in meeting anticipated manpower requirements
Brickmasons	Owensboro, Ky.	27	December 1982	265	
Carpenters	Owensboro, Ky.	319	September 1982	700	Sister locals are available; no problems foreseen in meeting anticipated manpower requirements
Cement finishers	Owensboro, Ky.	81	July 1982	72	Adjoining locals in Paducah, Ky., Evansville, Ind., and Louisville, Ky., have workers available
Electricians	Owensboro, Ky.	458	April 1983	400-450	Workers are available from locals in Paducah, Ky., and Nashville, Tenn.; current shortage of locally available workers
Insulators	Evansville, Ind.	416	October 1983	350	Local membership is not large enough to meet peak needs
Ironworkers	Evansville, Ind.	484	December 1982	800	Sister locals are available
Laborers	Owensboro, Ky.	427	September 1982	100	Sister locals are available
Millwrights	Owensboro, Ky.	276	April 1983	250	Access exists to additional workers through surrounding locals
Operating engineers	Henderson, Ky.	256	October 1982	2500-3000	Local can draw workers from all counties in Kentucky except two, and can draw workers from several counties in Indiana; no problems foreseen in meeting anticipated manpower requirements
Painters	Evansville, Ind.	183	June 1983	300	Local can draw workers from seven counties in Kentucky and six counties in Indiana; no problems foreseen in meeting anticipated manpower requirements
Pipefitters	Owensboro, Ky.	2262	April 1983	350	Owensboro local has approximately 300 members and is able to draw from two large sister locals: Evansville, Ind., which has 600 members, and Paducah, Ky., which also has 600 members; probable shortages during peak construction period
Teamsters	Evansville, Ind.	61	December 1982	400	Local membership is large enough to handle the peak needs; no problems foreseen in meeting anticipated manpower requirements
Sheet metal workers	Evansville, Ind.	43	February 1983	350	Access to additional workers, through surrounding nearby locals; no problems foreseen in meeting anticipated manpower requirements
Piledrivers	Evansville, Ind. Owensboro, Ky.	9	July-September 1982		Crews for piledriving operations normally are obtained from metal workers and carpenters unions (Paraday, 1979); no problems foreseen in obtaining required workers
Others	Not Applicable	306	January 1983		Primarily nonunion personnel such as field technicians and engineers, clerks, maintenance crews, etc.

^aCurrent enrollment is the estimated labor force currently working out of the local union. This number not only includes the membership of the local but any other workers currently registered with adjoining unions.

Source of data: Boilermakers local in Louisville (1979); brickmasons local in Owensboro (Owens, 1979); carpenters local in Owensboro (1979); cement finishers local in Owensboro (Feldman, 1979); electricians local in Owensboro (Baggett, 1979); insulators local in Evansville, (Underhill, 1979); ironworkers local in Evansville (1979); laborers local in Owensboro (1979); millwrights local in Owensboro (1979); operating engineers local in Henderson (Stetel, 1979); painters local in Evansville (1979); pipefitters local in Owensboro (Cook, 1979); teamsters local in Evansville (Smith, 1979); sheet metal workers local in Evansville (Paraday, 1979).

Source: ER, Table 4.8.

Table T.1. (continued)

Craft categories	Location of local union	Requirement	Peak man-month	Enrollment in local union ^a	Comments
Piledrivers	Evansville, Ind. Owensboro, Ky.	9	July–September 1982		Crews for piledriving operations normally are obtained from metal workers and carpenters unions (Paraday, 1979); no problems foreseen in obtaining required workers
Others	Not Applicable	306	January 1983		Primarily nonunion personnel such as field technicians and engineers, clerks, maintenance crews, etc.

^aCurrent enrollment is the estimated labor force currently working out of the local union. This number not only includes the membership of the local but any other workers currently registered with adjoining unions.

Source of data: Boilermakers local in Louisville (1979); brickmasons local in Owensboro (Owens, 1979); carpenters local in Owensboro (1979); cement finishers local in Owensboro (Feldman, 1979); electricians local in Owensboro (Baggett, 1979); insulators local in Evansville, (Underhill, 1979); ironworkers local in Evansville (1979); laborers local in Owensboro (1979); millwrights local in Owensboro (1979); operating engineers local in Henderson (Stetel, 1979); painters local in Evansville (1979); pipefitters local in Owensboro (Cook, 1979); teamsters local in Evansville (Smith, 1979); sheet metal workers local in Evansville (Paraday, 1979).

Source: ER, Table 4.8.

Table T.2. Representative major construction projects in the SRC-I region

Plant	Owner	Location	Construction schedule			Estimated peak work force	Current work force (1981)
			Begin	Peak	End		
Synthetic fuels plants							
SRC-I ^a							
Demonstration	DOE	Newman, Ky.	1981	1983	1984	3,500—5,000	0
Commercial	DOE	Newman, Ky.	1987	1989		5,000—10,000	0
W. R. Grace Synfuels ^b	DOE	Baskett, Ky.	1983	1986	1988	6,500	0
Tri-State Synfuels ^c	DOE Texas Eastern	Geneva, Ky.	1983	1986	1988	15,000	0
H-Coal ^d	Ashland Oil	Cloverport, Ky.	1984	1986	1988	5,000	0
Electric generating plants							
D. B. Wilson ^e							
No. 1	Big Rivers		1981	1984	1985	1,200	0
No. 2	Electric Co.	Matanzas, Ky.		1985	1986		
A. B. Brown ^f							
No. 2	Southern	West Franklin, Ind.	1980	1984	1985	610	80
No. 3	Indiana Gas and Electric				1988	610	80
Gibson Plant ^g	Public Service of Indiana	Princeton, Ind.	1978	1981	1982	1,610	1,200
Hancock Plant ^h							
No. 1	Kentucky	Cannelton Dam, Ky.	1984	1987	1989	1,000	0
No. 2	Utilities				1994		
Rockport ⁱ							
No. 1	Indiana-Michigan	Rockport, Ind.	1977	1982	1985	3,100	1,240
No. 2	Power Co. (American Electric Power)				1986		

^aSource: C. Boston, Oak Ridge National Laboratory, February 1981.

^bSource: K. Stephali, W. R. Grace Project Management, March 1981.

^cSource: J. Christopher, Texas Eastern, March 1981.

^dSource: J. Grant, Ashland Oil, March 1981.

^eSource: H. Timmons, Big Rivers Electric Co., March 1981.

^fSource: J. Vanmeter, Southern Indiana Gas and Electric, March 1981.

^gSource: T. Webb, Public Service of Indiana, March 1981.

^hSource: R. Whitmer, Kentucky Utilities, March 1981.

ⁱSource: J. Jones, American Electric Power, March 1981.

T.2 REGIONAL INDUSTRIAL MULTIPLIER SYSTEM

T.2.1 Introduction

The total economic effect of a project is substantially greater than the direct cost of building and operating the facility because the total includes secondary economic effects as well as the initial investment. The additional, or secondary, effect is estimated through a multiplier relationship: the ratio between the total increase in economic activity as a result of a project and the initial project investment. The initial effect, known as the final-demand change, represents the change introduced into the economy by the project itself. The secondary effect is the sum of the additional economic activity generated in the region by the initial effect. The analyses are particularly important because economic stimulation and new jobs created are often the key benefits of the construction or operations phases of a project, and lost jobs are a major source of controversy when an ongoing project must be terminated.

During construction of a new power-generating facility, for example, the initial economic effect is represented by expenditures for (1) equipment and materials purchased from local manufacturers and distributors and (2) labor. The local direct suppliers in turn purchase goods and services from secondary suppliers (e.g., wholesalers). The secondary suppliers in turn rely on other suppliers farther removed from the project. These successive rounds of interindustry purchases and sales are the secondary economic effects of the project.

The size of the regional multiplier depends on the proportion of direct and indirect input requirements that can be supplied by the region's economy, which in turn depends on the specific needs of the project and the ability of the regional economy to supply the inputs. Conceptually, therefore, the multiplier is different for every specific combination of industry and site in the nation.

T.2.2 Alternative methodologies

Economists have developed several alternative means for estimating the total economic effect, given the initial effect. The three main approaches are the economic base model, the econometric model, and the input/output (I/O) model.

The economic base model provides the simplest approach to estimating total economic effect. This model divides the regional economy into two sectors, the export, or basic, sector, which produces goods and services for export to other regions, and the residentiary, or nonbasic, sector, which produces goods and services for local consumption. The income earned (or employment) in the impact analysis requires identifying the initial change in the export sector. The product of this initial change and the multiplier is the total change in income (employment).

In the econometric model, the economy is represented by a set of interrelated equations describing the interactions among economic components. Time-series data are assembled for the variables of the model, and regression analysis is used to estimate coefficients of the equations. The economic impact analysis usually involves introducing the initial change in the appropriate equation of the model and recalculating the other equations to obtain the total impact.

The I/O model describes the flows of goods and services to markets and between industries in a region. Each industry in the economy has a particular set of inputs required to produce its output; these requirements generally differ from those of other industries. The I/O model describes the structure of the economy and may be used to analyze the implications of the changes in one portion of the economic effects that are set off by the final-demand change. Implicit in this process is a multiplier that relates total change to a specific initial change.

Each approach has advantages and disadvantages. The economic base model is simple to apply, but it fails to provide results tailored to the specific project being analyzed. Equal initial changes, whether in agriculture or energy supply, will produce equal total changes. The econometric model offers results that are moderately sensitive to differences in the nature of the project, but the data requirements for a long time series for all variables and the time required to assemble and estimate the model generally rule out its use, particularly for areas smaller than a state. The I/O model generally provides more useful industrial detail than the

other two. But, even though it does not require time-series data, an I/O model is usually costly to construct, and applications involving regions smaller than a state are difficult, again because of data limitations.

T.2.3 RIMS multiplier

HDR-Sciences uses a variation of the I/O approach known as the Regional Industrial Multiplier System (RIMS).^{*} This system was developed to overcome the cost and/or small-area data limitations associated with traditional approaches and to provide both geographic and industrial flexibility. It is a system of interrelated data files and computer programs designed to estimate I/O-type regional multipliers for any of the industries specified in the Bureau of Economic Analysis (BEA) national I/O model and for any region that can be defined as one or more counties in the United States.

The system combines several advantages of the economic base and I/O approaches to regional impact analysis to produce regional multipliers that are conceptually similar to I/O multipliers. RIMS relies on secondary data sources; it is sensitive to differences between industries; it operates at a detailed industrial level; and it is relatively inexpensive to apply.

The regional multiplier estimates the portion of succeeding waves of expenditures that occur within a defined region, thus providing a measure of the increased economic activity within the region. RIMS estimates project-specific multipliers needed to estimate changes in regional gross output, regional employment, and regional earnings by first computing the study industry's dependence on other regional industries.

The relationship is used to estimate the multiplier effect of an increase in final demand in a given industry on the regional gross output. Earnings-to-gross-output ratios are then used to translate the output increase into increases in earnings. For any given region, the ratio of employment to earnings is used to obtain an estimate of the total increased employment within the region.

Each industry requires inputs that are converted to an output, which serves as input to other industries. For example, the manufacture of electric motors requires, as some of its inputs, copper, electricity, labor, and transportation. When the electric motors are completed (and become an output) they are purchased by (and become inputs to) the copper industry, the electric appliance industry, and others. Some of these suppliers and some consumers are located in the region of interest; others are not. An I/O model ordinarily requires the development of an entire I/O matrix to account for this interdependence. While retaining many of the analytical opportunities of the I/O framework, RIMS avoids the need for this costly process by viewing the gross output multiplier as containing four elements: initial change, direct effect, indirect effect, and induced effect.

The initial-change component in the multiplier represents project expenditures that will occur in the study region. Because this initial change is exactly equal to project expenditures, it is always represented in the multiplier by unity (1.000). The remaining components, the secondary economic effects, are added to the initial economic effect to provide total economic effect.

The direct-effect component accounts for (1) industry input requirements and (2) the ability of the area to meet them. The former is obtained from the national I/O model; the latter is derived from data relating to the study region (e.g., U.S. Bureau of the Census, County Business Patterns Program). Inputs required by the study industry but not produced in the region (or produced in insufficient quantity) must be imported by the region, thus reducing the direct effect component of the regional multiplier.

The input requirements are identified in the BEA national I/O model. The first step in regionalization is the evaluation of this set of requirements in light of what is known about the project or specific industry. The suitability of the national model industry for the

^{*} The RIMS system was developed in the Regional Economic Analysis Division of the Bureau of Economic Analysis, U.S. Department of Commerce. The HDR version of RIMS has been refined and updated by staff to meet client and government requirements.

project analysis is assessed, and project-specific adjustments are made in the national model input requirements on the basis of available project descriptions or engineering information.

Input requirements that result from this first step represent the technical requirements of the industry. The second step in regionalization reconciles the technical requirements of the industry with the capacity of the region to supply the required inputs. The technical requirements are replaced by regional direct coefficients reflecting the actual purchases of inputs from suppliers within the study region. This step is accomplished with the use of the location quotient, which is a double ratio of the form:

- industry i employment in the study region/total employment in the study region, and
- industry i employment in the nation/total employment in the nation.

County Business Patterns data are used to estimate these location quotients. If the location quotient for a given input is zero, no production is carried on in the region. Thus, all the required input must be imported, and the regional direct effect is zero. If the location quotient is equal to or greater than one, production in the region is assumed to be sufficient to supply the study industry, and the regional direct effect is equal to the national direct requirement. In cases where the location quotient is greater than zero but less than one, the region is assumed to supply some of the input requirement, the proportion being equal to the value of the location quotient.

The location quotient test is applied to each regional industry that potentially supplies inputs to the study industry. The sum of all resulting regionalized coefficients is the direct component of the regional multiplier.

The indirect component and the induced component are computed as a single combined value in RIMS. The indirect-induced effects are those resulting from expansion of supplier and service industries to meet the needs of the directly affected industry, as well as changes in local consumption expenditures. The indirect interactions measure additional rounds of expenditures and production that result from the initial stimulus. Local consumer's incomes are increased by direct and indirect effects, and some part of the income increases will be spent in the region, stimulating additional economic activity. This effect of increased incomes to local consumers is the induced effect and is an extension of the indirect component. Estimation of the indirect-induced component is possible through the finding that, in an I/O model under empirically common conditions, the indirect-induced component can be estimated as a linear homogeneous function of the direct-component. A sample of 17 I/O models containing 500 observations was used to develop the relationship.

T.2.4 Updated RIMS program

Implementation of the RIMS methodology requires the articulation of several data bases. National input-output data provided by the Bureau of Economic Analysis must be coordinated with county business pattern employment figures furnished by the Census Bureau.

In contrast to the 1967 tables, the latest (1972) national input-output tables did not produce interindustry direct requirement coefficients. Such coefficients must now be generated through appropriate combination of published "use" and "make" tables.

Each row of a use table shows sales to (1) each industry and (2) final users of the output of the commodity named at the beginning of the row. Each column shows the value of the input of commodities and the value added that is generated in production of the industry named at the head of the column. Each row of a make table reveals the value of each of the commodities produced by the industry named at the beginning of the row. The columns of a make table show the total output of each commodity produced in each industry.

Each industry is assumed to have its own technology, which is determined by its principal product; in other words, all commodities, whether principal or subsidiary, produced in one industry are made by the same process and therefore require the same input structure. This is referred to as the assumption of an industry technology. (The assumption of a commodity technology, though perhaps preferable from a theoretical viewpoint, can yield negative coefficients and is not considered suitable for impact analysis.) Under this assumption, an input-output coefficient matrix (A) can be obtained as a matrix product of appropriately scaled versions of

the use (U) and make (V) tables. $A = BD$, where $U = B\hat{g}$ and $V = D\hat{q}$. The vector $\hat{g}$ is a diagonal matrix with industry outputs in the diagonal, and $\hat{q}$ is a diagonal matrix with commodity outputs in the diagonal. The industry technology was employed to compute an industry coefficients table; the most disaggregated use and make tables (511 industries) available from the Bureau of Economic Analysis were used. Household coefficients were calculated as value added divided by total inputs. To extract employee compensation from value added — which consists of employee compensation, indirect business taxes, and property-type income — value added was multiplied by the proportion of employee compensation in value added at the broad industrial division level.

To generate regional location quotients, the relative proportions of employment in specific industries in the region to be investigated to those in the nation must be known because the input-output data are national in nature. Employment estimates for four-digit Standard Industrial Code (SIC) industries were obtained from county business pattern publications for the latest available year, 1976. Because many figures are not revealed, due to disclosure rules, a reconciliation procedure was implemented to estimate employment for nonreported industries. This procedure required employment estimates at one level of industrial classification that conformed hierarchically to employment estimates at the next broader level. Because five levels of industrial classification exist, a computer subroutine was written to match any of four given levels with the level immediately above it.

Because the industrial classifications employed by the Bureau of Economic Analysis and the Census Bureau are disparate, a bridge program was written so that location quotients could be computed for each of the I/O industries. This was accomplished by taking the published bridge and rearranging (sorting) it so that SIC industries — as opposed to I/O industries — were in ascending order. This facilitated the assignment of county business pattern employment estimates to the appropriate I/O industries as data were read in from magnetic tape, in order of ascending SIC codes.

Once I/O industry regional employment estimates are obtained in this fashion, regional location quotients (LQs) — the ratios of regional to national industrial concentrations — are computed. These LQs are then applied to the national input-output coefficients, generated under the industry technology assumption, to calculate regional direct multipliers.

This procedure can be summarized in the following four equations. [The dot (.) refers to summing across that subscript.]

$$A_{ij}^r = (R_i) (A_{ij}^n), \quad (T.1)$$

$$EC^r = g(P_1, P_2, S), \quad (T.2)$$

$$C_{.j}^r = F(A_{.j}^r, EC^r), \quad (T.3)$$

$$M_{.j}^r = A_{.j}^r + C_{.j}^r + 1, \quad (T.4)$$

where

A_{ij}^r = estimated regional direct coefficient,

R_i = regionalizing factor for industry i ,

A_{ij}^n = national direct I/O coefficient,

EC^r = factor describing the economic characteristics of the region,

P_1 = agriculture proportion of total nongovernment earnings,

P_2 = manufacturing proportion of total nongovernment earnings,

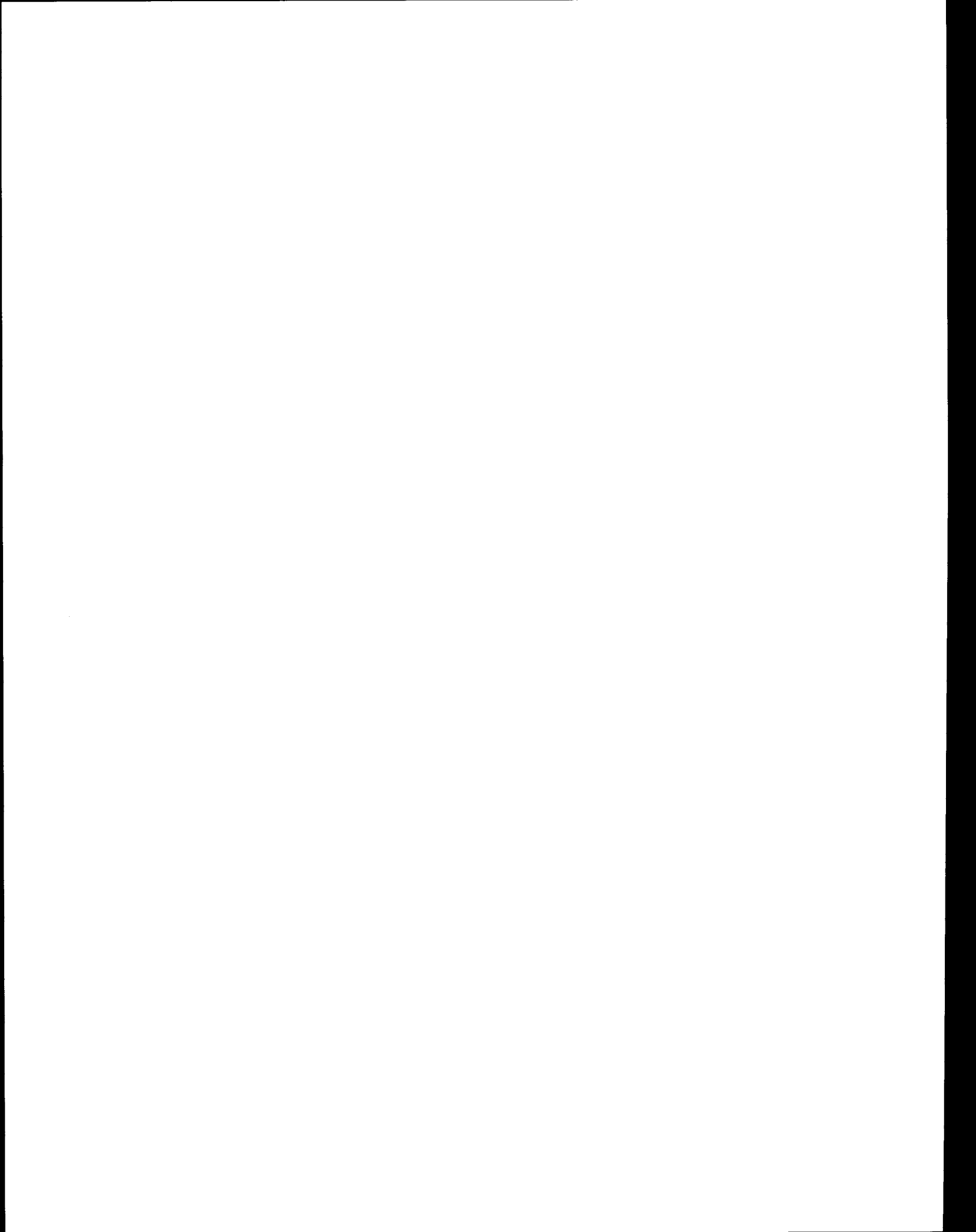
S = regional nongovernment earnings divided by national nongovernment earnings — a measure of the economic size of the region,

$C_{.j}^r$ = estimated indirect-induced component of the multiplier for industry j,

$A_{.j}^r$ = estimated direct component of the multiplier for industry j,

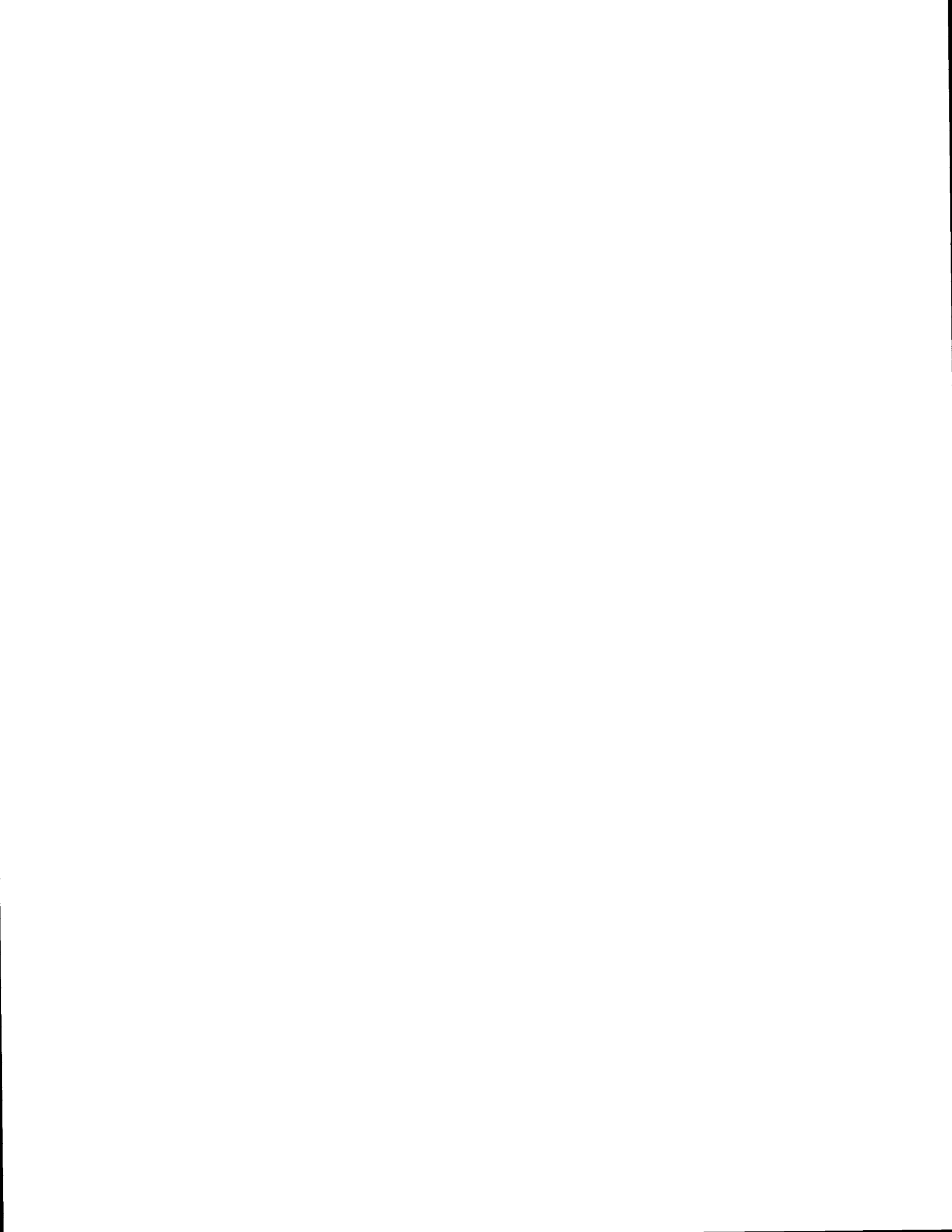
$M_{.j}^r$ = estimated total multiplier for industry j.

Equation (T.1) shows employment editing of the national table and further regionalization by location quotients. Equation (T.3) indicates that the indirect-induced component of the multiplier is estimated as a function of both the direct component and regional economic characteristics, which are specified in Eq. (T.2). Equation (T.4) is the multiplier identity. One overall multiplier, $(M_{.j}^r)$, is estimated for each column industry. The multiplier represents the effect of a change in final demand for each column industry's output on the total regional output of goods and services, as well as a change in the associated effects on regional earnings.



APPENDIX U

LETTERS CONCERNING ARCHAEOLOGICAL AND HISTORICAL SURVEYS





Department of Energy
Oak Ridge Operations
P.O. Box E
Oak Ridge, Tennessee 37830

June 16, 1980

Kentucky Heritage Commission
ATTN: Ms. Marsha Richmond
State Historical Preservation Office
104 Bridge Street
Frankfort, Kentucky 40601

Gentlemen:

COMPLIANCE WITH THE NATIONAL HISTORIC PRESERVATION ACT; DOE'S PROPOSED SRC-I PROJECT IN DAVIESS COUNTY, KENTUCKY

Attached you will find two reference documents that have been prepared in support of the Environmental Impact Statement for the proposed SRC-I Project near Newman, Kentucky. The Draft EIS is scheduled for release for public review and comment by the end of June.

The first report, Appendix M, Historical/Architectural Survey, was prepared in late 1977 and gives a brief historical perspective of the plant site area and identifies five specific structures as possibly having some architectural significance. A recently revised map on page six of the report shows the location of these five structures relative to the SRC-I site property. As the map indicates, only two of the structures are actually located on the proposed plant site, and impacts to all the buildings by the project will be limited to visual or aesthetic factors. Based on our understanding of the regulatory criteria pursuant to the National Historic Preservation Act, it would not appear that any of these buildings are of such significance as to be considered eligible for the National Register of Historic Properties. We regret that the Xerox copies of the photographs of the buildings are of such poor quality. If you believe it necessary for you to have better pictures, we can probably have Goetzman and Follmer send you reprints of the original photographs.

The second report, Appendix N, Archaeological Reports, 1979 and 1980, is in two parts. Part I was prepared in 1979 and identified two archaeological sites, 15DA73 and 15DA74, that needed field surveys to determine the possible presence of deeply buried cultural materials. Part II is a report of the subsequent surveys conducted on the two sites in December, 1979. As the report indicates, no deeply buried cultural deposits were found, and no further archaeological work was deemed to be necessary.

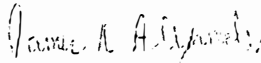
Kentucky Heritage Commission

2

On the basis of these two reports and our review of the applicable regulations criteria, DOE has concluded that the SRC-I project as now conceived should have no quantifiable impacts or effects on any existing resources that would be afforded protection under the National Historic Preservation Act. We request your review of this determination and, if you agree, formal documentation of your concurrence for inclusion in the SRC-I Environmental Impact Statement. If you believe we may be in error or might have overlooked any potentially eligible properties, please contact us as soon as possible so that we may implement the required eligibility determination and mitigation procedure in a manner timely with preparation of the final EIS.

If you have any questions or need additional information, please contact me at 615-576-0849.

Sincerely,



J. K. Alexander
Environmental Engineer
Environmental Protection Branch
Safety and Environmental Control
Division

MS-331:JKA

Enclosures: As stated

cc: J. F. Pearson, AMSRCP, ORO, w/o encl
J. L. Morris, DOE-HQ-FE, w/o encl



Kentucky Heritage Commission
101 Bridge Street
Frankfort, Kentucky 40601

July 7, 1980

Mr. James K. Alexander, Environmental Engineer
Department of Energy
Oak Ridge Operations
P.O. Box E
Oak Ridge, Tennessee 37830

Dear Mr. Alexander:

Thank you for your correspondence of June 16 concerning the proposed SRC-I project near Newman, Kentucky. My staff and I reviewed the historical/architectural survey report prepared in 1977. Our review of the report indicates no structures included in or eligible for inclusion in the National Register of Historic Places will be effected by the proposed SRC-I project.

Our review of the archaeological reports indicates that 15 Da 73 and 15 Da 74 do not meet the criteria for inclusion in the National Register of Historic Places. Therefore, no further archaeological work is warranted.

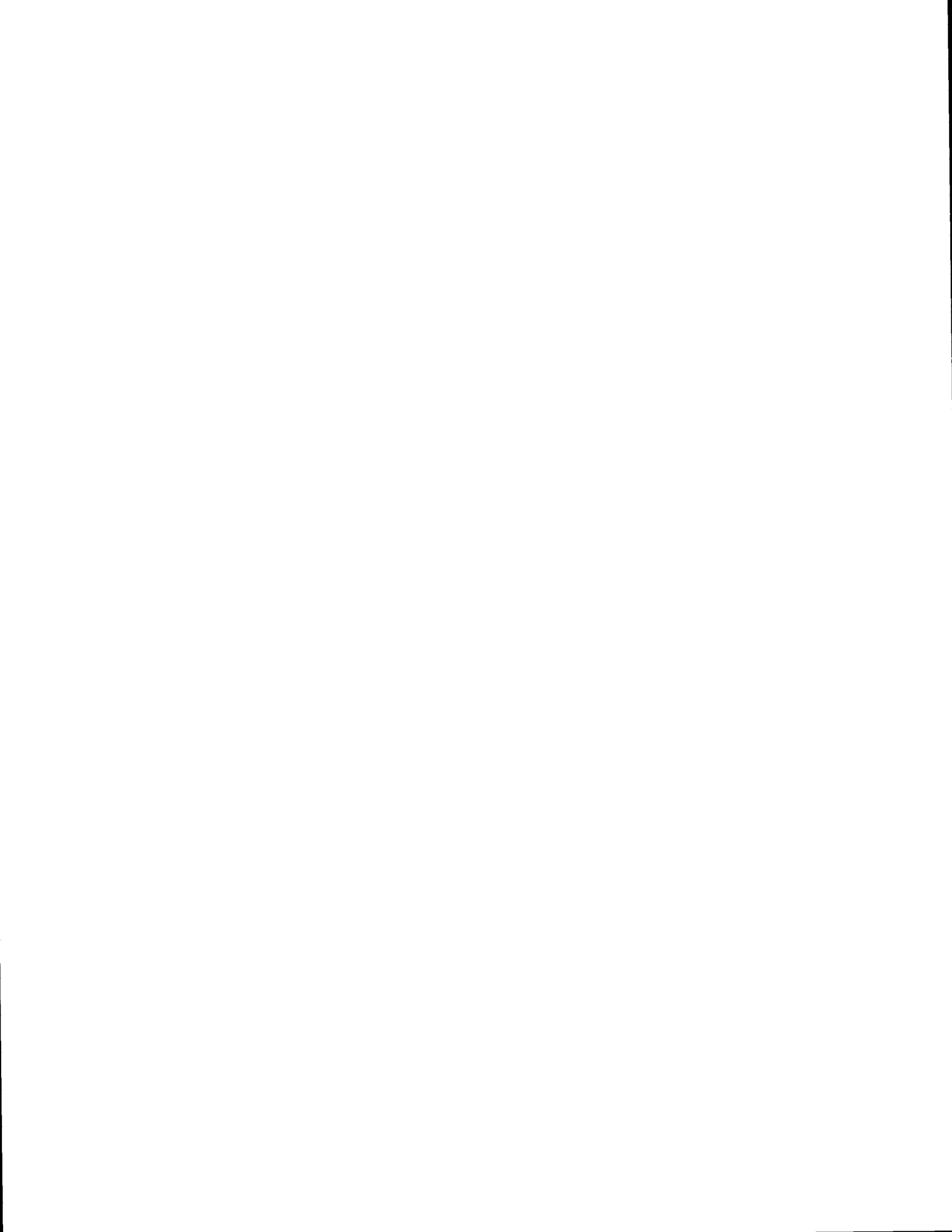
We concur with the Department of Energy's assessment that no sites or structures included in or eligible for inclusion in the National Register of Historic Places will be effected by the proposed SRC-I project. Therefore, our office has no objections to the proposed undertaking.

Sincerely,

A handwritten signature in cursive script, reading "Donna C. Hopkins".

Mrs. Donna C. Hopkins
Acting Executive Director and Acting
State Historic Preservation Officer

DCH:klw



Appendix V
THE CARBON DIOXIDE ISSUE

Appendix V
THE CARBON DIOXIDE ISSUE

V.1 CARBON DIOXIDE RELEASE TO THE ATMOSPHERE

All methods of large-scale energy production have environmental consequences. Release of carbon dioxide (CO_2) to the atmosphere is a major concern associated with the use (burning) of fossil fuel as an energy source.¹⁻³ Of all liquid and gaseous emissions from fossil fuel energy production, coal, petroleum, and natural gas, only CO_2 is retained in significant quantities in the atmosphere.⁴ Atmospheric CO_2 permits incoming short-wave radiation to reach the earth, but absorbs long-wave, infrared radiation.⁵ Infrared radiation is the principal outgoing radiation from the earth's surface. As atmospheric CO_2 levels increase, the amount of terrestrial radiation which is absorbed increases accordingly.⁶

Part of the terrestrial radiation absorbed by the atmospheric CO_2 is reradiated back to the earth, resulting in elevated global temperatures, known as the greenhouse effect.⁷ Theoretically, the trapping and reradiation of energy back to earth, with the ensuing increase in global temperatures, will alter climatic patterns.⁸⁻¹⁰ Although the relationship between atmospheric CO_2 levels and global temperature changes has never been empirically proven, many researchers believe that CO_2 -induced climatic change will result in elevated sea levels as polar ice caps melt, and in the northward and southward latitudinal shifting of agricultural zones.¹¹⁻¹² Whether or not these changes actually occur, when they may occur, and to what degree they will occur is a matter of open debate.

Atmospheric CO_2 levels are increasing and have been for a considerable length of time. Since 1958, several monitoring programs, most notably the Mauna Loa, Hawaii monitoring program, have documented the atmospheric CO_2 increase.¹³ It is estimated that atmospheric CO_2 levels are increasing at an annual rate of about 1.5 ppm with a background of about 333 ppm at the present time.¹⁴ The estimated increase in atmospheric CO_2 since 1860 is a range of 40 to 70 ppm.¹⁵ If the current increase in fossil fuel use continues at 4.3% per year, with the present distribution of CO_2 between the atmosphere, biosphere, and oceans, the atmospheric concentration of CO_2 can be expected to double by the year 2035. Annual growth rates of 1.0 to 3.0% of fossil fuel usage delay the projected doubling time of atmospheric CO_2 levels by 5 to 25 years.¹⁶

The significance of the synfuel contribution to the already increasing levels of atmospheric CO_2 is an important issue in the ongoing debate concerning future fossil fuel usage. The central issue of the argument revolves around the higher CO_2 emissions from synfuels than from the directly burning fossil fuels (Table V.1).¹⁷ When the Btu's of all products and by-products are compared to the Btu's of the feed coal, the efficiency of coal liquefaction generally ranges from 60 to 70%. Many of the Btu's absent in the final products are discarded from the plant as carbon bound with oxygen, forming CO_2 gas. Although the CO_2 emissions from synfuels production and use exceed those from other fossil fuels, during the demonstration phase of the project these emissions will represent a very small fraction of the U.S. and world CO_2 emissions.

As illustrated by Table V.1, CO_2 emissions from the production and use of synfuels are significantly higher than emissions from any other fossil energy source. Synfuel production emits high levels of CO_2 because energy from fossil fuel is required to convert coal to synthetic fuel. Estimates of the excess amount of CO_2 synfuel production will emit varies slightly from one source to the next, but the range is generally between two to three times greater than natural gas, slightly less than two times the amount for petroleum, and less than 50% more than coal.^{18,19}

Table V.1. Relative amounts of carbon released in carbon dioxide for various fossil fuels

Fuel	Carbon in carbon dioxide (in 10^{15} g) ^a
Oil	2.0
Gas	1.45
Coal	2.5
Coal: converted to gas or oil (synthetic fuels)	3.4

^aCarbon released in CO₂ per 100 quads of energy released as heat.
(One quad = 10^{15} Btu.)

Source: Woodwell, et al., "The Carbon Dioxide Problem: Implications for Policy in the Management of Energy and Other Resources," *Council on Environmental Quality*, July 1979, p. 6.

Significance of the CO₂ issue

Regardless of whether synfuels become a major contributor to our energy needs, worldwide CO₂ levels are predicted to double during the next century. The doubling of CO₂ levels by 2035² assumes a continued high growth rate of energy demand and fossil fuel use. If synthetic fuels are substituted for petroleum and natural gas, the doubling time for atmospheric CO₂ concentrations is shortened, but not significantly. It is important to realize that as synfuels begin contributing to the nation's energy ends, the use of other fossil fuels will decline, reducing CO₂ emissions from conventional sources.

The actual share the United States will contribute to worldwide CO₂ emissions is dependent on the fossil fuel mixture used, development of nonfossil energy sources, and the growth of fossil fuel use by other countries. Based on the scenario proposed by President Carter, baseline calculations from synfuel CO₂ releases have been calculated assuming a production rate of 1 million barrels a day by 1985, 2 million bbl/d by 1990, and 5 million bbl/d in the year 2000. This rate of production was then projected to the year 2050 with an anticipated rate of 60 million barrels of synfuel per day.²⁰ By 1990, synfuels will be contributing a small percentage to man-made CO₂ emissions. Preliminary studies indicate a two million bbl/d synfuels program will represent a 3% increase in CO₂ emissions from U.S. fossil-fuel combustion and production. These emissions will represent less than 1% of global man-made emissions in 1990. Using the current projections for synthetic fuel development, the U.S. emissions of CO₂ from synfuels will represent 1.9% of the world total in 2025 and 3% in 2050.²¹ These baseline calculations are believed, by the Institute of Energy Analysis, to be based on an unrealistically high energy use scenario. This rate of energy production is equal to 125 quads, which is approximately twice the amount of present production. In addition, all energy projections of a few years ago were much higher and, every year, the projections for the future are getting lower. The fraction of the U.S. total energy that will come from this scenario in the year 2050 is 37.5%.²²

The United States currently contributes approximately 28% of the world's man-made CO₂ emissions.²³ If current projections regarding a shift in the reliance on petroleum to coal prove true at the national and world scales, total U.S. and world emissions of CO₂ will dramatically increase. An interesting sidelight of this projection is that the U.S. share of world CO₂ emissions will decrease in relative terms while increasing in absolute terms. This argument has been seized upon by proponents of the synthetic fuels and coal development advocates in the nation as a rationale for adopting coal and coal conversion technologies as a major part of our energy program. As the world moves away from petroleum reliance to coal reliance, total CO₂ emissions will increase. It is projected that the U.S. contribution to total CO₂ emissions will decrease to 8% in 2025 as developing countries increase their use of fossil fuels.²⁴

Justifying synthetic fuels and coal usage based on total projected world emissions of CO₂ tends to obfuscate the significance of the amount the U.S. contributes to the atmosphere. In a recent presentation to the U.S. Senate Committee on Energy and National Resources, Professor David Rose (MIT) attempted to put all of the issues regarding fossil fuel use, technologies, and

CO₂ emissions into perspective.²⁵ The thrust of Rose's argument was that more thought should be given to the logic of developing a large-scale synthetic fuels program given the uncertainty of the climatological consequences that may ensue from increasing atmospheric CO₂ concentrations. The shift to a national and worldwide reliance on coal as a primary energy source, as a result of this problem, needs to be reassessed. The inertia which such a technological shift may build up over several decades will be difficult to reverse should global warming, resulting from increased CO₂ concentrations, prove to be a major world problem.²⁶

Because of the small scale of the synthetic fuel demonstration projects, the global impact of their CO₂ emissions will be minimal. The above discussions assumed high daily outputs of synthetic fuels in commercial-scale plants in predicting the impact of CO₂ emissions. The demonstration plants will produce small quantities of synthetic fuels and thereby small quantities of CO₂. The ultimate purpose of the demonstration projects, however, is to demonstrate the feasibility of a large-scale commercial synthetic fuels industry. This should be kept in mind when comparing the impacts of synfuels to the potential environmental impacts of other energy alternatives.

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21. Ref. 19, p. 16, footnote 19.
22. Ref. 19, p. 16, footnote 19 (comments by Dr. Ralph Rotty).
23. Ref. 19, p. 21, footnote 19.
24. Ref. 17, p. 2, footnote 17.
25. Professor D. J. Rose, *On the Global CO₂ Problem*, a presentation prepared for the U.S. Committee on Energy and Natural Resources, Apr. 3, 1980.
26. Ref. 25, p. 14, footnote 25.

Appendix W

PERMITS



Appendix W

PERMITS

The permit schedule outlined in this Appendix is based on the construction schedule used throughout this FEIS. In the event that the construction schedule changes, the dates for submitting permit applications will be adjusted accordingly.

Table W.1. Permit requirements^a

Agency/permit	Date permit required	Date application required	Date application scheduled	Remarks
Federal				
Environmental Protection Agency				
PSD	3/82	1/81 (12/80)	(12/80)	
NPDES				
Construction runoff	3/82	10/81	10/81	Not required per EPA Region IV
Sewage treatment plant	7/84	1/84	10/83	
Other plant discharges	7/84	1/84	10/83	
RCRA (sludges and slag)	7/83	1/83	10/82	To be part of NPDES BMP. Plan approval not required
SPCC plan for operation				
PSCC plan for construction		3/82	3/82	
Dredge spoils	7/82	1/82	12/81	
U.S. Army Corps of Engineers				
Section 101 and 104 permits				
Barge dock	7/82	3/82	3/82	
Water intake	7/82	3/82	3/82	
Water outfall	7/82	3/82	3/82	
Martins Creek and Bryants Ditch	Not applicable	Not applicable	Not applicable	Permit not required per COE letter dated December 23, 1980
Federal Aviation Administration				
Construction hazards to air traffic				Not required for structures under 200 ft
Commonwealth of Kentucky				
Department of Natural Resources and Environmental Protection				
Construct air pollution source	3/82	1/81	(12/80)	
Construct water pollution source	4/83	3/83	1/83	
Construct landfill	7/83	1/83	10/82	
Construct in a floodway	7/82	3/82	3/82	File same time as COE permit Required after wells have been drilled, at the time the water is to be used
Water withdrawal permit	7/83	5/83	4/83	
Construct public water supply	7/83	5/83	4/82	
Construction runoff	3/82	10/81	10/81	
Air pollution operating permit	2/86	1/86	11/85	
Water pollution operating permit	7/84	6/84	5/84	
Landfill operating permit	8/82	7/84	6/84	

^aBased on April 1, 1982, as the date for start of construction.



Department of Energy
Oak Ridge Operations
P.O. Box E
Oak Ridge, Tennessee 37830

November 7, 1980

International Coal Refining Corporation
ATTN: Dr. John Tao
P. O. Box 2752
Allentown, PA 18001

Gentlemen:

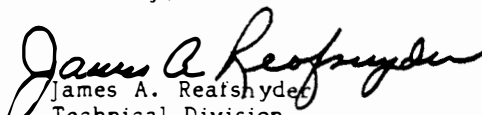
RECEIPT OF NEW SOURCE DETERMINATION REGION IV

Enclosed is a letter from Rebecca W. Hanmer, of the U.S. EPA, Region IV, ruling that the SRC-I Demonstration Plant is effectively a new source, and in accordance with Section 511(c)(1) of the Federal Water Pollution Control Act, issuance of an NPDES permit will be subject to the provisions of the National Environmental Policy Act of 1969.

As discussed with Region IV at the meeting on October 14, it is hoped that EPA's co-authorship of the DOE EIS will satisfy the requirements of the EIS for the NPDES permit, in the interest of saving time. Bob Howard, section chief in Region IV's EIS Branch, has indicated that through the mechanism of EPA as cooperating agency for the DOE EIS and through execution of the work plan being generated between the two agencies, EPA will in fact consider itself co-author to the DOE EIS. This is a welcome viewpoint, and Mr. Howard indicated that no formal further request to establish co-authorship would be necessary.

If you have any questions on this matter, please contact me or Gabriel Marciante at 615-576-1051, or 576-0850, respectively, or FTS 626-2429/-0850.

Sincerely,


James A. Reafshyde
Technical Division
Solvent Refined Coal Projects

MS-331:GJM

Enclosure

CC:

R. Hanmer, EPA-IV Admin.

Bob Howard EPA

Chuck Boston, 4500N, MS D-33, ORNL

M. L. Rogowsky, MS 5A-114, FORSTL/HQ

J. F. Pearson



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION IV

345 COURTLAND STREET
ATLANTA, GEORGIA 30303

OCT 22 1980

REF: 4E-WE

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

Mr. John F. Pearson, Jr.
 Assistant Manager for Solvent
 Refined Coal Projects
 Department of Energy
 Oak Ridge Operations
 P.O. Box E
 Oak Ridge, Tennessee 37830

Re: SRC-I Demonstration Plant, Newman, Kentucky, NS#0171

Dear Mr. Pearson:

As a result of various meetings and discussions with my staff and the additional information you submitted on October 1, 1980, I have made the following determinations relative to the discharge to the navigable waters of the United States from your proposed Newman, Kentucky demonstration plant:

COAL PREPARATION PLANT COMPONENT

1. Construction of this facility was not in progress as of January 12, 1979.
2. This component of your facility falls within the Coal Preparation Plants and Associated Areas Subcategory of the Coal Mining Point Source Category.
3. New Source Performance Standards for this industrial category were promulgated in the Federal Register on January 12, 1979.
4. There is a New Source Performance Standard within this category which can reasonably be considered applicable to this component of your facility.

ALL OTHER COMPONENTS

1. Construction of this facility was not in progress as of October 1, 1980.
2. Your facility generally falls within the Synthetic Fuel from Coal Category.
3. New Source Performance Standards for this industrial category have not been proposed in the Federal Register as of October 1, 1980.

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-2-

4. There is a reasonable presumption that a New Source Performance Standard within this category (which can reasonably be considered applicable to your facility) will be proposed in the Federal Register prior to start of construction of these other components.

Based on the above determinations I have further determined that construction of your facility did not begin prior to publication of any proposed New Source Standards in the Federal Register which could reasonably be considered to apply to your discharge. As a result of this determination I have therefore concluded that you are a new source and in accordance with Section 511(c)(1) of the Federal Water Pollution Control Act, as amended, (33 USC 1311), issuance of an NPDES permit to your facility is subject to all provisions of the National Environmental Policy Act of 1969 (83 Stat. 852).

If you should disagree with this ruling, you may submit a request for an adjudicatory hearing and/or legal decision within thirty (30) days of the receipt of this letter. The request and two copies thereof must be submitted to the Regional Hearing Clerk, Environmental Protection Agency, 345 Courtland Street, Northeast, Atlanta, Georgia 30365. The submission of the request will be within the time period if mailed by Certified Mail before the 30th day. The request must:

1. State the name and address of the person making such request;
2. Include an agreement by the requestor to be subject to examination and cross-examination and to make any employee or consultant of such requestor or other person represented by the requestor available for examination at the expense of such requestor or such other person upon the request of the Presiding Officer, on his own motion, or on the motion of any party;
3. State with particularity the reasons for the request;
4. State with particularity the issues proposed to be considered at the hearing.

Additional information on adjudicatory hearings and legal decisions is found at Title 40, Code of Federal Regulations, Section 125.36, 39, Federal Register 27081.

If you have further questions concerning this matter, please contact Mr. William H. Cloward of our Water Enforcement Branch at (404)881-2017.

Sincerely yours,

John A. Lutz, Deputy
for
Rebecca W. Hammer
Regional Administrator

cc: Mr. D. Elmo Lunn
Division of Water Quality Control
TN Dept. of Public Health

Appendix X

U.S. DEPARTMENT OF AGRICULTURE — SOIL CONSERVATION SERVICE LETTER
ON PRIME FARMLANDS

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UNITED STATES DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

333 Waller Avenue, Lexington, KY 40504

April 23, 1980

Mr. Roger L. Kroodsma
 Research Staff Member
 Oak Ridge National Laboratory
 Environmental Sciences Division
 P.O. Box X
 Oak Ridge, TN 37830

Dear Mr. Kroodsma:

The following information is furnished as requested in your letter dated March 28, 1980.

A soil map of the proposed construction site is attached. Prime farmland soils are colored green, additional farmlands of statewide importance are colored yellow, and other soils are colored red. There are no unique farmlands on the proposed site.

Approximately 91 percent of the soils on the site are prime farmland soils. They are listed below.

<u>Map Symbol</u>	<u>Soil Name</u>
EkA	Elk silt loam, 0 to 2 percent slopes
EkB	Elk silt loam, 2 to 6 percent slopes
Gn	Ginat silt loam
Hu	Huntington silt loam
Ja	Jacob silty clay loam
Mh	Melvin silt loam
Ne	Newark silt loam
OtA	Otwell silt loam, 0 to 2 percent slopes
OtB	Otwell silt loam, 2 to 6 percent slopes
Wh	Weinbach silt loam

Approximately 2 percent of the soils on the site are additional farmlands of statewide importance. They are listed below.

<u>Map Symbol</u>	<u>Soil Name</u>
EkC	Elk silt loam, 6 to 12 percent slopes
WnC	Wheeling loam, 6 to 12 percent slopes



Mr. Roger L. Kroodsma

Page 2

Approximately 7 percent of the soils on the site are other soils. They are listed below.

<u>Map Symbol</u>	<u>Soil Name</u>
AlF	Alluvial land, steep
EkE	Elk silt loam, 12 to 50 percent slopes, severely eroded
ElC3	Elk silty clay loam, 6 to 12 percent slopes, severely eroded

If we can provide additional information, please contact us.

Sincerely,

for Allan Hard
Glen E. Murray
State Conservationist

Attachment

DAVIES AND HANCOCK COUNTIES, KENT.



Appendix Y

BARGE DOCKING FACILITY

(Adapted from Dames & Moore study, No. 10259-019-21, May 7, 1980.)

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Appendix Y

BARGE DOCKING FACILITY

Y.1 COMPLIANCE WITH LAWS, EXECUTIVE ORDERS, AND EXISTING REGULATIONS

The proposed project includes consideration of the construction of a barge slip and dock at the proposed site in Daviess County, Kentucky. The barge slip would be constructed with access to the Green River near River Mile (RM) 19. The dock would be located within the barge slip. The purpose of this appendix is to assess the impact of this facility as required by various environmental laws and regulations.

The proposed construction of a barge slip and dock and associated land disposal of dredged material must comply with various laws, executive orders, and their associated regulations. These regulations, described below, are designed to protect navigation, surface and groundwater quality, wetlands, floodplains, fish and wildlife, and historical and archaeological resources.

Section 10 of the River and Harbor Act of 1899 (30 States 1151; 33 USC 403) gave the U.S. Army Corps of Engineers a mandate to prohibit the obstruction or alteration and construction of any structure in or over any navigable water of the United States without a permit. The regulations which implement this Act are contained in the Army Corps of Engineers Permit Program Regulations (33 CFR Part 320 and Parts 322 through 329).

The barge slip, unloading facility, and dredge disposal area and its associated effluent will require Corps of Engineers permitting under 33 CFR Parts 322 and 323. The dredging activity and construction of the dock must comply with the Army Corps of Engineers Regulations 33 CFR Part 322 - Permits for Structures or Works in or Affecting Navigable Waters of the United States. If the diked dredge disposal area is within the 100-year floodplain, it will also be reviewed as a structure or work in or affecting navigable waters of the United States.

Effluent from the dredge disposal area constitutes a discharge of dredged material to the water of the United States. Therefore, it will be regulated under Corps of Engineers regulations 33 CFR Part 323 - Permits for Discharge of Dredge or Fill Material Into Waters of the United States pursuant to Section 404 of the Clean Water Act. Material discharged for bank stabilization may also be regulated under this section.

Corps of Engineers regulations 33 CFR Part 320 outlines the general criteria used to evaluate all Corps permit applications; of particular interest is Sect. 320.4 - General Policies for Evaluating Permit Applications. The following general criteria are applicable to permitting of the proposed barge slip unloading facility and discharge of dredged material:

1. public interest review,
2. effect on wetlands,
3. fish and wildlife,
4. water quality,
5. historic, scenic, and recreational values,
6. interference with adjacent properties or water resources projects,
7. floodplains, and
8. selected other Federal, State, or local requirements.

The public interest review is a consideration of economic benefits verses general environmental concerns. This review should consider the following general criteria:

1. the relative extent of the public and private need for the proposed structure or work;
2. the desirability of using appropriate alternative locations and methods to accomplish the objective of the proposed structure;
3. the extent and permanence of the beneficial and/or detrimental effects that the proposed structure or work may have on the public and private uses to which the area is suited; and
4. the probable impact of each proposal in relation to the cumulative effect created by other existing and anticipated structures or work in the general area.

The Corps of Engineers, pursuant to Executive Order 11990 entitled "Protection of Wetlands and the River and Harbor Act," also regulates activities in wetlands to avoid adverse impacts, where possible, to minimize destruction, and to preserve the values of wetlands. The Corps will consider whether the proposed activity is primarily dependent on being located in, or in close proximity to, the aquatic environment and whether feasible alternative sites are available. The Corps will also consult with various Federal agencies to assess the cumulative effects of activities in the region. In addition to the Corps of Engineers' policies, State regulatory laws or programs for classification and protection of wetlands must be considered.

Consideration of the impact of the barge facility and related activities on fish and wildlife is a major concern. In accordance with Fish and Wildlife Coordination Act, Corps of Engineers officials will consult with the Regional Director, U.S. Fish and Wildlife Service, and the head of the agency responsible for fish and wildlife for the State in which the work is to be performed, with a view to the conservation of wildlife resources by prevention of their direct and indirect loss and damage due to the activity proposed in a permit application. They will give great weight to these views on fish and wildlife considerations in evaluating the application. The applicant will be urged to modify the proposal to eliminate or mitigate any damage to such resources. Where appropriate, the permit may be conditioned to accomplish this purpose.

Applications for permits for activities which may affect water quality or discharge of dredge or fill material will be evaluated for compliance with applicable effluent limitations, water quality standards, and management practices during the construction, operation, and maintenance of the proposed activity. State certification of compliance with applicable effluent limitations and water quality standards required under provisions of Section 401 of the Clean Water Act will be considered conclusive with respect to water quality considerations unless the Regional Administrator, Environmental Protection Agency (EPA), advises of other water quality aspects to be taken into consideration. Any permit issued may be conditioned to implement water quality protection measures.

Several Federal acts require the Corps of Engineers and other Federal agencies to consider the effect of permitted activities on historic, scenic, and recreational values. Historical sites, which include cultural and archaeological sites, are protected under two Federal acts. The National Historic Preservation Act established an Advisory Council to review and comment upon activities licensed by the Federal Government that will have an effect upon properties listed in the National Register of Historic Places, or eligible for listing. The Preservation of Historical and Archaeological Data Act empowers the Secretary of the Interior to take action necessary to recover and preserve the data prior to commencement of the project when a Federally licensed project alters any terrain such that significant historical or archaeological data is threatened.

Scenic and recreational areas should also be protected. These areas include rivers designated as wild or scenic and national parks, wilderness areas, national lakeshores, national monuments, and other Federal or State designated areas.

The Corps of Engineers will not issue a permit for structures or work which would interfere with adjacent properties or water resource projects. Interferences such as increased siltation or erosion and general public access or right of navigation must be avoided.

The Corps of Engineers have established regulations (33 CFR Part 239) for activities in the floodplain, pursuant to Executive Order 11988 on Floodplain Management. These regulations

require evaluation of whether activities located in a floodplain (100-year) that require Department of the Army permits are in the public interest; and whether alternatives are available to avoid adverse effects from and incompatible development in floodplains. The activity should not result in an increase in flood impacts on human safety, health, and welfare.

Other Federal, State, or local requirements must be considered prior to issuance of a permit. For example, the Endangered Species Act is one act of concern prior to issuance of a permit. This act requires that the agency shall not jeopardize the continued existence of such endangered or threatened species or result in the destruction of such species' habitat, which is determined by the Secretary of Interior or Commerce to be critical (50 CFR Part 17).

The Resource Conservation and Recovery Act (RCRA) can also affect activities of land disposal and treatment of dredged material (solid waste). The purpose of the act is to promote environmentally safe disposal of solid waste. Contaminated dredged material has the potential for impact on ground and surface waters and, therefore, its disposal can be regulated under this act. The Corps of Engineers will review disposal activities to ensure that unregulated disposal of hazardous dredged material does not occur.

The National Environmental Policy Act (NEPA) requires Federal agencies to review environmental impacts of these actions. Corps of Engineers' permitting of activities that have the potential for significant impact on the environment must conform to the act.

Activities on navigable water must also adhere to the U.S. Coast Guard regulations in navigation lights, aids to navigation, navigation charts and related data, policy, practices, and procedures.

Processing of an application for a Department of the Army permit normally will proceed concurrently with the processing of other required Federal, State, and/or local authorizations or certification. Where the required Federal, State, and/or local certification and/or authorization has been denied, the application for a Department of the Army permit will be denied without prejudice to the right of the applicant to reinstate processing of the application if subsequent approval is received from the appropriate Federal, State, and/or local agency. Even if official certification and/or authorization is not required by State or Federal law, but a State, regional, or local agency having jurisdiction or interest over the particular activity comments on the application, due consideration shall be given to those official views as a reflection of local factors of the public interest.

Y.2 BARGE DOCKING FACILITY

The purpose of this appendix is to evaluate the environmental effects of barge transportation as a transportation method for construction equipment, feed coal, and SRC liquid and solid products. This transportation method would require construction of a barge dock facility at the site. Fig. Y.1 shows the location and size of the proposed barge slip and the preliminary design for the dock is presented in Fig. Y.2.

During the initial design stages, two major barge dock location alternatives were reviewed. These included a dock located on the shoreline of the Green River and one on a barge slip connected to the river. Although a dock located on the shoreline would be out of the major navigation channel, some potential for obstruction to navigation did exist. Therefore, the barge slip was selected as the preferred alternative.

Several alternative locations for disposal of dredged material were also reviewed. The alternative selected is the one which will be located out of the 100-year floodplain and cause the least disruption of native vegetation.

The preferred barge dock proposal has three scenarios: (1) barges used only for unloading construction equipment for the demonstration plant; (2) supplementary to scenario 1 to handle some feed coal if the mine is not adjacent to a railroad for the 6000 tpsd SRC-I facility; and (3) expanded further to accommodate material handling for the 30,000 tpsd commercial facility. The impacts of three barge dock scenarios at the proposed site are presented in this appendix. Section Y.4 discusses pollution control for coal delivery by barge. The impacts are based on preliminary design information provided by the International Coal Refining Company and the site-specific environmental data contained in the Environmental Report entitled "SRC-I Solvent Refined Coal Demonstration Facility Daviess County, Kentucky."

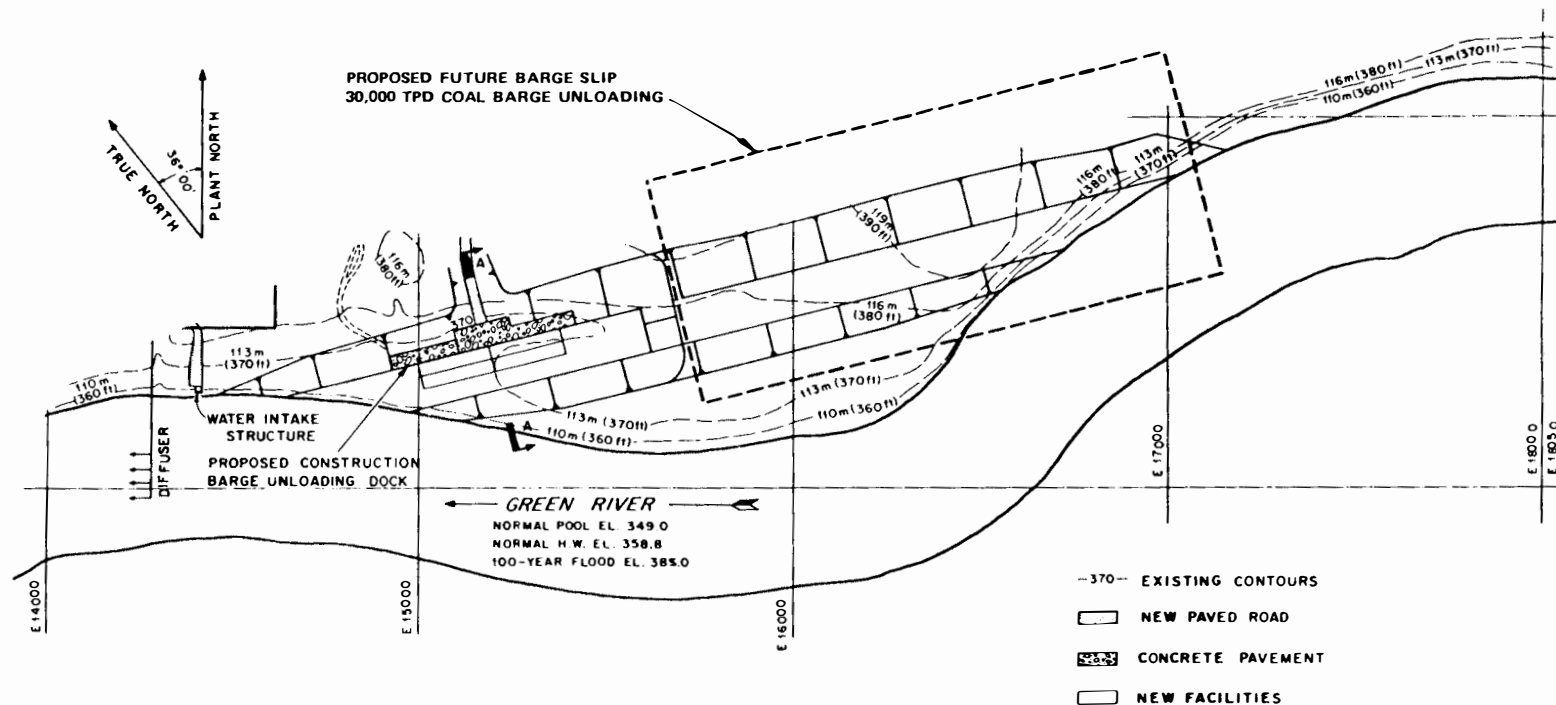


Fig. Y.1. Planned location of barge dock facility for the proposed SRC-I site.

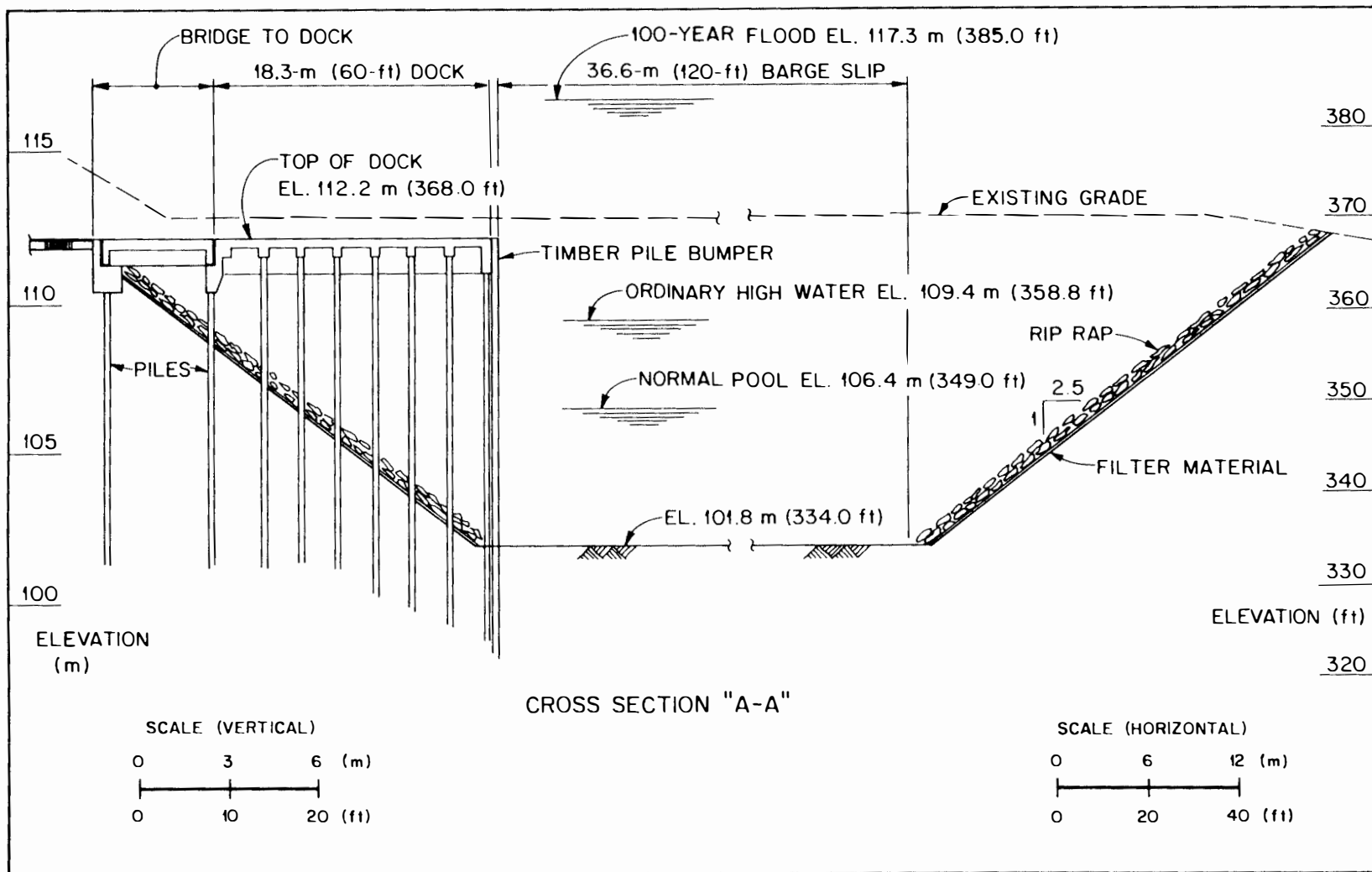


Fig. Y.2. Preliminary design showing cross section of the barge dock facility planned for the proposed SRC-I site.

Y.2.1 Actions under consideration

Scenario 1: Base case (demonstration plant)

Barge transportation would be used only for transportation of construction equipment; railroads would be used for transporting all coal and products. This scenario would consist of constructing a barge slip and an unloading dock. The facility would be used during construction to unload equipment which is too large to be transported by road or rail. The slip will be located at approximately RM 18.8 and could have an estimated length of 213 m (700 ft). Figure Y.1 details the size of the proposed barge slip for this scenario.

Scenario 2: Supplement to base case (demonstration plant) (not an alternative)

Some of the coal would be delivered by barge if the mine is not adjacent to a railroad. This scenario is a supplement (not an alternative) to Scenario 1 which would ensure a feasible mode of coal delivery to the proposed SRC-I facility.

Scenario 3: Commercial plant

The barge dock facility will be expanded to accommodate feed coal for a 30,000 tons per stream day (tpsd) facility. Product transportation is uncertain.

Y.2.2 Construction methods

The construction of the barge facility for unloading process equipment will begin as soon as possible after start of plant construction. The duration of the construction work is estimated to be approximately six months.

Earth removal for construction of the barge slip will use several methods. Scrapers will be utilized for all dry land excavation. Drag lines will be used for excavation below the water table, and scrapers or dump trucks will be used to haul the material to a storage site. A hydraulic dredge will be used to cut the final connection to the river channel. Removal of dredged material will be either by truck or pumping.

The clay overburden and all suitable material, if any, will be dried, stockpiled, and used to construct embankments during plant construction. Unsuitable material will be stored in the disposal pond. Figure 2.3 in Sect. 2 shows the location of the storage and disposal ponds for excavated and unsuitable materials (see boxes 36 and 37).

A diked area sufficient to contain the excavated material will be located on the high, terraced area on the southeast portion of the site. If possible, the bottom of the dike will be located above the 100-year flood elevation. The expected 100-year flood elevation at the Newman site is currently being reviewed. The original estimate of 385 ft mean sea level (MSL) was based on the U.S. Army Corps of Engineers' prediction for the Ohio River. The proposed disposal area will be located based on these new estimates of the 100-year flood elevation. As a worst case, the diked area would have to accommodate about 411,000 m³ (450,000 yd³) with Scenario 3.

Discharge from the disposal pond will be routed to the treatment basins which are designed to handle site construction drainage. Other alternatives such as discharging to Martin Creek or directly to the Green River may be investigated later.

During construction, riprap will be used to stabilize the banks of the barge slip. Because of the preliminary design of the facility, the type of the riprap to be used is unknown.

Y.2.3 Operation methods

The coal unloading facility required in Scenarios 2 and 3 will probably use a clam-shell to unload coal from the barges. The coal will be transported to the plant by an overhead, enclosed belt conveyor. A fog or atomized mist system will be provided at the coal discharge points for the unloading and transfer operation. The dust control and application method will be similar to the railcar unloading system. Section Y.4 discusses pollution control for coal delivery by barge.

Any wastewater generated from the material handling facility on the dock will be collected and routed to the plant wastewater treatment facilities.

Y.3 ENVIRONMENTAL EFFECTS

Y.3.1 Scenario 1

Y.3.1.1 Construction

Groundwater

The clay unit encountered in boring No. 10, as described in the soils and groundwater section, may act as an impermeable boundary to groundwater exchange with the Green River if it has a wide and continuous areal distribution. If this impermeable boundary is breached during construction of the barge slip, the groundwater flow regime from the site may be changed so that the groundwater is discharged through this opening. This would result in an increase in the hydraulic gradient and a corresponding increase in groundwater velocity in the site area. This effect will be confined to the site, and there will be no regional impact.

Another implication of the potential change in site groundwater velocity is the reduction in containment time for any plant-related contaminant such as leachate from material or solid waste disposal areas. To mitigate this potential problem and comply with RCRA regulations, a groundwater monitoring system will be designed to provide early detection of any plant-related leachate so that containment measures could be taken before the contamination moved offsite.

Surface water

Hydrology. Most of the excavation will be associated with development of the barge slip. The proposed slip for Scenario 1 will lie out of the river channel, and the open end of the slip will face west-northwest while the river flows in a west-northwest direction at this location (Fig. Y.1). For these reasons, the barge slip will have little effect on either the direction or speed of the river flow.

Water quality. Construction will cause temporary local increases in suspended solids, nutrient levels, and chemical and biological oxygen demand. However, as a hydraulic dredge will be used to remove bottom materials, the release of contaminants from the bottom sediments to the Green River will be low. Sediment data indicate that the trace elements boron, iron, manganese, and cadmium are present in high concentrations. However, when oxygenated surface waters are mixed with reduced sediments and interstitial reduced forms of iron and manganese, oxidation occurs and oxyhydroxide particulates are formed (Dames & Moore, 1980). These freshly precipitated colloidal hydrous oxides act as scavengers; adsorbing trace metals. Several studies have even shown small decreases in the soluble amounts of trace metals during dredging activities (Dames & Moore, 1980).

The insoluble and adsorbed PNA compounds that are physically resuspended and not transported by the dredge will most likely resettle to the bottom at varying distances downstream depending upon their mass and the water velocity.

As reduced bottom sediments are displaced, dissolved oxygen in the immediate area will act as an oxidizing agent. Depending on the conditions at the time of dredging, this will reduce levels of dissolved oxygen in the immediate area. Since flowing rivers often contain moderate amounts of dissolved oxygen even near the bottom, this usually would present a minor problem. During low flow and late summer temperatures, however, low dissolved oxygen levels near the bottom could be aggravated by dredging operations. However, because of the type of dredging proposed, these temporary effects should not be noticeable below the western boundary of the site.

Increases in suspended sediments will most likely cause the greatest change to ambient water quality during dredging operations. The resuspension of bottom sediments will result primarily from movement of the dredge barge and not from hydraulic dredging directly. Suspended particles will travel downstream to a distance dependent on current velocities and particle size.

Dredged material stored in a holding pond will contain chemical species found in the bottom sediments and interstitial water. As they are raised from the bottom and pumped ashore, they will be exposed to a more oxygen-rich environment than is found on and in the river bottom. One chemical change that can occur is the oxidation of sulfides to sulfate, which lowers the

pH and dissolves heavy metals of previously insoluble heavy metal sulfide precipitates. This is especially important where reduced dredged spoils are kept in aerobic conditions for extended periods (Dames & Moore, 1980). Polynuclear aromatic hydrocarbons will settle and should not constitute a problem.

Aquatic ecology

Benthos. Major impact of dredging on the benthos would be limited to those organisms in the area removed from the river channel to the shoreline when the barge slip is open to the Green River. Based on a velocity profile performed by Dames & Moore in July, 1979, about 300 m (984 ft) downstream of the proposed barge slip, the bottom would have to be dredged 13 m (43 ft) from the shore when the river is at normal pool. The area dredged would be in the shape of a parallelogram and would equal approximately 3300 m² (360 x 99 ft or 35,640 ft²). Based on densities of benthos ranging from 266-1006 organisms/m², this would result in the direct removal of 877,800 to 3,319,800 organisms, mostly oligochaetes, midge larvae, and Asiatic clams. The greatest removal would occur during late summer/fall and the least during winter. These impacts will not be significant due to rapid recruitment into the area following dredging and the relatively small area affected.

Other effects would result from the release of suspended solids which would then settle on areas that were not directly displaced. The effect of this will be small as the Green River already carries a heavy sediment load, and the benthos are largely silt-tolerant species.

Fish. Mature fish will avoid the area of construction and the resulting suspended sediment plume. Impacts to ichthyoplankton will depend largely on the time of year construction occurs. Primary impacts would be caused by entrainment into the hydraulic dredge. If construction begins in June, freshwater drum and catfishes will be affected. After mid-July, ichthyoplankton densities decline, but species of catfish would still be affected. Construction occurring from September through February would have little effect on ichthyoplankton.

Since the dredging will entrain only a very small proportion of the total number of organisms passing the dredged area and because of the high fecundity and inherent high mortality rate of fishes, this impact of short duration would be negligible in terms of total impact.

Terrestrial biology

Vegetation. Construction of the barge slip will result in the disturbance of approximately 213 m (700 ft) of shoreline habitat. Since the woodlands extend approximately 40 m (131 ft) inland, about 0.8 ha (2 acres) of riparian vegetation will be removed. This represents 3.2% of the total site woodland habitat and about 0.2% of the total site area. Also, a 183- x 46-m (600- x 150-ft) extension of riparian woods farther off the river would be lost. This represents the loss of another 0.8 ha (2 acres). Together the total woodlands lost to construction represent 6.4% of the woodland area and 0.4% of the total site. The disposal pond will be located in a field that should represent a minor loss of native vegetation.

The habitat that would be lost by construction of the barge slip is not unique to the site region but does represent a loss to a declining natural habitat.

Wildlife. Primary impacts during construction will be direct disruption of habitat and less direct effects such as noise, odor, and dust accompanying construction activities. During construction, most birds and mammals will avoid the immediate and adjacent areas.

The loss of habitat should not have an impact of significance to the area. This habitat is not contiguous with similar habitats and, therefore, has limited usefulness, particularly for large mammals.

Noise

During construction of the barge slip and dock, noise levels should be similar to estimates presented in the Environmental Report, entitled "SRC-I Solvent Refined Coal Demonstration Facility, Daviess County, Kentucky" for different phases of construction. Noise generated

during excavation of the process plant and settling ponds is estimated at 94.1 dB at 15 m (50 ft). This noise level should be similar to that expected for barge slip construction. The noise level projected during construction of the foundation, which includes pile driving, should be similar to construction of the barge dock. The noise level for the barge dock construction should be approximately 92.1 dB at 15 m (50 ft).

Construction noise for the proposed plant is expected to produce noise of 63.5 dB at the nearest residence, which is 990 m (3260 ft) from the site. The barge slip and dock facility is in excess of 1500 m (5000 ft) from the nearest residence. Therefore, noise levels from the barge slip and dock should not cause a significant increase in construction noise impacts.

Barge traffic

Navigation on the Green River is from mile 0 at the mouth to mile 103, with a project depth of 2.7 m (9 ft) and a maintained width of 61 m (200 ft) by the Corps of Engineers. From mile 103 to mile 108, the 2.7 m depth is maintained privately, as there is a coal loading dock at the upstream location.

The effect the project would have on transportation on the Green River is strongly influenced by the capacity of Locks 1 and 2. Both locks have about the same capacity (51.3 million tons per year). The locks are designed to handle 4 barges that constitute a tow. A coal barge contains approximately 1500 tons. Therefore, one tow would transport 6000 tons of coal through a lock per cycle.

Tonnage moved on the Green River has varied from approximately 17 million tons per year in 1970 to 13.5 million tons per year in 1977 (last available statistics). The reason for a decline in tonnage is due to recent regulations that have limited western Kentucky coal as a fuel for the electric power industry. Western Kentucky coal is high in sulfur and requires increased scrubbing for sulfur dioxide removal. Therefore, this portion of the mining industry is slightly depressed.

Excavation will be required for the barge dock for unloading construction equipment. During this construction there will be equipment (barges, pile drivers, dump scow) at the river shore. This equipment and particularly the dredge will tend to occupy part of the navigable channel, and suitable markings will be provided to warn passing river traffic. Disturbance to barge traffic should be minimal because of the short time required to dredge the connection to the Green River.

Y.3.1.2 Operation

Barge traffic

The use of the dock facilities for unloading construction equipment which is too large for truck or rail transportation will not affect transportation on the Green River or through the locks. Transportation attributed to construction will have an insignificant effect on the Ohio River as well.

Water quality

Operation of the dock will not result in any direct plant discharges to the Green River. The majority of the tonnage received at the dock will be equipment or equipment-related so that potential spills or accidents would not affect the aquatic biota.

Biology

Operational impacts to the aquatic and terrestrial biota should be minimal. Primary impacts to aquatic life will be related to barge traffic which causes disturbances of the bottom sediments in shallow waters.

Noise would be the main impact to wildlife. However, many species will become conditioned to the noise, and the operational impact will be very minor.

Noise

During construction of the SRC-I plant the dock facility will commence operation to unload equipment. The major nonmobile noise source will be the diesel motor on the crane. This equipment will operate intermittently during daylight hours only. The noise impact of this type of operation should be minimal (note rationale in construction section).

Y.3.2 Scenario 2Y.3.2.1 ConstructionGroundwater

Same as Scenario 1.

Surface water

Same as Scenario 1.

Aquatic ecology

Same as Scenario 1.

Terrestrial ecology

Same as Scenario 1.

Noise

Same as Scenario 1.

Y.3.2.2 OperationBarge traffic

Because each barge carries about 1500 tons of coal and there are four barges per tow (U.S. Army Corps of Engineers 1980), 1.2 tows per day would be required for the demonstration plant. Loading of SRC solid product would probably require a maximum of one additional tow per day. This could add 4.4 movements per day to this area of the river. In addition, establishment of a 30-d stockpile would require an initial 36 movements to and from the site. Kieffer (1980) has indicated that three commercial scale synthetic fuels plants on the Green River will present no problems to the lock and dam system. River traffic has remained well below the design capacity (an approximate capacity of 51.3 million tons per year). Tonnage on the Green River has varied little in recent years; the largest amount, 17 million tons, was moved in 1970, while the smallest amount, 13.5 million tons, occurred in 1977 (Nick Kieffer 1980).

Water quality

Diesel exhaust on the tugs is vented to the air and, therefore, water pollution emanating from barge traffic would consist primarily of oil and grease. Other operational water quality impacts would include settling of fugitive dust and coal spillage during transport and unloading. Rail car unloading has been found to release 0.4 lb of fugitive dust for each ton of coal (EPA 1974). Based on leachate tests of Kentucky No. 9 coal (Boston & Boegly 1979) leaching of the settled dust would produce a leachate similar to that shown in Table P.1.

Small increases in arsenic, iron, and sulfates would result from leachate. The small quantities of these materials should result in minor impacts.

Biology

Adult fish will avoid the area around the entrance to the barge slip during barge movements but will be little affected when no barges are in motion. Some loss of ichthyoplankton near shore during spring and summer will occur as a result of engine backwash. This will be insignificant due to the small area additionally disturbed and the low number of barge movements per day (approximately 5).

Operational impacts to riparian vegetation will consist almost entirely of air pollution in the form of fugitive dust and diesel emissions. These effects would be limited to very near the proposed facility and, therefore, impact should be minor.

General activity around the docking facility, including road traffic, barge traffic, machinery noise, and the conveyor system will cause larger mammals and many birds to avoid the area. Small rodents and most reptiles and amphibians will probably be little affected.

Air quality

The primary air quality impact of the operation is the dock material handling facility. It is projected that approximately 10,000 to 12,000 tpsd of coal and product will be handled by the facility.

Levels of fugitive dust emissions for rail unloading of coal has been projected at 0.4 lb/ton of coal (EPA 1974). However, rail unloading is an inherently dusty operation. The level of emissions for the barge unloading should not approach that level for several reasons. Barge unloading does not generate as much air current to move dust as does rail unloading. Also, most fines associated with the coal seive to the bottom of the barge where moisture tends to wet the fines. These factors combine to make barge unloading a more dust-free operation than rail unloading. However, State regulations do not differentiate between these types of operations in terms of fugitive dust.

Little is known about the size or dust potential of the SRC-I product. However, the impact should not exceed that for rail unloading of coal.

Several factors should limit impact of fugitive emissions. The wetting agents used as mitigating measures should limit the amount of emission. Also, the conveyor will be covered. Therefore, the major impact should be within the plant and possibly within the barge slip.

Noise

The major nonmobile noise source during operation will be the coal unloading facility. The type of equipment has not been selected. Preliminary equipment considerations include a clam-shell unloader which could handle 1500 or more tons/h or a bucket type unloader rated at 3000 to 5000 tons/h. The clam-shell unloader could unload the daily coal requirement in 4-5 h for the 6000 tpsd plant and would be adequate for the 30,000 tpsd plant if unloading around the clock.

The clam-shell unloader noise is generated by the diesel motor. The clam-shell itself will not produce a significant noise. Based on the projected unloading rate, coal unloading could be limited to 4 or 5 h of the 8-h-d shift for 6000 tpsd and 20 to 21 h for 30,000 tpsd. Noise levels of 82 dB are expected for this equipment.

The bucket type unloader will produce noise from an electric motor and also from the movement of the mechanical bucket. This unloader would need to operate only 2-3 h a day during the 8-h day shift. Noise levels of 90 dB are expected from this equipment.

The noise impact should be minimal from the intermittent day time operation of either type of equipment because of the distance to the nearest noise sensitive area (Sect. X.3.1.1).

Y.3.3 Scenario 3

Y.3.3.1 Construction

Groundwater

An impact similar to that described in Scenario 1 is expected. The effect will be minor and quite localized if the clay layer is breached at all.

Surface water

Hydrology. Some of the Green River flow will be diverted through the barge slip. This will cause a path of "least resistance" and could result in bank erosion near the upstream end of the slip.

Water quality. As in Scenarios 1 and 2, construction impacts on water quality will result primarily from the suspension of sediments during dredging. It is believed that heavy metals and organic compounds released from the sediments will not be dissolved in the water column. The short duration of the actual bottom and shoreline dredging will also reduce potential for impacts.

Aquatic ecology

Impacts to the aquatic biota will be similar to those described for Scenario 1. These will include: (1) additional loss of benthic organisms, (2) increased loss of ichthyoplankton due to gill smothering and entrainment, and (3) fish avoidance of the upstream portion of the slip during dredging.

Again, the impacts should be insignificant due to the silt-tolerant organisms present, rapid recruitment following dredging, and the short duration of waterfront construction. The greatest impact would occur in late spring-early summer when ichthyoplankton densities are high.

Terrestrial ecology

Vegetation. Southeasterly extension of the barge slip to join the Green River will result in additional loss to the woodland. This will remove approximately 1.7 ha (4.1 acres), or another 6.4% of the woodland area onsite. Combined with the woodland loss incurred by Scenarios 1 and 2, the total loss would be almost 12.8% of the total wooded area onsite.

This construction will not affect unique vegetation or significantly reduce the riparian woodland in the area but does represent a loss to a declining natural habitat.

Wildlife. The main impact of construction will be habitat loss as described under "Vegetation." This includes the separation of about 1.7 ha (4.1 acres) of riparian woodlands, which will prevent overland migration. Also, this area will be under water during floods which approach the 100-year magnitude. Some mammals will be eliminated. The total impact of the third scenario will be to eliminate over 3.4 ha (8.2 acres) of riparian woodland habitat available to wildlife. This level of impact should not be significant due to the already reduced quality of the habitat.

Noise

Similar to Scenarios 1 and 2.

Y.3.3.2 Operation

Barge traffic

Based on a receiving rate of 36,500 tons/d of coal, 6.1 coal barges per day would be required. If these barges then return empty, about 12 movements per day would result from coal-related

barge traffic alone. This amount of coal moved on the Green River, 13.3 million tons per year, would very nearly equal the total tonnage presently moving on the river. However, if this coal comes down the Green River, it will not have to lock through Lock and Dam No. 1, thus eliminating additional congestion in this pool. The design capacity of Lock No. 2 could be approached if additional coal-requiring plants (such as Baskett) are built on the river.

The movement of product will add more barges to the river. This movement would probably be in a downstream direction through Lock No. 1. If the product from the Baskett site (below Lock No. 1) also moves downstream, this will relieve congestion in Lock No. 1.

Water quality

Water quality in and downstream of the barge slip would be lowered by tug emissions, coal spillage, and settling of fugitive dust. Primary pollutants would consist of the leachate in western Kentucky coal as described earlier and presented in Table P.1. Since the slip is open to the river at its upstream end, the downstream end will act much like a point discharge in carrying these pollutants into the river. Also, this plume will immediately pass by the water intake device. Relocation of the intake is being considered.

Because of the quantity of pollutants and dilution available in the Green River, violation of water quality standards is not expected.

Biology

Aquatic biology. Increased barge traffic near shore at both ends of the barge slip will result in greater avoidance by fishes. As ichthyoplankton are more concentrated near shore, these increased levels of suspended solids, coupled with barge traffic, will result in ichthyoplankton mortality. However, natural mortality is so high that this impact will be undetectable.

Benthos will be affected by coal spillage from barges and settling of fugitive dust from unloading operations. Sediment quality at the mouth and downstream of the barge slip will deteriorate, and benthos living in these areas will contain increased amounts of heavy metals and organic compounds. Due to the limited area that will be affected, the impact will be minor.

Vegetation. Impacts will result from fugitive dust and diesel emissions as in Scenario 2. These impacts will be very localized.

Wildlife. Loss of habitat was discussed under construction impacts. The primary effect of operation would be avoidance of the immediate and adjacent areas. This will increase competition in surrounding habitat by more individuals trying to occupy a smaller area. This will be especially true of species that utilize riparian habitat such as gray fox, fox squirrel, woodchucks, opossum, and several bat species.

The loss of 1.7 ha (4.1 acres) should not result in a significant impact.

Air quality

Air quality impacts will be similar to Scenario 2. However, duration of unloading activities will increase emissions by approximately twice over Scenario 2. The major impact should be limited to the plant property and possibly to the barge slip.

Noise

The major nonmobile noise source during operation will be the coal unloading facility. A bucket type unloader rated at 3000 to 4000 tons/h may be used. The bucket unloader could unload the daily coal requirement in 9-12 h for the 30,000 tpsd plant.

The bucket type unloader will produce noise from an electric motor and also from the movement of the mechanical bucket. During the demonstration phase, this unloader would only need to operate 2-3 h a day during the 8-h day shift. Noise levels of 90 dB are expected from this equipment.

Equipment operation should have a minor impact as the distance to the nearest residence is over 1500 m (5000 ft).

Y.4 CONTROL OF DUST PARTICULATE MATTER EMISSIONS FROM COAL DELIVERY BY BARGE

Y.4.1 Introduction

Transportation of coal by barge is being investigated as an alternative to the transportation of coal by rail car. The barge slip will be located on the Green River, which is the southern boundary of the plant site.

Y.4.2 Venting operation

The main sources of emissions include particulate emissions from unloading operations and conveyor and conveyor transfer points.

Y.4.2.1 Particulate emissions from unloading operations

Coal barges will deliver 7000 tons/d (wet basis) of cleaned and washed coal to the site. Each barge will be unloaded by the clamshell bucket of a traveling gantry crane that traverses along the dock. The clamshell bucket lifts the coal from the barge and delivers it to a hopper which in turn feeds the coal to a conveyor. Both the hopper and conveyor are connected to the gantry crane.

Y.4.2.2 Conveyor and conveyor transfer points

A fully enclosed belt feeder will deliver the coal to the conveyor, which is connected to the gantry crane. The coal will be fed to the conveyor at several points, thereby requiring the conveyor to be fully open. The coal is conveyed a maximum distance of 590 ft fully open and then sprayed with chemical wet suppressants before transport to the Coal Preparation Area.

The coal preparation area emissions are discussed in Appendix C, Sect. C.2.2.3.

Table Y.1 lists uncontrolled particulate emission estimates. A reliable emission factor for calculating fugitive emissions from a coal barge is not available; therefore, a factor for rotary dump from a railcar is used.²²

Table Y.1. Uncontrolled emissions

Operation	Coal handling schedule	Emission factor	Emissions (lb/year)
Fugitive sources			
Coal unloading	7000 TPD	0.007 lbs/ton ^a	16,170
Conveying and transfer	7000 TPD	0.2 lbs/ton	462,000
Point sources			
Dust collector exhaust fan	8 hr/day 330 day/week	2.0 grains/scfm	8,000,000

^aData from U.S. Environmental Protection Agency, *EPA Region VIII Interim Policy Paper, Air Quality Review of Surface Mining Operation*, Table 1, item 9.

Y.4.3 Proposed control system

Current methods available to control coal handling particulates include the use of three commonly used control techniques: dust suppressant chemicals, dust containment provisions at transfer points, and fabric filter dust collectors. All of these methods will be incorporated into the coal unloading facility.

The dust suppressant chemical planned for use at the facility will be Johnson March's "Compound M-R," Dust Suppression System Inc.'s "Compound JB," or an equivalent. These compounds are diluted with water and fogged through nozzels onto the coal. The application of the dust suppressing compounds reduces surface tension, which results in increased wetting, penetration, and spreading capabilities of the liquid mixture. This increases the capacity to wet the coal and consequently to control dust formation. It also enables the coal to flow more freely.

The control methods described in Sects. Y.4.3.1 and Y.4.3.2 will be used for the barge unloading and transfer of coal to Area 11.

Y.4.3.1 Barge unloading operations

The clamshell bucket will lift coal from the barge and discharge it into a hopper located on the dock. Dust-laden air from the hopper will exhaust through a fabric filter to the atmosphere, and the reclaimed dust will be returned to the hopper. The dust collection system will be arranged so that the dust-laden air will be drawn down into the hopper for collection.

A fully enclosed belt feeder will discharge the coal from the hopper to a conveyor.

Y.4.3.2 Conveyor and conveyor transfer points

As previously mentioned, the initial coal conveyor connected to the gantry crane will be open to the atmosphere.

The open conveyor will discharge the coal to a partially enclosed (top and sides) conveyor. The transfer will occur in a transfer house where the coal will also be sprayed with dust suppression liquid.

The subsequent transfer point will also be enclosed in a transfer house. At this point the coal will be sufficiently wetted with dust-suppression liquid to preclude additional wetting.

Y.4.4 Control efficiency

Y.4.4.1 Barge unloading operations

The quantity of dust emitted during barge unloading is relatively small in comparison with railroad car unloading.²³ Barge unloading does not generate as much air current to move dust as rail unloading. Also, most fines associated with coal will sieve to the bottom of the barge where moisture tends to wet the fines.

Because the fugitive particulate emissions for barge unloading were calculated using an emission factor for railcar unloading, it is believed that the reduction in air currents will allow the use of an 85% control efficiency for calculating controlled fugitive particulate from barge unloading.

The hopper will exhaust into a dust collector which will vent at a concentration of 0.01 grains/SCF.

Y.4.4.2 Conveyor and conveyor transfer points

For the most part, coal will be heavily wetted, conveyors will be partially closed, and transfer points will be completely enclosed. An efficiency of 90 to 99% has been assumed for conveying of coal.

Table Y.2 lists uncontrolled and controlled emission rates.

Table Y.2. Uncontrolled and controlled emissions

Operation	Uncontrolled emissions (lb/year)	Efficiency (%)	Controlled emissions (lb/year)
Fugitive sources			
Coal unloading	16,170	85	2,425
Conveying and transfer	462,000	99	4,620
Point sources			
Dust collector exhaust fan	8,000,000	99.5	40,700

Y.4.5 Best available control technology rationale (from PSD permit application)

Y.4.5.1 Barge unloading operations

An alternative considered was the installation of a transparent cover over the clamshell bucket as suggested in ref. 23. Because the clamshell bucket will be operating near the river, moisture will cause coal fines to adhere to the cover, thereby causing a problem with operator visibility.

Y.4.5.2 Conveyor and conveyor transfer points

The initial conveyor located on the gantry crane cannot be covered because of the nature of the operation. This represents about 10% of the distance the coal will be conveyed. The remaining conveyors will be partially enclosed (tops and sides). The conveyor transfer points will be totally enclosed by transfer houses and the coal will be wetted with dust-suppression liquid.

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Appendix Z
HEALTH EFFECTS



Appendix Z

HEALTH EFFECTS

A summary of the potential occupational and public health effects associated with coal conversion is given in Sect. 4.1.1 of this FEIS. Section Z.1 presents a summary of the health and safety programs at the SRC pilot plants and proposed for the demonstration plant. Section Z.2 presents a summary of the health and environmental research program proposed for the SRC-I demonstration plant. A summary of results to date for the SRC-I and SRC-II pilot plants is given in Sect. Z.3. The detailed DOE environmental plan for SRC technologies is given in Appendix Y of the SRC-II FEIS (DOE/EIS-0069).

Z.1 SUMMARY OF HEALTH AND SAFETY PROGRAMS AT THE FORT LEWIS AND WILSONVILLE PILOT PLANTS AND PROPOSED FOR THE DEMONSTRATION PLANT

The demonstration plant health program will be patterned after and based on information obtained and developed since 1974 from the health program for the SRC pilot plants at Fort Lewis, Washington, and Wilsonville, Alabama.¹

The health and safety program proposed for the SRC-I demonstration plant will consist of (1) a Health Protection Program aimed at protecting personnel from potential toxicological effects of some coal-derived materials and (2) a General Industrial Health and Safety Program aimed at protecting personnel from conditions and materials common throughout much of the chemical- and petroleum-processing industries. Both programs are discussed in the following sections.

Z.1.1 Health protection program

A comprehensive health protection program planned for the SRC-I demonstration plant will include the following subprograms:

1. education,
2. hygiene,
3. medical,
4. monitoring, and
5. toxicology.

Z.1.1.1 Education

Objectives of the demonstration plant educational program will be to (1) inform the worker of the known and potential hazards in the work environment, particularly those associated with exposure to coal-derived materials and (2) motivate the worker to use appropriate protective measures.

At the Fort Lewis SRC pilot plant, all new employees receive a health protection indoctrination that begins with an audiovisual slide presentation. This slide presentation shows the employee the potential health hazards present in the plant, the measures taken by the company to protect the employees, and what the employees must do to protect themselves. The presentation begins with a brief explanation of the plant process, then progresses to cover a variety of topics ranging from hazardous compounds, air monitoring, and animal toxicity studies to clothes changing during shift (when clothes get excessively contaminated), ear protection, footwear, gloves, skin barriers and emollients, skin cancer, skin-wipe samples, reporting of skin abnormalities and injuries, respirators, and first-aid equipment. The slide presentation concludes by encouraging the employee to ask questions concerning the health protection program. All new employees are issued a health protection manual. Employees are then taken through the locker/changehouse area and shown the location of (1) entrances and exits (for both before and after work); (2) their lockers and stalls; (3) the shower, soap, and towels; and (4) clean and dirty

clothing storage areas. During the tour of the locker/changehouse, the employee is encouraged to ask questions. Following the tour, the new employee is taken to the nurse's office for completion of the health protection induction.

Health protection classes on various subjects have been held for SRC employees since the spring of 1974. Generally, the classes are presented by the Supervisor of Health Protection, who is assisted by the SRC industrial hygiene technician. Occasionally, various members of the Corporate Medical Department, such as the Regional Medical Director or the Regional Senior Industrial Hygienist, have given health protection presentations. In addition to the SRC health protection slide presentation, classes in the SRC Health Protection Program cover the following topics: health and hygiene, toxic hazards to the human body, and toxic gases (SO_2 , H_2S , and CO).

Z.1.1.2 Hygiene

Workers in the demonstration plant will be provided with protective equipment, clothing, facilities, and techniques to minimize exposure to coal-derived materials.

At the Fort Lewis pilot plant, each process area employee is issued rubber boots, leather high-top safety shoes, a hard hat, work coats, skin emollient, barrier creams, and two weeks' supply of work uniforms, underclothing, and socks. Each employee is assigned a locker in the locker room (clean area) and a stall in the changehouse (dirty area).

To protect the worker and to prevent carrying coal-derived contaminants off the plant site, special procedures have been developed for process area workers.

Upon coming to work, the employees go directly to the locker room and change into a clean uniform, which includes underwear, shirt, pants, and socks. Then, proceeding to the changehouse in shower shoes, the employees don work footwear, headgear, and rain suit, if needed. They then proceed to the work area, and the procedure is reversed at the end of their shift. On the way to the shower, dirty underclothing is left in a mesh bag in the changehouse (dirty area), and the dirty uniform is dropped in a dirty-clothes bin to be laundered. The employees are encouraged to thoroughly wash any coal product from their body. Skin examinations with an ultraviolet light are periodically given by the plant nurse to determine the effectiveness of the employees' showers. Because of the concern over the role of UV light in carcinogenesis, such examinations will be conducted in the demonstration plant only in the cases of significant skin contamination with coal tar product. The examination will be limited to the site of skin contact and will use a low-intensity (4 to 6 watt) UV light source. Any employee experiencing a spill of coal-solution solvents or chemicals during work is required to shower and change clothes as soon as possible.

Employees entering vessels or undertaking exceptionally dirty jobs are required to wear rain suits or coveralls over their uniforms and appropriate gloves. Impervious gloves providing good grip and wrist protection are favored by the employees. Neoprene appears to be more resistant to the solvent than other materials.

Z.1.1.3 Medical

The demonstration plant medical program will seek to (1) detect any occupationally related changes in worker medical profiles at the very earliest stages; (2) reverse, to the extent possible, any untoward impact; and (3) establish causality and preventive strategies if any occupationally related health problems are detected. The anticipated approach will be an extension of the SRC pilot plant program and will use preemployment and periodic medical examinations together with intensive analysis of such examinations and the occupational and personal histories of the workers.

The medical program for all exposed employees at the SRC pilot plant was started in 1974, before the plant was put into operation. Before an applicant is hired and annually thereafter, a medical examination is performed that consists of a medical history and a complete physical examination.

A complete blood count is performed consisting of a white blood cell count, hemoglobin, hematocrit, mean corpuscular hemoglobin concentration, and a differential count of white cells. Blood chemistries are performed that include total protein, albumen, calcium, inorganic phosphorus, cholesterol, uric acid, creatinine, total bilirubin, alkaline phosphatase, creatinine phosphokinase, lactic dehydrogenase, serum glutamic oxalacetic transaminase, potassium, sodium, blood urea nitrogen, and glucose. A urinalysis, including microscopic examination, is also done.

The skin is examined carefully for evidence of lesions, and the employees are asked to report any unusual skin conditions or lesions. The annual skin examination is supplemented by a quarterly skin examination by the plant nurse. Employees with dermatologic problems requiring a physician's care are referred by the plant nurse to a board-certified dermatologist.

Posterior-anterior and lateral chest x-rays are taken and interpreted by a board-certified radiologist. Pulmonary function tests are performed by the plant nurse.

Evaluation of the findings of the surveillance medical program has indicated no discernible changes in the medical profiles of the exposed employees. The only known occupational health problem encountered at the SRC pilot plant is mild transient dermatitis from skin contact with coal-derived materials.

The most common medical problem has been eye irritation; 50 to 60 cases, approximately 10 of which involved substantial quantities of coal-derived solvents contacting the employees' eyes, have been treated. In all cases, these eye irritations responded satisfactorily to first-aid treatment consisting of eye irrigation with saline solution. Follow-up medical examinations by an ophthalmologist confirmed the absence of any prolonged or permanent eye damage. The strongly irritating characteristic of the lower boiling fractions of SRC liquids is probably due to their phenolic content.

Comprehensive periodic assessment of the health of the plant population at the Wilsonville facility reveals the type of health experience that may be found in any mixed age male working population. Principal problems are hypertension, obesity, blood lipid abnormalities, and chest symptoms among smokers.

Special skin examinations and diagnostic follow-ups by a university-based dermatological group has not identified work-related skin disease.

About 25 cases of transient erythema and multiple cases of mild folliculitis (mechanics acne) have been observed. These cases have responded well to temporary suspension of exposure.

Two employees developed squamous cell cancers. One employee had previously worked nine years in a petroleum refinery and was a cigarette smoker. The Washington State Board of Industrial Insurance Appeals determined that the lip cancer was unrelated to his employment in the SRC pilot plant. The other employee had only worked at the pilot plant for one year in a supervisory capacity, and the cancer was diagnosed as the result of exposure to sunlight from his past work history in such areas as Kuwait.

Current experience with the SRC pilot plant employee population has not revealed any of the problems experienced in the Institute plant population where 60 skin lesions were excised from a group of 359 coal hydrogenation workers during a five-year period.² The intensive employee health programs, in place at the SRC pilot plant essentially since start-up, are felt to be the major differences between the plants.

Z.1.1.4 Monitoring

The demonstration plant monitoring program will monitor the workplace for conventional toxic materials and physical agents common to refinery and chemical operations as well as to those exposures unique to coal liquefaction. Development work is currently under way on techniques for monitoring dermal contamination by potentially toxic materials; if successful, these techniques will be implemented in the demonstration facility. Sect. 4.5 details the proposed environmental and health monitoring programs.

In late 1972, before construction of the SRC pilot plant at Fort Lewis, Washington, an ambient air and water quality study was initiated around the plant site. Designed as a baseline assessment of the air and water quality in the vicinity of the plant, the study would then be used for comparison with a similar study to be accomplished during full plant operation to assess the impact of the plant on the surrounding community. This study subsequently was expanded to include determination of the fate of trace elements in the SRC process.

The baseline study was conducted during the period of December 1972 to December 1973.¹ An air quality network composed of 15 sampling locations was established around the new facility in areas where a receptor would be exposed to a change in air quality. Measurements were made for suspended particulates, carbon monoxide; carbon dioxide, oxides of nitrogen, hydrocarbons, sulfur dioxide, and hydrogen sulfide. Water quality was measured through a series of sampling stations at locations on the adjacent lake, streams, swamps, and drainage ditches that might be influenced by the plant operation. Samples were collected and analyzed during the period December 1972 to August 1973. A biological examination of the lake, springs, creeks, and marshes adjacent to the facility was conducted in June 1973.

Start-up of the pilot plant began in late 1974 with integrated operation of the plant accomplished in February 1975. Environmental sampling and analyses will continue for the duration of the pilot plant operations. Hundreds of samples have been obtained and analyzed with these typical results for various materials.

	SRC-I	SRC-II
Airborne organic vapors, ppm	<0.1	<0.1
Benzene vapor, ppm	<<1	<<1
Total suspended particulates, mg/m ³	~0.7	~0.6
Asbestos fibers, fibers/ml	<0.1	^a
Hydrogen sulfide, ppm	Trace	Trace
Sulfur dioxide, ppm	≤0.04	≤0.04
Phenolic vapors, ppm	<0.008	<0.008

^aNo asbestos used in plant during SRC-II operation.

Results of the water sampling program for stations surrounding the pilot plant are shown in Table Z.1.

Table Z.1. Surface water quality at the Ft. Lewis SRC plant						
	Average values (seven sampling stations)					
	1973 ^a	1976	1977	1978	1979	1980
Dissolved oxygen, mg/liter	8.8	7.6	7.2	6.8	7.0	7.2
Specific conductance, μ ohm/cm	103	139	181	138	135	110
pH	6.8	7.1	6.6	6.4	6.8	7.7
Sulfate, mg/liter	10.8	9.9	26	16	17	21
Phenol, μ g/liter	<50 ^b	<50 ^b	<5	<5	<5	<5
Chemical oxygen demand, mg/liter	2.7	7.1	11.2	9.1	4.6	11.2
Phosphate, mg/liter	0.05	0.01	0.08	0.08	0.06	0.16
Nitrate, mg/liter	0.26	0.19	0.26	0.19	0.11	Not available

^aBaseline.

^bDetectable limit of analytical method then in use.

As a result of this program, the following can be concluded:

1. Air quality around the SRC pilot plant is essentially unchanged from those conditions that existed during the baseline study.
2. Overall, little change occurred in the patterns of water quality observed around the SRC pilot plant between the baseline period and the plant operating period.

3. Foliage studies in areas adjacent to the SRC pilot plant that would be probable receptors of airborne pollutants indicate no discernible effect upon the dominant vegetative species.

The more pertinent industrial hygiene sampling results in Wilsonville are presented in Tables Z.2 and Z.3. In Table Z.2 coal-tar-pitch volatile concentrations are listed by job category of the employee. The samples were obtained using personnel monitors. The Occupational Safety and Health Administration (OSHA) time-weighted average (TLV) for benzene-soluble coal-tar-pitch volatiles is 0.2 mg/m^3 . Most of the samples are down near the lower detection limit (approximately 0.03 mg/m^3). The one sample that is over the OSHA standard was taken during upset conditions.

Table Z.3 represents an analysis of individual polycyclic aromatic hydrocarbons (PAHs) and azaarenes from combined aerosol and vapor samples. The sample taking and analysis was conducted by Enviro Control, a subcontractor to the National Institute of Occupational Safety and Health (NIOSH). The results indicate that individual differences in the summed PAHs analyzed seem to be greater than the differences between job categories. Although most of the values in Table Z.3 are low, there are no TLVs for individual PNAAs.

The individual compounds are listed approximately in order of increasing molecular weight. The largest compound detected was pyrene, which was also the only compound detected that had four or more rings. This may well be due to the low volatility of the higher molecular weight PAHs and azaarenes. It should be noted that nearly 90% of the total sample was comprised of nonmutagenic/carcinogenic (for these classes of compounds), more volatile, two-ringed compounds. Most of the remainder was found in the weakly mutagenic/carcinogenic, three-ring compounds that are intermediate in volatility. Extremely small amounts of material were detected in the mutagenically/carcinogenically active, less volatile four-or-more-ringed compounds. Pyrene, the only compound detected in this group, is nonmutagenic/carcinogenic.

It thus appears that the substance analyzed as coal-tar-pitch volatiles on personnel samples contains very little mutagenically/carcinogenically active material. This seems to be due in part to the low volatility of the mutagenic/carcinogenic components.

Table Z.4 presents compiled data for even more volatile species that may have potentially toxic effects. The compounds listed include benzene, aniline, phenol, paracresol, and quinoline. All concentrations listed are well below any OSHA standard. Samples were not analyzed for the human carcinogen naphthylamine (a two-ring amine); however, concentrations are expected to be less than aniline (a one-ring amine) due to its lower volatility.

Z.2 DETAILED ENVIRONMENTAL PLAN: HEALTH AND ECOLOGICAL EFFECTS

DOE's detailed environmental plan for SRC technology is given in Appendix Y of the SRC-II FEIS (DOE/EIS-0069). Given adequate funding, the program will be implemented by DOE. This section summarizes the Joint Environmental Plan for Health and Ecological Effects proposed for the SRC-I demonstration plant. Should DOE discontinue its involvement in this project, the new project sponsor(s) would not be obliged to carry out the full program; but the sponsor(s) would be obliged to carry out the parts of the program required by regulation.

Research should be prioritized because financial constraints may prevent all of the proposed research from being completed. The research emphasis should be placed as follows:

- Chemical characterization of SRC materials.
- Biological testing of SRC materials, with emphasis on whole animal testing and in vitro studies designed to elucidate genotoxic response mechanisms. Essential testing includes dermal and inhalation carcinogenesis, teratogenesis, and male reproductive effects.
- An extensive monitoring program for the demonstration program that will allow estimation of both inhalation and dermal exposures to "indicator" compounds for each family of hazardous compounds expected to occur (e.g., polycyclic aromatic hydrocarbons, aromatic amines, aza-imino-arenes, phenols).
- Definition of the extent of variation in chemical and biological activity of SRC materials as a function of feedstock, temperature, pressure, and likely process modifications.

**Table Z.2. Coal Tar Pitch Volatile (CTPV) monitoring,
SRC-I pilot plant at Wilsonville, Alabama**

Title/operation ^a	Sampling time (min)	CTPV ^b (mg/m ³)
B operator	453	0.06
C operator	452	0.14
Lab, sampling and analysis	437	0.08
Oiler	446	0.17
Welder/millwright	453	0.07
B operator	458	0.09
Lab, inside	427	0.02
Instrument technician	465	0.06
B operator	460	0.02
Lab, sampling and analysis	433	0.03
Insulator	443	0.07
C operator	419	0.06
Instrument technician	451	0.12
B operator	448	0.12
Electrician	446	0.04
B operator	466	0.19
D operator	465	0.05
Chemist (boiler area)	455	0.19
Millwright	424	0.53 ^c
C operator	456	<0.02
D operator	436	<0.02
B operator	453	<0.03
D operator	435	0.04
Lab technician	431	0.04
Lab technician	436	<0.02
Millwright	417	0.10
Millwright	420	0.05
Lab technician	451	<0.02
Lab technician	447	<0.03
B operator	445	0.03
D operator	445	<0.02
Welder	448	0.02
Insulator	440	0.03
D operator	471	<0.02
C operator	472	0.05
D operator	451	<0.02
D operator	452	0.07
Lab technician	456	0.02
Millwright	440	0.02
Millwright	441	0.02
Insulator	413	0.19
C operator	465	<0.02

^aDuring the monitoring program, four categories of operators were defined, ranging from A operators, who spent most of their time in a relatively clean environment such as a control room, to D operators, who spent most of their time in the process area.

^bApplicable OSHA Standards: 0.200 mg/m³ (benzene solubles) for CTPV (TWA).

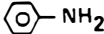
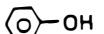
^cUpset conditions.

Table Z.3. PNA analytical results in $\mu\text{g}/\text{m}$ for personal samples, SRC-I process, Wilsonville, Alabama, November 12–17, 1979

Job category	Operator				Maintenance							Laboratory technician			Blanks ^a	
Job title	C	C	D	D	Pipefitter	Insulator	Insulator	Oiler	Instrument	Millwright	Millwright	Chemist	Chemist	Chemist	025	050
Sample No.	038	053	014	054	006	007	008	012	082	011	081	014	068	076		
Sample volume, liter	828	720	610	539	611	614	620	792	744	544	683	720	599	802		
Sample time	1435- 2215	0635- 1405	1431- 2220	0646- 1415	0720- 1510	0721- 1513	0723- 1520	0729- 1515	0700- 1516	0728- 1510	0700- 1508	1440- 2210	1436- 2217	0631- 1423		
Naphthalene	9.5	<i>b</i>	2.6	2.2	4.8	9.5	2.9	1.8	2.5	11.5	1.4	0.8	19.4	3.3		
Quinoline	0.05		0.04	0.04	0.1	0.2	0.09	0.01	0.09	0.3	0.07	0.3	0.2	0.2		
2-methylnaphthalene	9.3		3.3	5.2	12.09	13.1	5.6	1.9	5.9	11.2	3.9	1.8	17.2	4.3		
1-methylnaphthalene	1.4		0.8	0.9	1.9	3.0	1.06	0.4	1.0	2.1	0.7	0.3	3.4	1.0		
Acenaphthalene	0.01				0.01	0.01	<0.01		0.05	0.03			0.1	<0.01		
Acenaphthene	0.4		0.3	0.5	0.8	1.1	0.4	0.1	0.4	0.7	0.3	0.1	1.0	0.3		
Fluorine	0.2		0.2	0.2	0.4	0.7	0.2	0.09	0.5	0.5	0.2	0.9	0.8	0.2		
Phenanthrene/anthracene	0.5	0.05	0.8	0.8	1.2	1.4	0.7	0.3	0.6	1.0	1.0	0.4	1.4	0.6		
Acridine										0.01			0.03			
Carbazole																
Fluoranthene	0.02		0.1	0.06	0.1	0.08	0.05	0.07		0.07	0.09	0.05	0.06	0.04		
Pyrene	0.01		0.09	0.04	0.0	0.09	0.04	0.04		0.06	0.06	0.05	0.06	0.02		
Benzo(a)fluorene																
Benzo(b)fluorine																
Benz(a)anthracene																
Crysene/triphenylene																
Dimethylbenz(a)anthracene																
Benzo(c)pyrene																
Benzo(a)pyrene																
Perylene																
Dibenz(a,j)acridine																
Dibenz(a,i)carbazole																
Indeno(1,2,3-c,d)pyrene																
Dibenzanthracene																
Benzo(g,h,i)perylene																
Anthanthrene																
Coronene																
Dibenzpyrene																
Total	11.8	0.05	8.2	9.1	21.5	29.2	11.0	4.7	11.0	27.5	7.7	4.4	43.6	10.0		

^a As $\mu\text{g}/\text{sample}$.^b Not detected.Source: L. R. Harris et al., *Coal Liquefaction: Recent Findings in Occupational Safety and Health*, DHHS (NIOSH) publication 80- 122.

Table Z.4. Wilsonville personnel monitoring

Compound		Samples (No.)	Concentration (ppm)
Benzene		21	0.01
Aniline		23	0.06
Phenol		2	0.08
Paracresal		6	0.07
Quinoline		13	0.0006

Source: NIOSH Contract No. 210-78-0101

The Health and Ecological Studies Plan (HESP) will provide information on the properties of SRC-I products, waste materials, and internal process streams which can be used to assess the health and ecological impacts that might result from exposure to these materials. This information will be used in ongoing assessment of the environmental impacts of the demonstration facility. The HESP will be implemented simultaneously with the initial design engineering and construction of the facility, prior to operation. Results of the HESP will guide future modifications to process design, environmental impact mitigation measures, and worker health and safety programs which may be needed to develop a medically and environmentally acceptable SRC-I process.

The research to be carried out under HESP will be conducted in four phases. Most of the studies suggested for the first three phases will be completed before operation of the plant begins. The fourth phase, involving development of environmental monitoring techniques, may continue during plant operation.

The first four phases are described here in some detail. Initial testing using pilot plant materials has begun under Phase I, and results obtained to date are presented below. Future results will be reported in public literature and research status reports.

Experimentation during the first three phases will be based on samples of SRC-I materials obtained from pilot plants, process demonstration units and laboratory-scale development units representing the unit operations utilized in the demonstration plant design. Sources of these materials are discussed below. For those materials where there is currently no directly analogous process, sample materials will be collected from the available sources and processed to give materials more representative of the anticipated demonstration plant operations.

The purposes of these studies are threefold. First, they will characterize materials sufficiently to identify those streams that may cause health or ecological risk in order to assess the relative magnitude of the risks. Secondly, they will provide guidance to future studies of environmental and health effects during the demonstration plant operation. Finally, they will give insight into the characteristics of the materials which can aid in the development of mitigation measures for potential impacts.

Phase I of this research involves screening for the characteristics of SRC-I materials that impact various biological systems during acute exposures. Phase II of the plan will determine long-term effects of chronic exposures and will include studies on the biological effects of lower doses of typical SRC-I materials produced under operating conditions corresponding to the demonstration plant design. Phase II research efforts will also include intensive studies of environmental fate and transport of SRC-I materials. Phase III will explore the effects of altered plant operating conditions on the toxic properties of these SRC-I materials. Results of Phase I screening will provide guidance for Phase II investigations, both for selection of materials requiring further study and for possible design modifications to ameliorate undesirable characteristics in SRC-I products. Phase IV will develop methods for monitoring effects

specific to SRC-I operations at the demonstration facility and potential commercial sites. Data from Phases I and II are expected to provide indicators of biological and ecological effects and a basis for assays for potentially harmful chemical entities which should be monitored in the work place and local environments.

The program will be routinely updated to more specifically define later phase research efforts. Studies suggested in this plan are consonant with the Environmental Concerns and Requirements stated in the Environmental Development Plan for Coal Liquefaction (DOE/EDP-0012, March 1978) and in the Project Environmental Plan (Appendix Q) for SRC processes.

Z.2.1 Phase I

Phase I of this research involves screening SRC-I materials for potential biomedical and ecological effects. SRC-I materials are being obtained from existing facilities which are being operated to bracket potential demonstration/commercial conditions. Table Z.5 presents those materials to be screened during Phase I. Sampling to obtain these materials is described later. Three categories of materials are being studied: SRC-I products (of occupational and environmental concern), SRC-I waste materials (also of occupational and environmental concern), and internal process stream (primarily of occupational concern). SRC-I materials (Table Z.5) currently being screened in Phase I, were obtained from the Wilsonville, Alabama, pilot plant.

Table Z.5. Slate of samples for Phase I
biological and ecological assays

Sample	Description	Source	Starting
Raw feed coal	Solid	Wilsonville	Fall 1980
SRC product	Solid	Wilsonville	Fall 1980
Two-stage liquefaction solid	Solid	Hydrocracker	Spring 1981
Light SRC	BP 850–1050°F, solid	Wilsonville	Fall 1980
Process solvent	BP 450–850°F	Wilsonville	Fall 1980
Naphtha	BP 160–400°F	Wilsonville, coker, and hydrocracker	Fall 1980 ^a
Distillate	BP 400–650°F	Wilsonville, coker, and hydrocracker	Spring 1981
Heavy oil	BP 650–859°F	Wilsonville and hydrocracker	Spring 1981
Ash concentrate	Solid	Wilsonville	Fall 1980
Gasifier fly ash	Solid	GKT (West Germany)	Fall 1980
Gasifier bottoms	Solid	GKT (West Germany)	Fall 1980
Green coke	Solid	Coker	Fall 1980
Calcined coke	Solid	Calciner	Fall 1980
Unconverted combustion product	Solid	Burn test (PETC)	Summer 1981
Green coke water	Liquid	Coker	Fall 1980
Treated wastewater	Waste treatment plant materials	Air products	Winter 1980–1981
Oily sludge	Waste treatment plant materials	Air products	Winter 1980–1981
Metal-bearing sludge	Waste treatment plant materials	Air products	Winter 1980–1981
Biological solids	Waste treatment plant materials	Air products	Winter 1980–1981
SRC-I product leachate	Liquid	Wilsonville	Fall 1980
Gasifier leachates	Liquid	GKT (West Germany)	Fall 1980

^aCoker and hydrocracker liquids (Spring 1981).

Phase I screening consists of three basic types of tests: genetic damage testing, rodent acute-toxicity testing, and ecological assays of materials which may enter the environment.

Potential for genetic damage from exposure to SRC-I materials will be evaluated by assays which indicate mutation and chromosomal alteration in microorganisms and mammalian tissue culture cells ("in vitro" tests). These tests (Table Z.6) will be used to screen for potential genetic effects, and will be used to select materials for further study. If a material shows potential for such effects it will be assayed in long-term chronic effects tests (Phase II). Criteria for Phase II analyses includes high potential for environmental/occupational exposure. Thus,

Table Z.6. Submammalian biomedical assays: Phase I

Material	Ames, mutation	Yeast, mutation	Inductest, DNA damage	CHO cell, mutation	Unscheduled DNA synthesis, DNA damage	Sister chromatid exchange, chromosomal damage	Dermal cytogenetics
SRC product	X	X	X	X	X	X	X
Coal	X	X	X	X	X	X	X
Two-stage liquefaction solid	X		X	X		X	
Light SRC	X		X	X		X	
Process solvent	X	X	X	X	X	X	X
Naphtha	X	X	X	X	X	X	X
Distillate	X	X	X	X	X	X	X
Heavy oil	X		X	X		X	
Gasifier fly ash	X		X	X		X	
Gasifier bottoms	X		X	X		X	
Green coke	X		X	X		X	
Calcined coke	X		X	X		X	
Combustion products (unconverted)	X		X	X		X	

materials which do not show genotoxicity in Phase I assays may still be assayed by Phase II tests.

Acute toxicity tests with rodents (Table Z.7) will help determine if short-time exposures to high concentrations of SRC-I materials are hazardous. Acute tests will also provide data on dose levels to be used in rodent teratology studies and Phase II studies of chronic effects. Potential teratogenic effects will be assessed by examination of fetal tissue from pregnant animals which have received subacute doses of SRC-I materials during specific gestation periods.

Table Z.7. Phase I biomedical assays in rodent species

Material	Acute toxicity			Eye irritation, rabbit	Skin sensitization, guinea pig	Aspiration hazard, rats	Teratogenicity, rats and mice
	Oral, rats and mice	Dermal, mice	Inhalation, rats				
SRC product	X	X	X	X	X		X
Coal	X	X	X	X	X		X
Light SRC	X						
Process solvent	X	X	X	X	X	X	X
Naphtha	X	X	X	X	X		X
Distillate	X	X		X	X		X
Heavy oil	X	X		X			X
Gasifier fly ash	X	X		X			X
Gasifier slag	X	X		X			X
Green coke	X	X		X			X
Calcined coke	X	X		X			X
Combustion products (unconverted)	X	X		X			X

Phase I ecological assays will be performed with major SRC-I product and waste streams (Table Z.8) which potentially may enter the environment. Process and treated waters will be analyzed as they become available. These assays will evaluate acute and chronic effects of SRC-I materials on various trophic levels in an aquatic ecosystem. Test organisms will include phytoplankton, zooplankton, benthic invertebrates, and fish.

Table Z.8. Phase I ecological assays

Material	Algal test	Daphnia test	Detritivore test	Fish test	Plant growth
SRC product	X	X	X	X	X
Coal	X	X	X	X	X
Naphtha	X	X	X	X	X
Distillate	X	X	X	X	X
Heavy oil	X	X	X	X	X
Gasifier fly ash	X	X	X	X	X
Gasifier bottoms	X	X	X	X	X
Calcined coke	X	X	X	X	X
Unconverted combustion products	X	X	X	X	X

Phase I screening assays will be carried out using SRC-I materials listed in Table Z.5, to give a preliminary indication of potential risk associated with each material. In the case of solid materials such as SRC-I product and gasifier mineral residue, initial screening assays will be performed on aqueous leachates. When necessary, liquid materials will be studied using appropriate solvents.

In addition, Phase I studies will be carried out on subfractions of the original SRC-I materials which are separated chemically by various extraction or other separation techniques. Such assays, coupled to appropriate chemical analyses, allow determination of chemical compounds and/or compound classes causing observed genetic effects. These organically extracted materials are not representative of possible sources of health or ecological impact. Their study may, however, provide guidance towards mitigation techniques should later Phase II studies indicate potential adverse impacts.

Phase I research will provide initial data on potential biomedical and ecological effects of SRC-I materials. Thus, Phase I will aid in:

- setting research priorities for Phase II research involving longer term, more extensive biomedical and ecological assays and chemical analyses;
- providing initial qualitative analyses for assessing environmental damage anticipated from developing a commercial SRC-I process;
- providing insight as to which chemical species and classes of compounds are associated with biomedical and ecological effects which are identified; and
- giving initial guidance to mitigation measures which may require development.

Figure Z.1 shows the estimated time to complete Phase I biomedical and ecological studies.

Z.2.2 Phase II

During Phase II, the SRC-I materials in Table Z.9 will be subjected to longer term, more extensive biological and ecological analyses. These represent the materials considered to have the greatest potential for significant impact. One of the intentions of this series of investigations is to provide the necessary data to comply with the requirements of EPA's Toxic Substances Control Act for Premanufacturing Notification.

In addition, materials showing a positive response in Phase I screening will also be tested during Phase II.

Certain Phase II assays such as those dealing with carcinogenicity, teratogenicity, and behavioral effects require data from Phase I to determine the doses of materials to be administered to experimental animals. Phase II assays will provide data on carcinogenic and other pathological

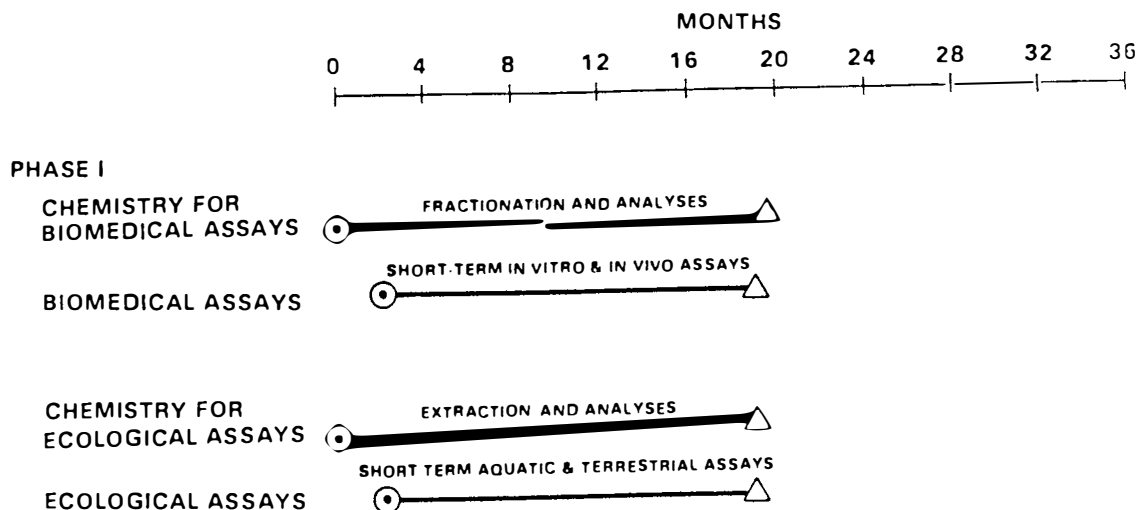


Fig. Z.1. Estimated time to complete Phase I biomedical and ecological studies, assuming receipt of material at time zero.

effects from long-term, low-dose exposures to SRC-I materials. Data from Phase II will also be used to evaluate Phase I tests for sensitivity and applicability as predictors of in vivo biological effects. For example, the mutagenic potency of SRC-I materials in Phase I in vitro tests will be compared with carcinogenicity in rodents. These data will provide guidance for the design of Phase III experiments.

Phase II ecological assays and chemical analyses will consider accumulation and fate of SRC-I materials in the environment (Table Z.10). Studies with model experimental ecosystems will evaluate long-term consequences of SRC-I materials spilled in water or on land. Exposure of animal populations to SRC-I materials may occur through substances entrained in terrestrial and aquatic food chains. These materials may be modified by chemical and biological processes in the environment and in tissues of organisms. Selection of SRC-I materials for bioconcentration/bioaccumulation and food chain studies will depend on a variety of factors including results of Phase I ecological, and Phase I and II biomedical assays, engineering and chemical considerations, and potential release scenarios.

Results from Phase II biomedical and ecological research will provide:

- a reasonable evaluation of which materials of concern may require efforts to mitigate potential health and ecological impacts,
- correlation between the short-term in vitro and in vivo assays performed in Phase I and the longer term studies conducted in Phase II,
- a more quantitative assessment of potential environmental risk anticipated from developing a commercial SRC-I process, and
- a basis for development of control technologies and management procedures designed to ameliorate potential health impacts and environmental risks.

Table Z.9. Phase II biomedical assays

	Calcined coke	Two-stage liquefaction solid	SRC-I product	Naphtha	Middle distillate	Heavy distillate
Acute toxicity						
Oral ^a	X			X	X	X
Dermal ^a	X			X	X	X
Inhalation ^a	X	X	X	X	X	X
Eye irritation ^a	X	X	X	X	X	X
Dermal sensitization ^a		X	X	X	X	X
Skin irritation ^a	X	X	X	X	X	X
Aspiration				X		
Subchronic toxicity						
Dermal ^a	X	X	X	X	X	X
Inhalation		X	X	X	X	
Chronic toxicity						
Dermal		X	X	X	X	X
Inhalation			X	X	X	
Teratology						
Dermal		X	X	X	X	X
Inhalation		X	X	X		
Reproductive toxicity						
Dermal multigeneration	X	X	X	X	X	X
Male fertility	X	X	X	X	X	X
Transplacental carcinogenicity	b	b	b	b	b	b
Mutagenicity^a						
Dermal carcinogenicity	X	X	X	X	X	X
Developmental toxicity	b	b	b	b	b	b
Neurobehavior	b	b	b	b	b	b

^aTests required by the U.S. Environmental Protection Agency (TSCA) for Premanufacturing Notification.^bAnalyses are contingent on results of Phase I assays and Phase II assays of carcinogenic effect.

Table Z.10. Phase II ecological studies

Materials	Bioconcentration ^a	Bioaccumulation ^b / biomagnification ^c	Fate ^d
Coal	X	X	X
SRC-I product	X	X	X
Naphtha	X	X	X
Distillate	X	X	X
Heavy oil	X	X	X
Gasifier bottoms	X	X	X

^aBioconcentration is the accumulation of test material into and/or onto test organisms from water.^bBioaccumulation is uptake of test material into and/or onto organisms from water and food sources.^cBiomagnification is a special case of bioaccumulation in which concentrations of chemical residues in tissue increase as the residue passes through the food chain.^dDisposition of inorganic and organic constituents of SRC-I materials through soil and water as mediated by hydrological, chemical, and biological factors.

Figures Z.2 and Z.3 show the estimated time to complete Phase II biomedical and ecological studies.

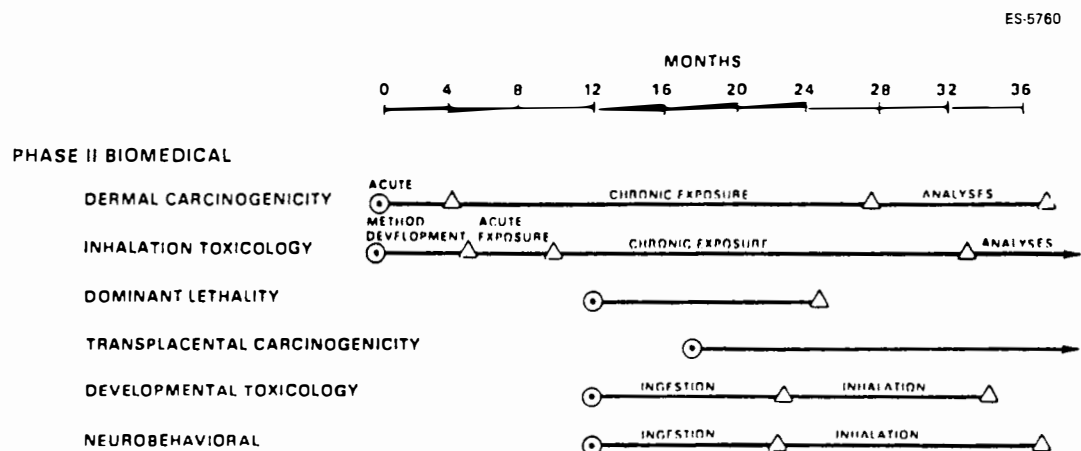


Fig. Z.2. Estimated time to complete Phase II biomedical studies, assuming receipt of material at time zero.

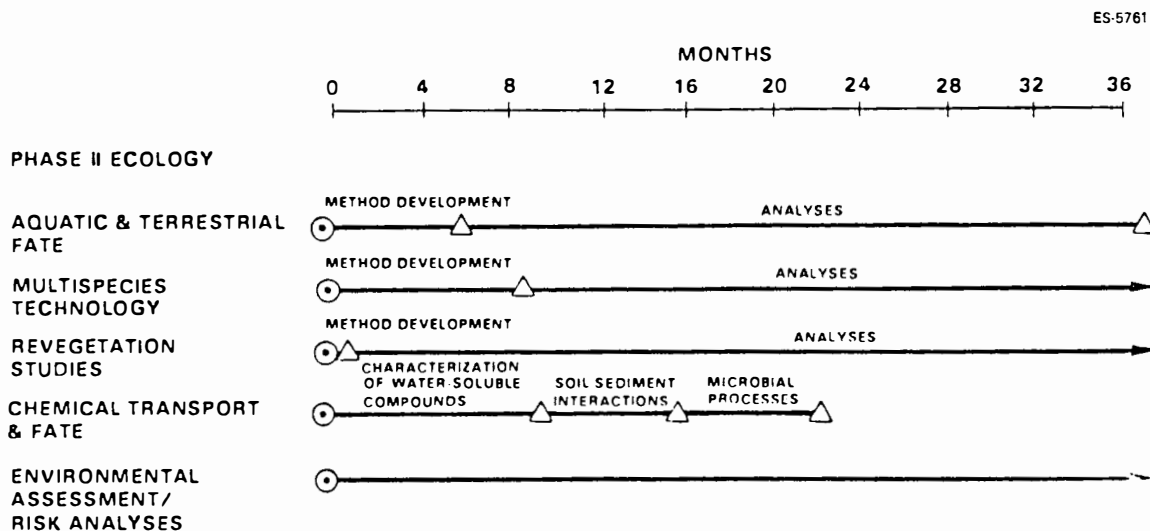


Fig. Z.3. Estimated time to complete Phase II ecological studies, assuming receipt of material at time zero.

Z.2.3 Phase III

Phase I and II research will analyze effects of SRC-I materials produced under stable, equilibrium operating conditions. Phase III research will examine effects of process modifications, control technologies, and changing operational conditions such as facility upset, start-up, and shutdown on environmental properties of SRC-I materials. Short-term biomedical and ecological assays (Phase I) which correlate with longer-term whole animal and ecosystem studies (Phase II) will be used in Phase III. Phase III efforts will be initiated as warranted to provide:

- a basis for determining effectiveness of such aspects as control technology and process modification relative to decreasing potential environmental effect and
- a third analysis of environmental risk which would consider effects of altered plant operations.

Z.2.4 Phase IV

The purpose of Phase IV is to utilize insights developed during Phases I, II, and III to develop methods, assays, and procedures which will ensure obtaining the most useful information during demonstration plant monitoring.

During Phase IV a facility monitoring program will be developed which will allow:

- development of more effective environmental management procedures in areas of waste disposal and industrial hygiene for both demonstration and commercial SRC-I facilities and
- quantitative environmental risk assessment of a developed commercial SRC-I process.

Industrial hygiene programs and control technologies appropriate to SRC-I are being studied and the HESP is expected to aid in the development of both. Because the actual utilization of some SRC-I products is still not well defined, environmental and health effects relevant to product end use will be studied, when appropriate, during the operation of the demonstration plant. Programs to carry out these studies will be defined during Phase III. It is anticipated that studies of impacts due to end-use, especially involving utilization of SRC-I materials as refinery and petrochemical feedstocks, will proceed in phases similar to those already described.

Z.2.5 Toxicological testing strategy

The complete toxicological testing of SRC-I materials is a multitiered testing program, each level of which represents a system more closely approximating human response than the next lower level. The first level of screening is the simplest for quickly obtaining a preliminary indication of potential biological effect for a wide variety of materials. In practice, in vitro tests primarily determine cytotoxic and mutagenic potential of materials in submammalian and mammalian cell cultures. However, the full slate of SRC materials (Table Z.5) will also be tested for acute toxicity and teratogenicity in Phase I small animal assays. Materials that give positive results in Phase I would then be tested in longer-term Phase II small animal assays.

First-level screening tests are carried out sequentially by using a number of different species and strains of microorganisms which respond to a variety of mutagenic mechanisms. If a material tests positive with any single strain, it is then tested for mutagenicity in mammalian in vitro cellular systems. Generally, if a material from Table Z.5 should give negative results in the battery of submammalian tests the possibility of further testing would depend on the degree of potential exposures.

Several materials, which are end products of the process and to which public exposure is possible, will be given a more complete series of mammalian in vitro and in vivo tests, regardless of possible negative results of initial screening tests. These are listed in Table Z.9.

Z.3 INITIAL RESULTS OF BIOMEDICAL SCREENING TESTS

Of the proposed "Demonstration Plant" materials that could potentially impact human health and/or the environment, only process solvent has been screened to date. The process solvent was collected from the Wilsonville, Alabama pilot plant during simulated "Demonstration Plant" conditions (Table Z.11). The results are presented in Table Z.12. Also shown are screening data for materials taken from Gulf's Fort Lewis facility while it was operating in the SRC-I mode. These materials are thought to be similar to those produced at Wilsonville. The results show that the higher-boiling-point coal liquids from Fort Lewis were mutagenic but that the lower boiling point liquids were not. These results are in accord with previous results (refs. 2 and 3). Research will be conducted during the next year that will more closely define the boiling point range in which carcinogenic/mutagenic activity is detected.

Table Z.11. Operating conditions at time of sampling for preliminary screening

Condition	Wilsonville (measured value)	Phase I design basis (calculated value)
Feed coal (MF)	KY #9 (Fies Mine)	KY #9
C, %	73.8	71.0
H, %	5.16	5.0
N, %	1.54	1.5
S, %	2.96	3.7
O, %	8.97	8.4
Ash, %	7.69	10.5
Coal feed concentration, %	38.5	38.5
Dissolver temperature, °F	840	840
Dissolver space rate, lb/ft ³ ·h	38	38
Total pressure	2100 psig	2000 psig

Table Z.12. SRC-I toxicological testing results

Material	Submammalian: Ames Test (Revertants/μg)	Mammalian (in vitro): Syrian hamster embryo cells (No. transformants/μg)
SRC-I (Wilsonville)		
Process solvent, 450–850°F	0.54	
SRC-I (Fort Lewis)		
Process solvent, 480–850°F	12	0.15
Wash solvent, 380–480°F	<0.01	
Light oil, C ₅ –380°F	<0.01	

Sources: Fossil Energy Reports, FE/496–15, 16, 17, 18, 19, available from the National Technical Information Center, Springfield, Virginia; and J. L. Eppler et al., "Evaluation of Feasibility of Mutagenic Testing of Shale Oil Products and Effluents," *Environmental Health Perspectives* 30:179–154 (June 1979).

Results also show the Wilsonville process solvent to be less mutagenic than the Fort Lewis process solvent. Further chemical analyses of these materials will be conducted to determine why the observed difference is so great.

Process solvent is fractionated from liquid reactor effluent and subsequently recycled to be slurried with and hydrogenate the coal. Because it is an internal and enclosed stream, worker exposures would be limited to maintenance personnel and operators exposed to fugitive emissions; however, other process streams, especially those containing high-boiling-point liquids, are expected to be hazardous.

To put these results in a better perspective, the SRC-I materials are compared with SRC-II materials, shale oils, petroleum crudes and pure carcinogens in Table Z.13. The skin-painting test performed on mice most closely approximates human response among the tests conducted. Based on these results, the order of skin cancer potency in these tests on mice is: pure carcinogens > SRC-II heavy distillate, shale oil, and petroleum crude > SRC-II light oil. Based on Ames test data, SRC-I process solvent would have equal or less carcinogenic potency than SRC-II heavy distillate and shale oil.

Table Z.13. Battelle comparative toxicological testing results

Material	Submammalian: Ames Test (Revertants/ μ g)	Mammalian (in vitro): Syrian hamster embryo cells (No. Transformants/ μ g)	Mammalian (in vivo): Minimum dose inducing tumor response (mg/application)
SRC-II			
Heavy distillate, 550–850° F	40	0.7	2.3
Middle distillate, 350–550° F	<0.1		
Light distillate C ₅ –350° F	<0.1		>20.0
SRC-I (Wilsonville):			
Process solvent, 450–850° F	0.54		
SRC-I (Fort Lewis):			
Process solvent, 480–850° F	12	0.15	
Wash solvent, 380–480° F	<0.1		
Light oil, C ₅ –380° F	<0.1		
Shale oil		0.3	2.1
Paraho 16	0.6		
Paraho 504	0.6		
Livermore L01	0.6		
Crude petroleum			
Prudhoe Bay	<0.1	± 0.002	
Wilmington	<0.1	± 0.002	1.7
Carcinogens			
Benzo(a)pyrene	114	0.76	0.005
2-aminoanthracene	5430		<0.005 ^a

^a Lowest dose tested.

Sources: Fossil Energy Reports FE/49-15, 16, 17, 18, and 19, available from the National Technical Information Center, Springfield, Virginia; R. J. Sexton, *Arch. Environ. Health* 1:208 (1960); C. S. Weil and N. I. Condra, "Carcinogenic Effect of Materials on the Skin of Mice," *Arch. Environ. Health* 1:187 (September 1980); and J. L. Eppler et al., "Evaluation of Feasibility of Mutagenic Testing of Shale Oil Products and Effluents," *Environmental Health Perspective*, 30:179–154 (June 1979).

An area of particular concern with regard to coal liquids is their potential teratogenic effects. Experiments conducted at Battelle PNL⁴ demonstrated that female mice given intestinal doses (by gavage) of Fort Lewis process solvent can produce malformed fetuses and fetuses of decreased weight when compared with controls. The latter effect was also seen with Fort Lewis light oil. The minimum dose to effect these results was 0.34 g/kg/day administered intestinally (by gavage). Doses producing these effects approach doses that produced acute toxicity in the mother. So far as we are aware, this level is orders of magnitude greater than doses workers will be exposed to at the Demonstration Plant.

Z.3.1.1 Initial hydrotreating studies

Hydrotreating research has been conducted on SRC-II distillate blend ($\pm 30\%$ $< 300^\circ\text{F}$, $\pm 90\%$ $< 580^\circ\text{F}$), and the results are presented in Table Z.14. By catalytically hydrotreating this material and increasing hydrogen in the product by 1.95% (weight basis), mutagenic activity was reduced 97.5%. Chemical analyses showed that most nitrogen-containing compounds (a highly mutagenic fraction in coal liquids) underwent transformation during hydrotreatment which eliminated or greatly reduced their concentration in the resulting product. The demonstration plant is designed to have an expanded-bed hydrocracker (hydrotreating process), but the extent of its use and on which materials it would be used have yet to be determined. Based on these and future results, the DOE may propose design and/or operational modifications to the plant for the purpose of mitigating or eliminating potential health and environmental problems.

Table Z.14. The effect of catalytic hydrogenation on the mutagenicity of SRC-II distillate blend^a

Material	H added by wt (%)	Total revertants, fractionated material	Reduction (%)	Total revertants, unfractionated material
Feedstock		1.20		2.54
Moderately hydrotreated	1.95	0.03	97.5	<i>b</i>
Severely hydrotreated	2.85	0.01	99.2	<i>b</i>

^a $\pm 30\%$ $< 300^\circ\text{F}$, $\pm 90\%$ $< 580^\circ\text{F}$.

^bNot detected.

Source: Pacific Northwest Laboratory, Appendix to Biomedical Studies on Solvent Refined Coal (SRC-II) Liquefaction Materials: A Status Report, PNL-3189.

Z.3.1.2 Initial ecological studies

At this time, only limited ecological effects studies using pilot plant materials have been conducted and published. The effect of Fort Lewis SRC-I solid product on germination and growth of barley was investigated by mixing or layering the SRC-I solid with soil and placing the mixture in a field lysimeter. When soil and SRC-I solid were mixed 1:1, little effect on germination, growth or yield was found. When barley was grown on a 3-dm layer of soil placed over a 1-dm layer of SRC-I solid, growth and yield were reduced, apparently because of the inability of the roots to penetrate the SRC-I solid product layer. Tables Z.8 and Z.10 identify future SRC-I demonstration plants.

REFERENCES FOR APPENDIX Z

1. Fossil Energy Reports, FE/496-15, 16, 17, 18, 19; available from the National Technical Information Center, Springfield, Virginia.
2. R. J. Sexton, *Arch. Environ. Health* 1: 208 (1960).
3. C. S. Weil and N. I. Condra, "Carcinogenic Effect of Materials on the Skin of Mice," *Arch. Environ. Health*, 1: 187 (September 1980).
4. J. L. Eppler et al., "Evaluation of Feasibility of Mutagenic Testing of Shale Oil Products and Effluents," *Environmental Health Perspectives*, 30, 179-154 (June 1979).
5. D. D. Mahlum, ed., *Chemical, Biomedical, and Ecological Studies of SRC-I Materials from the Fort Lewis Pilot Plant: A Status Report*, Battelle Pacific Northwest Laboratory, Report PNL 3474.
6. Pacific Northwest Laboratory, Appendix to Biomedical Studies on Solvent Refined Coal (SRC-II) Liquefaction Materials: A Status Report, PNL-3189.
7. Pacific Northwest Laboratory, *The Mutagenic and Chemical Properties of SRC-I Materials: A Status Report*, Report PNL-3604.
8. W. C. Weimer et al., *Initial Chemical and Biological Characterization of Hydrotreated Solvent Refined Coal (SRC-II) Liquids: A Status Report*, Battelle Pacific Northwest Laboratory, Report PNL-3464.

Appendix AA

HAZARDS EVALUATION PROGRAM FOR THE SRC-I DEMONSTRATION PLANT



Appendix AA

HAZARDS EVALUATION PROGRAM FOR THE SRC-I DEMONSTRATION PLANT

AA.1 SAFETY HAZARD AND REVIEW PLAN AND SCHEDULE

The following discussion provided by International Coal and Refining Company (ICRC) describes the safety review procedures for the design and construction of the SRC-I facility. These procedures were established to identify, prevent, or minimize all risks associated with operation of the proposed facility. All safety features incorporated in the SRC-I plant will be documented in the Preliminary Safety Analysis Report (PSAR) required by the U.S. Department of Energy (DOE).

AA.1.1 SAFETY PROGRAM

AA.1.1.1 Phase 0 - Preliminary Hazards Analysis

During the preliminary design phase of the SRC-I project, a preliminary hazards analysis was performed. The purpose of this review was to identify the major hazards associated with the SRC-I design concept and ensure that major pieces of equipment necessary for the safe operation of the facility would be included in the plant. A review such as this, early in the design stages, ensures that the factors necessary for safe plant operation will be included in the basis of the detailed design.

The method of analysis utilized for these safety reviews was a systematic inquiry into modes of failure of individual equipment, often referred to as the "How Can" method (i.e., How can a specified major component fail in such a way as to cause a hazard?). For each major piece of equipment and generic type of minor equipment which is utilized in the process, a team of engineers identifies hazards that might be associated with that equipment under both normal operating conditions and emergencies. Then a series of "How Can" questions are formulated to determine what events can lead to each individual hazard. This series of questions identifies the mechanism of failure (or normal operating characteristics) leading to a hazard, possible causes for failures, and possible mitigation measures to be applied. Recommendations are then made for measures to be applied during detailed design.

Each area of the preliminary SRC plant design was reviewed by teams of engineers asking "How Can" questions for hazards related to a particular system in the process. The answers to these questions provided the basis for designing safety features into the system. A "How Can" worksheet was prepared during the review of each system during Phase 0 design. On these worksheets, "How Can" questions are listed initially. The consequences or hazards that could arise from the postulated event are listed next, followed by possible causes. The final column presents recommendations to be considered during detailed design (Phase I) to prevent or minimize the hazards.

This analysis was performed in all systems of the Phase 0 design. The following areas were reviewed:

- Coal Preparation
- SRC Processing
- Critical Solvent Deashing
- Air Separation

- Gasification (Gasifier and Shift Section)
- Gas Treating (DEA, Selexol, and Ammonia-Sulfide Water Stripper)
- Gas Compression
- Sulfur Recovery (Claus and Bevon Sulfur Recovery)
- Hydrogen Purification
- Coker/Calciner
- LC-Finer
- Water Treatment
- Solids Storage
- Liquid Storage
- Utilities
- Off sites (Flare Stack)
- Interconnecting Systems

Preliminary hazards reviews were performed on the above systems as designed for the Phase 0 work during April and May 1979. The results and documentation of these reviews were included in the Phase 0 reports for the SRC-I demonstration plant.

AA.1.1.2 Phases I and II — process hazards review

The detailed design of the SRC-I demonstration plant will undergo an intensive and systematic examination of the process called a process hazards review (PHR). The purpose of this review will be to identify all risks to the general public or plant employees associated with the operation of the plant and to develop practical recommendations to eliminate or control the hazards. Because comprehensive detailed safety reviews can only be done when detailed design information becomes available, the PHRs will be primarily carried out concurrently with the later stages of detailed engineering design. This is the earliest stage when these reviews can be done effectively, and will allow for inclusion of safety equipment, design modifications or other mitigating measures in the plant. The preliminary hazards reviews that were performed during Phase 0 will be referenced throughout these detailed safety reviews, depending upon the extent of process changes that may occur between the Phase 0 and Phase I design.

Process areas in which hazards are considered to present severe consequences will be considered for a quantified risk analysis. This analysis will use historically determined failure rates of process components, along with estimates of the probability of human error, to determine the probability of occurrence of the hazardous events. Changes will then be made in the design to reduce the risk to an acceptable level.

The PHRs will be carried out by teams composed of process engineers, design engineers, and safety engineers. Additional engineering backgrounds may be included on the team depending upon the complexity of the system being reviewed. Personnel who work on the design of the SRC-I demonstration plant will be involved in the hazards reviews.

The review teams will rely on three methodologies to review the process. These are all accepted techniques currently used by industry for PHRs.

"What-if" analysis

This method will be applied when the teams are reviewing operating procedures. "What-if" aims at forecasting scenarios and determining the hazards of their consequences.

Failure mode and effect analysis

This method will be applied to those areas of the process which are proven technologies where commercial operating experience is available. Failure mode and effect analysis examines the effect on the system of a specific equipment failure.

Fault tree

This systematic method of analysis is used to determine the possible causes of a preselected undesired event. This method will be applied to the process equipment within the facility that represents a high risk area because of (1) commercially unproven technology or (2) the severe operating conditions of the equipment. This method will be used when a quantified analysis is required.

The process hazards reviews will be used as the basis for writing the PSAR. This document is required by DOE and will contain sufficient information to identify all of the basic safety features required to ensure safe operation of the SRC-I demonstration plant. The PSAR for the facility will be written prior to the completion of the Phase I design work, which is scheduled for December 1982. The PSAR will be developed in increments by plant area. The PSAR for each area will be completed before start of major construction in that area.

During Phase II construction, a Final Safety Analysis Report (FSAR) will be prepared. This FSAR will document how the commitments made in the PSAR have been incorporated into the plant during construction. The FSAR will be completed and submitted to the DOE for approval prior to startup of the SRC-I demonstration plant. Submission of the FSAR is presently scheduled for July 1984.

AA.1.1.3 Phase III — operations safety program

The FSAR will contain sections defining the administration of safety during plant operation. In general, the FSAR will define the safety organization, its authority, responsibilities, reporting requirements, safety performance goals, and emergency planning procedures.

Safety during plant operation will be the responsibility of all line supervisors. Two safety professionals will be on the SRC-I operations staff: a Safety and Health Director and a Safety Engineer. Their responsibilities will be defined in greater detail in the FSAR. In general, their job requirements will include interfacing with the local community on matters related to safety and health, safety training and education of plant personnel, periodic plant safety audits, and safety performance reporting.

AA.2 PRELIMINARY HAZARDS IDENTIFICATION

The potential hazards of the proposed facility were identified by examining the project documentation. The effort focused on consequences of accidents rather than the normal industrial hazards associated with normal operation and process upset conditions. It was recognized that such a facility will contain many normal industrial hazards, and because of their number, careful attention must be given during the design phase to ensure that reasonable protection is afforded onsite personnel.

At an early stage in the evaluation of a facility design, it is not possible to predict accurately the likelihood of occurrence of an accident. Identification and subsequent design attention should result in a design in which the risks have been minimized. Table AA.1 lists the hazardous materials in the SRC process, and Table AA.2 summarizes qualitatively the hazards identification effort on a plant area basis. See Figs. AA.1 through AA.6 for flow diagrams relevant to the SRC-I demonstration plant.

Table AA.1. Hazardous materials in SRC processes

Material	Assumed hazardous property
Coal dust	Explosive, flammable, toxic
Slag	Pyrophoric, possibly carcinogenic
Hydrogen	Flammable, explosive, asphyxiant
Methane	Flammable, explosive, asphyxiant
Carbon monoxide	Flammable, toxic
Carbon dioxide	Asphyxiant
Carbonyl sulfide	Flammable, toxic
Oxygen	Reactive, increased fire hazard
Nitrogen	Asphyxiant
Argon	Asphyxiant
Hydrogen sulfide	Flammable, toxic
Light oil (naphtha)	Flammable, toxic, explosive, carcinogenic
Medium oil	Flammable, toxic, explosive, carcinogenic
Heavy oil	Flammable, toxic, carcinogenic
Vacuum bottoms	Toxic, flammable, carcinogenic
Ammonia	Flammable, toxic
Sulfur	Flammable, toxic combustion products
Sulfur dioxide	Flammable, toxic
Hydrogen chloride	Toxic
DEA	Flammable, toxic
Selexol solvent	Flammable, toxic
Phenolics	Toxic
Hydrogen cyanide	Toxic
Liquified petroleum gas	Flammable, explosive

Table AA.2. SRC-I demonstration plant
preliminary hazards identification

System	Hazard	Accident	Result	Remarks
<u>SRC Process</u>				
Slurrying and Pumping	Coal slurry	Pipe, slurry feed pump rupture	Release of process solvent, coal slurry, fumes, minor fire, damage to equipment	All equipment in this system, with the exception of the letdown valves and the flash tank, are commonly used in industry.
Preheating and Dissolution	Coal slurry and hydrogen	Slurry preheater tube rupture and backflow from reactor	Fire, explosion, release of coal slurry, hydrogen and reaction products (hydrocarbon vapor, liquids and solids, toxic gas)	
	Fuel gas	Slurry or hydrogen preheater explosion	Equipment damage and injury to personnel	
	Reaction product	Coal dissolver rupture	Fire, explosion, release of toxic materials (H ₂ , CO, CH ₄ , H ₂ S, COS, NH ₃ , HCl, HCN)	
	Recycle and makeup hydrogen	Hydrogen preheater tube rupture	Fire, explosion	
Vapor Liquid Separation	Reaction product	Flash tank or letdown valve rupture	Fire, explosion, release of reaction products	
	High and low pressure off gas	Heat exchanger tube rupture, gas recovery compressor failure	Fire, explosion, release of high pressure off gas (H ₂ , CO, CH ₄ , COS, H ₂ S)	
Vacuum Distillation	Product slurry	Vacuum heater tube rupture, vacuum column rupture or explosion	Fire, release of product slurry (SRC, heavy and medium oils, unreacted coal, ash, medium and light oils, equipment damaged and injury to personnel)	
	Fuel gas	Vacuum tower heater explosion	Equipment damage and injury to personnel	
	Vacuum bottoms	Vacuum bottoms pump rupture	Release of vacuum bottoms liquids (SRC, unreacted coal and ash)	
Fractionation	Liquid products process solvent and vacuum tower overheads	Fractionation column rupture	Possible fire, release of naphtha, medium oil, fuel oil, fuel gas (CH ₄ , LPG, CO) and process solvent	The equipment used in this system design is commonly used in refineries.
Solvent Deashing	Process solvent, SRC	Deashing unit rupture	Major fire, explosion, release of materials such as benzene, xylene, toluene, medium and heavy oils, SRC, unreacted coal and ash	
<u>Product Upgrading</u>				
SRC Solidification	Molten solvent refined coal	Fire or rupture of vessel	Release of smoke and fumes from SRC	
	Solvent refined coal	Dust explosion	Fire, damage to equipment, release of smoke and fumes from SRC	

Table AA.2 (continued)

System	Hazard	Accident	Result	Remarks
<u>Product Upgrading</u>				
Coker/Calciner	Solvent refined coal	Combination tower, coking heater rupture, fire	Release of SRC, heavy and light oil and vapor, fire, damage to equipment, injury to personnel	The coker equipment is used commercially with the exception of the coke drums. The calciner equipment is used commercially.
	Fuel gas	Coking heater fire or explosion	Damage to equipment, injury to personnel	
Expanded Bed Hydrocracking	Coal slurry and hydrogen	Slurry preheater tube rupture and backflow from reactor, explosion	Fire, explosion, release of reaction products, damage to equipment and injury to personnel	This system is used commercially with a different feedstock.
	Reaction products	Expanded bed reactor rupture or explosion	Fire, explosion, release of reaction products and catalyst, damage to equipment and injury to personnel	
	Catalyst	Catalyst handling system failure	Fire, release of reaction products and catalyst	
	Hydrogen	Recycle compressor rupture	Fire, explosion	
	Reaction products	High pressure separator rupture	Fire, explosion, release of high pressure vapor and product slurry	
	Product naphtha and oil	Distillation column rupture	Fire, explosion, release of hydrocarbons	
	Heavy oil and bottom slurry	Vacuum tower explosion	Equipment damage, injury and release of toxic materials	
<u>Hydrogen Production</u>				
Air separation	Liquid oxygen	Rupture of liquid oxygen vessels/heat exchangers	Formation of explosive gel in the presence of liquid hydrocarbons; creation of fire hazard; low temperature hazard; oxygen-rich atmosphere	The process design is based upon an existing, commercially demonstrated cryogenic air separation process.
	Hydrocarbon contaminants	Explosion of LOX vessels	Damage to equipment, injury, possible fire	
	Liquid nitrogen	Rupture of liquid nitrogen vessels/heat exchangers	Vapor fog with possible hazardous concentration of nitrogen (asphyxiant)	

Table AA.2 (continued)

Table AA.2 (continued)

System	Hazard	Accident	Result	Remarks
Hydrogen Production				
Gasifier/Shift Conversion	Ash concentrate and pulverized coal	Dust explosion or fire	Damage to equipment, injury to personnel	The gasifier equipment is used commercially with coal feed; the shifting is a commercially used process.
	Oxygen, steam and coal slurry	Gasifier rupture or explosion	Fire or explosion, release of toxic material (CO, H ₂ S) injury or equipment damage	
	Raw synthesis gas	Waste heat boiler rupture, compressor fire, shift reactor explosion	Fire, explosion, release of toxic gas (CO, H ₂ S) injury or equipment damage	
	Raw makeup hydrogen	Vessel rupture	Fire or explosion, damage to equipment and injury to personnel	
Gas Systems				
Selexol Acid Gas Removal	Raw makeup hydrogen	Rupture of H ₂ S absorber, stripper, compressor	Fire, release of toxic gas (H ₂ S, COS, CO ₂ , HCl, NH ₃)	This is a commercial process.
DEA Acid Gas Removal	Low pressure raw fuel gas	Rupture of absorber, vessels	Fire, release of toxic gas (HCl, NH ₃ , H ₂ S, and COS)	This is a commercial process.
	High pressure hydrogen	Rupture of absorber, vessels	Fire, explosion, release of toxic gas (HCl, NH ₃ , H ₂ S, CO ₂)	
Ammonia sulfide water stripping	Sour water	Vessel rupture	Fire, release of toxic material (NH ₃ , H ₂ S)	This is a commercial process.
Compression	Makeup or recycle hydrogen	Compressor, knockout drum rupture	Fire, explosion, damage to equipment and injury	This is a commercial process.
Sulfur Recovery Claus Unit	Sour gas (CO ₂ , H ₂ S, NH ₃)	Fire, explosion, rupture of equipment	Fire, damage to equipment, release of toxic gas (H ₂ S, SO ₂ , NH ₃)	The Claus Unit is based on existing commercially demonstrated equipment
	Fuel gas	Rupture of vessels	Release of toxic gas (H ₂ S, SO ₂ , NH ₃)	
BSR Unit	Claus tail gas (H ₂ S, SO ₂)	Fire, rupture of vessels	Release of toxic gas (H ₂ S, SO ₂)	This is a commercial process.
	Low pressure raw fuel gas	Fire, rupture of vessels	Fire, damage to equipment, release of H ₂ S	

Table AA.2 (continued)

System	Hazard	Accident	Result	Remarks
Hydrogen Purification and LPG Recovery	Scrub oil (benzene and heavier hydrocarbons)	Fire or explosion, rupture of vessels	Damage to other facilities, fire or explosions	The LPG recovery is a commercial process.
	Hydrogen	Fire or explosion, rupture of vessels	Damage to equipment, fire or explosions	
	Fuel gas	Fire or explosion	Damage to nearby equipment	
	Low pressure fuel	Rupture of compressor, exchanger, knockout drum, columns	Fire, explosion, release of CH ₄ , LPG, CO, vapor cloud formation	
	Ethane	Fire, explosion or rupture of vessel	Fire, damage to equipment, vapor cloud formation	
	Carbon monoxide	Fire, explosion, or rupture of vessel	Fire, damage to equipment, release of asphyxiant	
<u>Utilities and Storage</u>				
Solids Storage	SRC	Fire in SRC storage	Damage to equipment, personnel injury	This is standard, commercially available equipment and design.
	Dust	Ignition of SRC dust, fire or explosion	Damage to equipment, personnel injury	
Liquids Storage	Product Oils (Naphtha, middle distillate, heavy oil)	Storage tank rupture, spill or leak, fire	Damage to equipment, personnel injury	
	LPG	Storage tank rupture, spill or leak, fire	Damage to equipment, personnel injury, vapor cloud formation	
	Process Chemical (MEA, Selexol, Caustic, Sulfuric Acid)	Storage tank rupture, spill or leak	Damage to equipment, personnel injury	
	Fuel oil, Process Solvent or SRC	Storage tank rupture, spill or leak, fire	Damage to equipment, personnel injury	
<u>Coal Preparation</u>	Coal	Fire	Result of smoke, CO, CO ₂ , and other coal combustion products.	
	Coal dust	Explosion	Large release of energy; fire with its release of coal combustion products; damage/injury to nearby equipment/personnel	

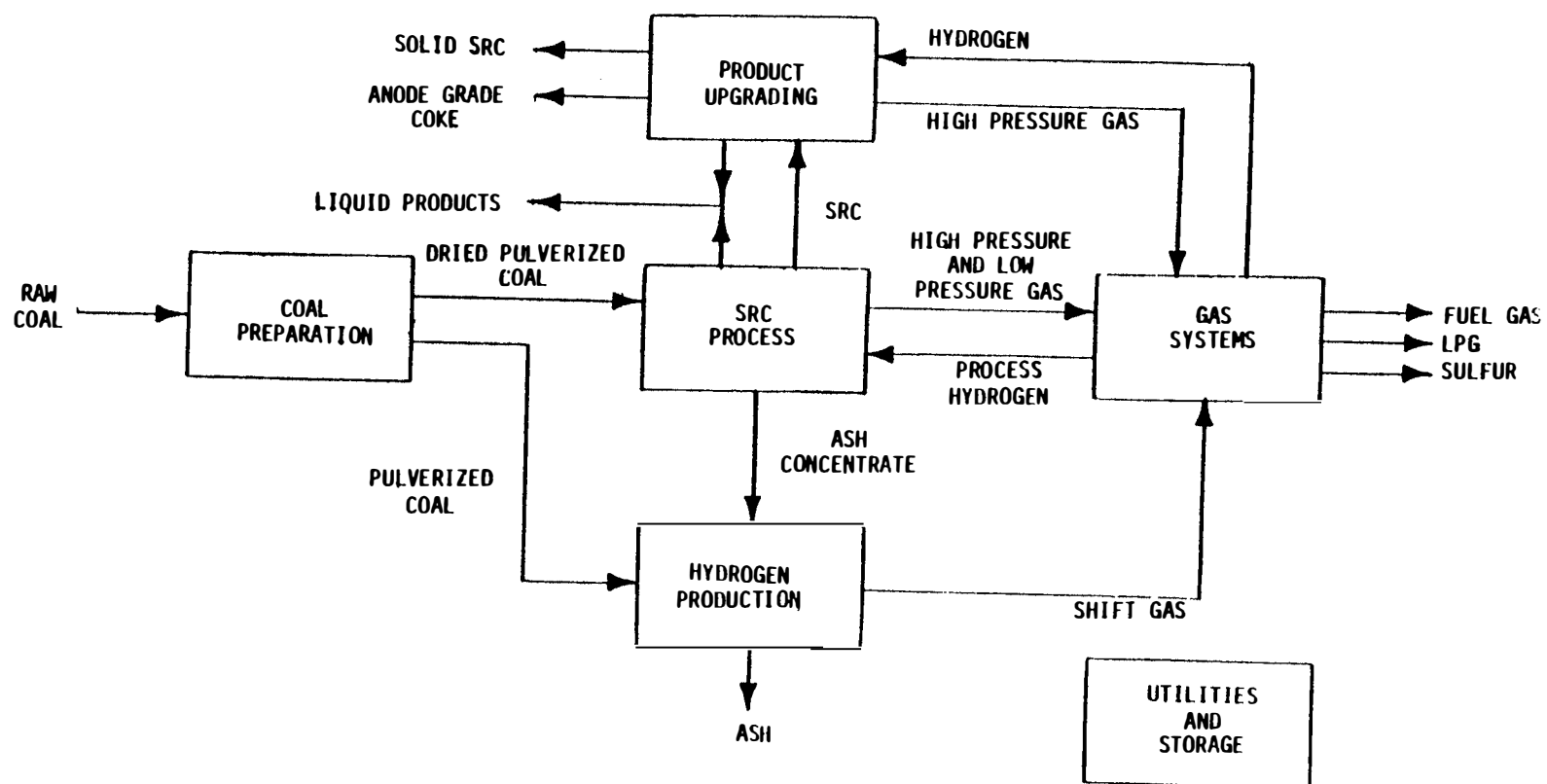


Fig. AA.1. SRC-I demonstration plant simplified block flow diagram.

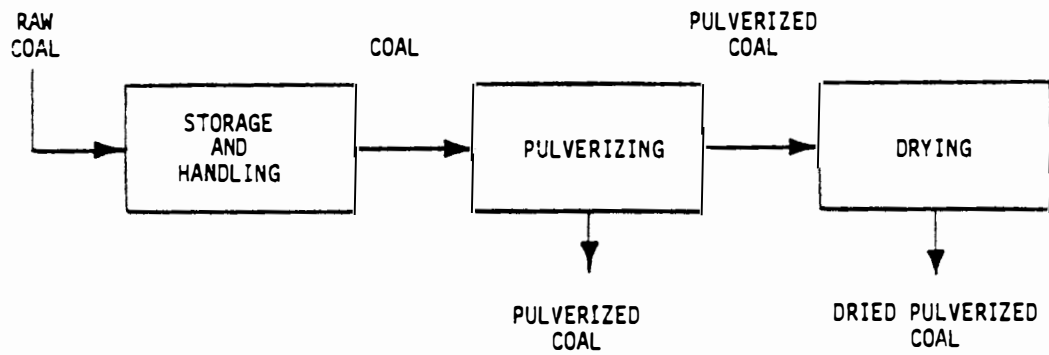


Fig. AA.2. Coal preparation system block diagram.

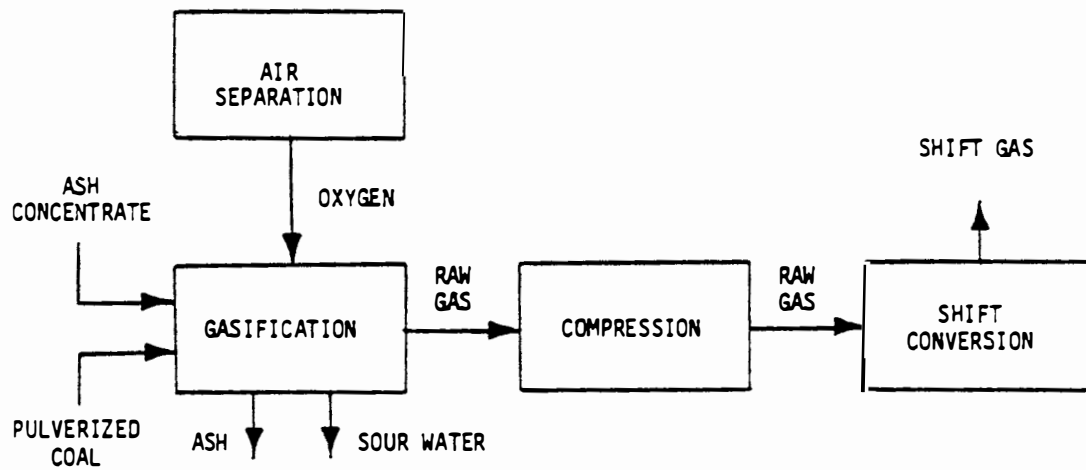


Fig. AA.3. Hydrogen production system block diagram.

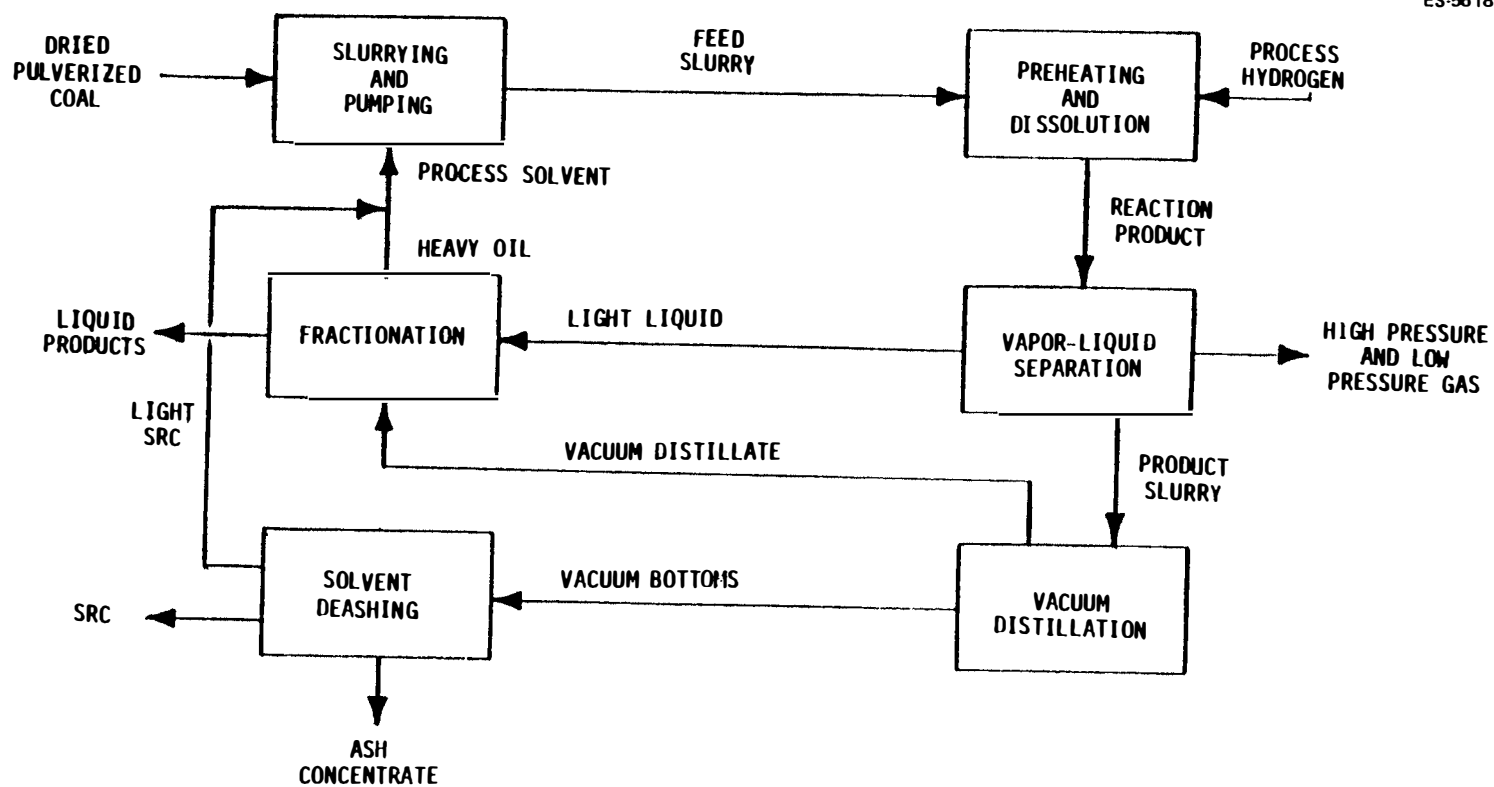


Fig. AA.4. SRC process system block diagram.

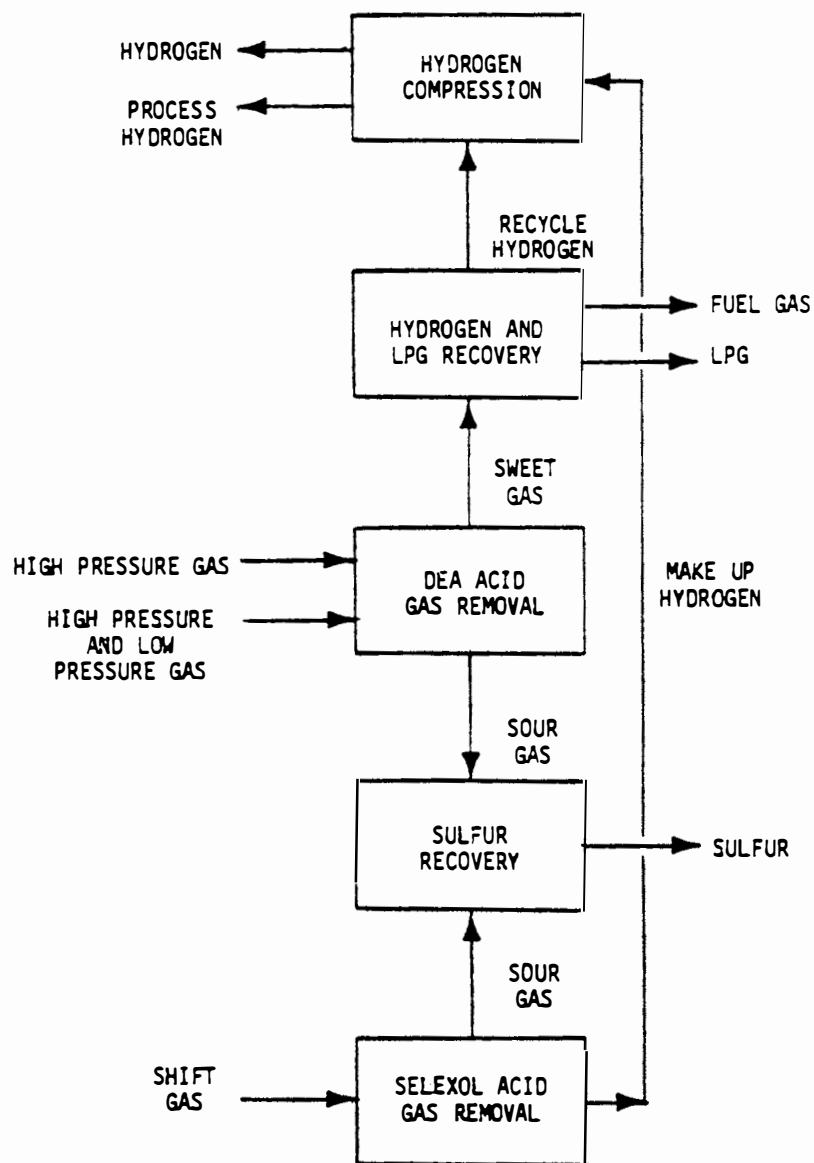


Fig. AA.5. Gas systems block diagram.

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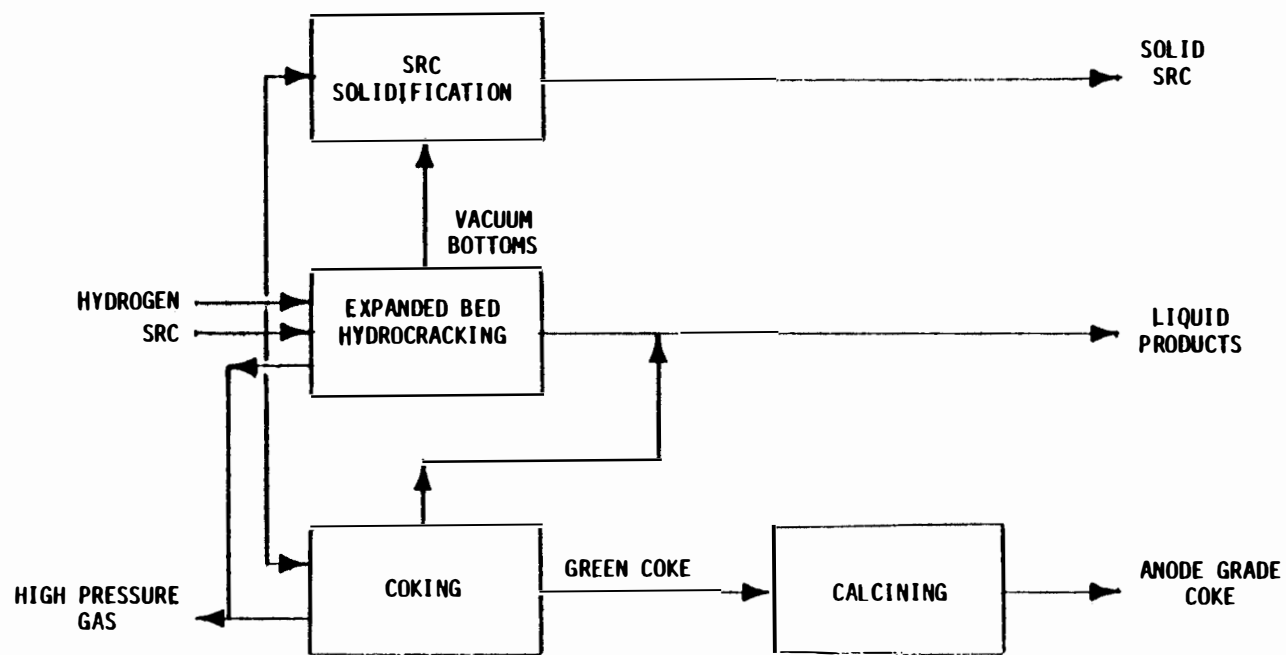


Fig. AA.6. Product upgrading system block diagram.

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Appendix BB
COAL-MINING-IMPACT ALGORITHMS

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Appendix BB

COAL-MINING-IMPACT ALGORITHMS

BB.1 INTRODUCTION

In Sect. 1.4, loading factors were given for the SRC, H-Coal, and Exxon Donor Solvent (EDS) processes. Because of the variety of sources from which this information was collected and the variations in assumptions from these sources, it was concluded that cumulative impacts could best be identified on the basis of a composite liquefaction plant, represented by the average emission from the three processes. For those emissions for which a composite factor could not be calculated, the SRC-I emissions were assumed to be representative. In developing the commercialization scenario, it was assumed that all coal liquefaction would have the same Btu output as the composite baseline unit plant but that inputs and effluents would vary according to type and quality of coal used as feedstock. To estimate environmental impacts associated with unit plant operations, a series of algorithms was developed based upon the composite plant characteristics. State-level input and output loadings for the plant distribution scenario can be calculated by multiplying unit plant loadings by the number of plants located in a state.

Coal-mining-impact algorithms have been developed on the basis of coal input to a unit plant, calculated in terms of total Btu required to produce 100,000 bbl/d of solvent-refined solids or liquids. In terms of the composite unit plant, this amounted to a coal input of approximately 1.032×10^{12} Btu/d. To calculate state-level coal requirements and the effluent loadings associated with this level of coal production, multiply the number of unit plants supplied by a state coal by the unit plant coal requirement or the effluent loading factor. Unit plants are assumed to use intrastate coal.

BB.2 ALGORITHMS

BB.2.1 Unit plant construction and operation

BB.2.1.1 Coal requirements

Assumptions

- Each unit plant requires a coal input of 1.032×10^{12} stream day, or 3.046×10^{14} Btu per year, based on 330 d (90% capacity) of plant operation per year.
- The Btu content (proximate analysis) of coal fed to a plant is approximately 11,600 Btu/lb for plants in Kentucky, and 13,000 Btu/lb for plants in West Virginia.

Algorithms

- Unit plant coal requirement (tons per year) =

$$\frac{3.406 \times 10^{14} \text{ Btu/year}}{B},$$

where

B = the heat content (Btu/ton) of the coal (for each state); that is, Illinois = 2.21×10^7 Btu/ton, Kentucky = 2.58×10^7 Btu/ton, and West Virginia = 2.74×10^7 Btu/ton.

BB.2.1.2 Air emissionsAssumptions

- The efficiency of particulate matter control is 98%.
- The efficiency of sulfur oxides control is 98%.
- The efficiency of nitrogen oxides control is 75%.

Algorithms

- Atmospheric emissions per plant (tons/year) = $C \times 330$ days of operation per year,
where

C = average emission by pollutant (particulates, SO_2 , NO_x , CO, and hydrocarbons) in tons per day from Table 1.4.

BB.2.1.3 Water use

Water use for a unit plant is assumed to be equivalent to net water consumption for the SRC-I plant, 11,808 gal/min. This equals 52.2 acre-ft/d or 19,046 acre-ft/year.

BB.2.1.4 Solid wasteAssumptions

- Each plant will produce over 100,000 bbl of fuel oil equivalent per day (106,700 bbl/d residual fuel equivalent).
- For plants producing 100,000 bbl/d fuel oil equivalent, the following amounts of waste materials will be generated annually (365-d operating year):
 1. approximately 180,000 tons of wastewater solids and
 2. approximately 1,000,000 tons of other waste solids.

Algorithm

- Total solid wastes produced per plant per year (assuming 90% capacity) =

$$\frac{0.90 \times 106 \times 10^3 \text{ bbl/d} \times A}{100 \times 10^3 \text{ bbl/d}},$$

where A = tons per year of solid waste generation.

BB.2.1.5 Employment

- Each plant will receive a peak construction force of 5000 to 10,000 workers.
- Each plant will require 2,200 operational workers.
- The number of miners has been calculated using state productivity data in which the
 number of miners = $\frac{\text{tons of coal consumed per day}}{\text{average tons mined per day per man}}$.
- All indirect employment is based on the same direct/indirect ratios used in the cumulative impact assessment (Sect. 4.2.5).

BB.2.1.6 Population

- Migration factors for all workers are assumed to be the same as the SRC-I case.
- Two-thirds of all workers (direct and indirect) are expected to bring families with an average size of 3.2.
- No further secondary impact is assumed for the operation population beyond that expected for the construction period.
- Mining manpower factors were derived from operational work-force characteristics.

BB.2.2 Coal miningBB.2.2.1 Coal mining by stateAssumptions

- Each state (Illinois, Kentucky, and West Virginia) contains two facilities each requiring 3406×10^{14} Btu/year of coal input.

Algorithm

- State coal requirements per year = $\frac{2 \times 3.406 \times 10^{14}}{\text{Btu ton}^{-1} \text{ state}^{-1}}$.

BB.2.2.2 Air emissionsAssumptions

- Emissions from underground mining are minor because of the predominance of electric-powered equipment.
- Emission factors for strip mining are listed in Table BB.1.

Algorithm

- Air emission by pollutant (tons/year) = $\frac{(A)(B)(C)}{10^5}$,

where

A = loading factor by state by pollutant (in tons per 10^5 tons of coal strip-mined),

B = coal mined per unit plant in tons per year,

C = percentage of coal strip-mined by state (Table BB.2).

BB.2.2.3 Water useAssumptions

- Coal mining activities that result in water consumption include dust control for roads, mines, and embankments and revegetation of reclaimed areas.
- Regional water use factors reflecting dust control and revegetation activities are from Table BB.3.

Table BB.1. Strip-mining air pollutant loading factors for selected states

	Strip-mining pollutants (tons per 10 ⁶ tons of coal mined)				
	Particulate matter	Sulfur oxides	Nitrogen oxides	Carbon monoxide	Organics
Illinois	0.50	0.45	6.25	3.80	0.70
Kentucky	0.50	0.45	6.25	3.80	0.70
West Virginia	0.15	0.30	4.55	2.80	0.40

Source: U.S. Department of the Interior, *Final Environmental Statement, Federal Coal Management Program*, Report No. 1972(142), Bureau of Land Management, Washington, D.C., 1979.

Table BB.2. Average seam thickness and percent of total coal strip-mined for selected states

State	Average seam thickness (ft)	Total strip-mined (%)
Illinois	6	45
Kentucky	5	55
West Virginia	5.5	22

Source: U.S. Department of the Interior, *Final Environmental Statement, Federal Management Program*, Report No. 1972(142), Bureau of Land Management, Washington, D.C., 1979.

Table BB.3. Water use factors for dust control and revegetation

State or region	Water use factor (Acre-ft per 10 ⁶ tons of coal)	
	Surface mining	Underground mining
Eastern states	4.460	5.88

Algorithms

- Surface mining water use (acre-ft/year) = $(A)(C)/100,000$

where

A = surface mining use factor in acre-feet per 100,000 tons of coal mined (4.46),

C = coal input to unit plant from surface mines in tons per year.

- Underground mining water use (acre-ft/year) = $(B)(C)/100,000$

where

B = underground mining water use factor in acre-feet per 100,000 tons of coal (5.88),

C = coal input to unit plant from underground mines in tons per year.

BB.2.2.4 Solid wastesAssumptions

- For surface mining, solid wastes generated are returned to mining pits and are not considered a solid waste for disposal calculations.
- For underground mining, the amount of solid waste generated is approximately 3% of the coal extracted.
- The percentage of a state coal supplied for liquefaction that is underground-mined is equivalent to the percentage of all coal mined in a state that is underground-mined.

Algorithm

- Mining wastes (tons/year) = $0.03(A)(B)$,

where

0.03 = solid waste generation factor for underground-mined coal,

A = percentage of underground-mined coal (by state),

B = coal supplied to unit plant in tons per year.

BB.2.2.5 Land disturbed by surface miningAssumptions

- Land disturbed by underground mining is minimal.
- The density of coal in a seam is 1750 tons/acre-ft,
- The average seam thickness equals the following (by State):

Illinois	6.0 ft
Kentucky	5.5 ft
West Virginia	5.5 ft

- The proportion of coal strip-mined (by State) equals the following:

Illinois	45%
Kentucky	55%
West Virginia	22%

Algorithm

- The surface area disturbed = $\frac{1}{1750A} (B)(C)$,

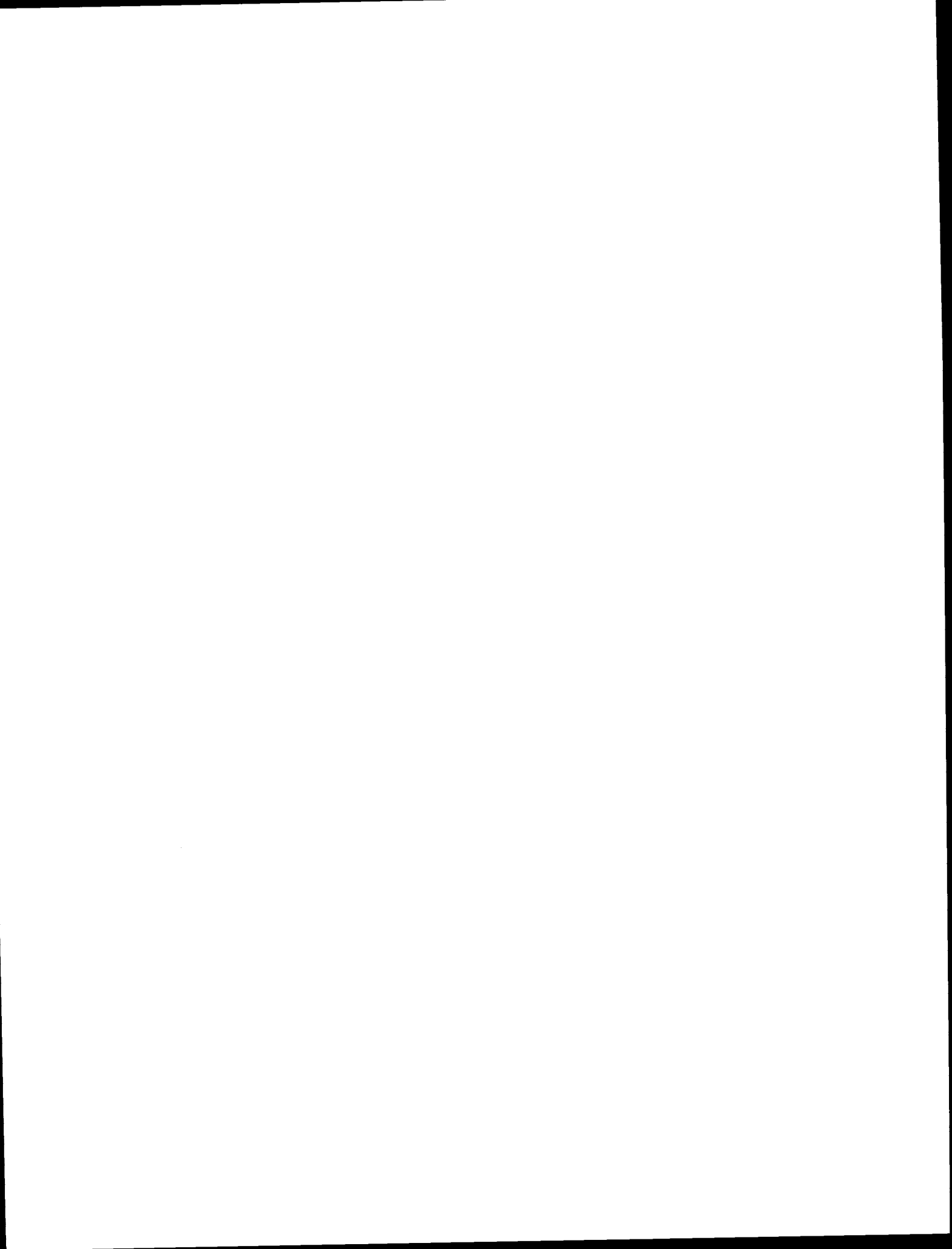
where

A = average seam thickness,

B = proportion of coal strip-mined,

C = coal input to unit plant in tons per year.

Appendix CC
WORKER RELOCATION MODEL



Appendix CC

WORKER RELOCATION MODEL

Reprint of *Assessing the Supply of Workers to Large Construction Projects*, a working paper prepared by the Labor and Policy Studies Program of Oak Ridge Associated Universities, January 1981.

INTRODUCTION

Large construction projects, particularly when located outside of large urban areas, can have significant impacts on the local labor market. In addition to drawing workers off of other construction projects in the area, workers with the appropriate skills but working in different industries may be attracted to the construction site. These, along with individuals unemployed or out of the labor force, supply the bulk of workers from the region around the site. Most of these workers from the local area will commute on a daily basis from their homes. However, some workers in the local labor market area, particularly when the project is large and of long duration, may move permanently or during the work week to a location closer to the work site to reduce daily commuting time or to improve living conditions.

For most large projects, the supply of workers from within about 70 miles around the site is insufficient to meet the demand for construction workers. As a result, many will be hired from outside the local labor market area. A few may be willing to commute extremely long distances on a daily basis. However, most of the workers from outside the local labor market area will choose to move, either permanently or temporarily, into the local area. Some of these workers will live in a temporary residence during the work week and travel home on the weekend while the others will move their permanent residence to the construction project area. In most cases, the supply of workers among local residents and movers to the area will be adequate to fill the needs of the project.

In determining the impact a large construction project has on the local community it is very important to distinguish between

- (1) Local Commuters - those commuting on a daily basis from within 70 miles of the work site.
- (2) Local Movers/Weekend-Travelers - those originally from within the 70 mile region who move to a more preferred location in the region either permanently or during the work week.
- (3) Distance Commuters - those who commute on a daily basis from outside the normal 70 mile commuting distance.
- (4) Distance Movers/Weekend-Travelers - those originally from outside the 70 mile region who move to within the region either permanently or during the work week.

In what follows, a model is described which can be used to predict the number of people on a given large construction project who fall into each of the above four categories. The results are based on population and the supply of construction workers in the region, unemployment in the region, commuting distance to the construction project, and total demand for workers on the project. The model is designed so that it can be used to analyze a variety of large construction projects in various locations.

THE MODEL

A variety of factors can be expected to affect the source of workers for any construction project. For any area in proximity to the work site the number of local commuters, local movers/weekend-travelers, and distance movers/weekend-travelers as defined above might be affected by any of a number of variables. Consider, for example, the area depicted in Figure A-1 which is within 70 miles of the construction project site as indicated. For workers living in the area while working on the project, three possibilities exist: (1) they are local commuters who lived in the area prior to working on the project; (2) they are local movers who moved to the area from within the 70 mile zone or; (3) they are distance movers who moved to the area from outside the 70 mile zone.

The number of local commuters coming out of an area (say a county) within the 70 mile commuting zone are hypothesized to be affected by the following variables:

Commuting Distance (CD) - the distance in miles from the county to the work site is expected to be directly related to the time required to commute to and from the site and inversely related to the number of local commuters attracted to the project.

Project Employment (PE) - the demand for workers on the construction project ought to be directly related to the number of commuters.

Unemployment Rate (UR) - as an indicator of slack in the local labor market, the county unemployment rate is expected to be positively related to the number of local commuters.

Competing Population (CP) - the population within the 70 mile zone but outside of the county in question represents the potential for competition from other workers and also the probability of competing projects to choose between. It should be inversely related to the number of local commuters out of a given county.

Construction Employment (CE) - the number of local craft construction workers in a county represents potential supply to the project and is expected to be directly related to the number of local commuters.

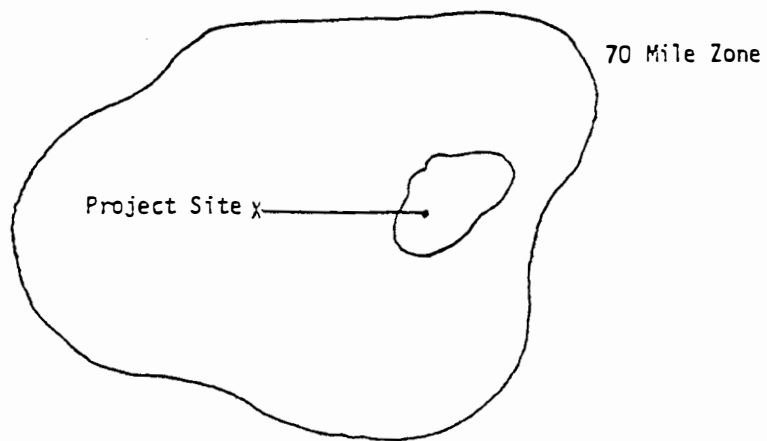


Figure A-1. Representation of the 70 Mile Radius Construction Labor Market Zone Around a Large Construction Project Site

In estimating the number of local movers/weekend-travelers and distance movers/weekend-travelers, the same variables are hypothesized to exert some predictable influence. A lengthy commute, for example, can be expected to discourage relocation to a particular county for the purpose of working on a construction project. The larger the employment on the project, however, the more local and distance commuters can be expected to relocate to any county within 70 miles. Higher unemployment rates may discourage relocation but the effect is likely to be small. Because of alternate possibilities for housing, a larger competing population will in all likelihood be inversely related to the number of construction workers moving permanently or during the work week to a typical county. A large construction work force, because it is positively correlated with population, and because of the information network on available housing, is expected to be associated with more construction workers relocating to an area within the 70 mile zone.

To allow for some interaction among the independent variables and to avoid imposing undesirable restrictions on the model, a non-linear, multiplicative form is assumed for the principal equations to be estimated. For the i th county in the 70 mile zone, the number of local commuters (LC_i) from the county, local movers/weekend-travelers (LM_i) into the county, and distance movers/weekend-travelers (DM_i) into the county are assumed to be related to the independent variables discussed above as indicated by the following equations:

$$LC_i = \alpha_0 \cdot CD_i^{\alpha_1} \cdot PE^{\alpha_2} \cdot UR_i^{\alpha_3} \cdot CP_i^{\alpha_4} \cdot CE_i^{\alpha_5}$$

$$LM_i = \beta_0 \cdot CD_i^{\beta_1} \cdot PE^{\beta_2} \cdot UR_i^{\beta_3} \cdot CP_i^{\beta_4} \cdot CE_i^{\beta_5}$$

$$DM_i = \gamma_0 \cdot CD_i^{\gamma_1} \cdot PE^{\gamma_2} \cdot UR_i^{\gamma_3} \cdot CP_i^{\gamma_4} \cdot CE_i^{\gamma_5}$$

On the other hand, the number of distance commuters working on the site, is related only to project employment. The following linear relationship is assumed:

$$DC = \phi_0 + \phi_1 PE$$

All four equations are defined in such a way that

i refers to a particular county within the 70 mile zone

LC_i is the number of workers on a particular project who live in County i while employed on the project and also lived in county i prior to work on the project, i.e., local commuters

LM_i is the number of workers on a particular project who live in county i either permanently or during the work week while employed on the project but who lived elsewhere within 70 miles of the project site prior to employment, i.e., local movers/weekend-travelers

DM_i is an estimate used to calculate the number of workers on a particular project who live in county i while working on the project, but who had lived more than 70 miles away from the project, i.e., distance movers/weekend-travelers

DC is the number of workers on a particular project who will commute to the work site on a daily basis from further away than 70 miles, i.e., the distance commuters¹

CO , PE , UR , CP , CE are as previously defined.

Unfortunately, it was not possible to constrain the model so that these four values (local commuters, local movers/weekend-travelers, distance movers/weekend-travelers, and distance commuters) add to the total employment on the project. To avoid inconsistent results, one equation must be dropped from the system and the value of the dependent variable estimated as a residual. The method providing the best results allows $\sum LC_i$ and $\sum LM_i$ to represent the supply of workers among local commuters and local movers/weekend-travelers. Any shortage, after accounting for a few distance commuters, is the number of additional workers who must be attracted as distance movers/weekend-travelers in order to satisfy project demand. That is,

$$DM = PE - \sum_i LC_i - \sum_i LM_i - DC$$

This value then becomes the most useful in assessing the regional impact represented by migrants to the area who come to work on the site.

To distribute the distance movers/weekend-travelers among the counties in the region, the estimates of DM_i can be used. If $DM_i / \sum DM_i$ is the proportion of all distance movers/weekend-travelers who can be expected to move to county i , then the revised estimate of the number of distance movers/weekend-travelers to county i (DM_i') can be written as

$$DM_i' = \frac{DM_i}{\sum DM_i} \cdot DM$$

What finally emerges from this is a model which predicts for a given project the number of local commuters, distance commuters, local movers/weekend-travelers, and as a residual, distance movers/weekend-travelers. The sum of these four categories of workers is equal to total employment on the project. The values for the local commuters, local movers/weekend-travelers, and distance movers/weekend-travelers are estimated for each county in the 70-mile commuting zone. Using the notation defined above,

¹County-level estimates are not provided for this variable because the number of workers from any one county outside the 70 mile zone is expected to be quite small. In addition, the data base used to estimate the model does not provide county information for many of these distance commuters.

the model can be summarized as follows:

$$LC_i = \alpha_0 \cdot CD_i^{\alpha_1} \cdot PE_i^{\alpha_2} \cdot UR_i^{\alpha_3} \cdot CP_i^{\alpha_4} \cdot CE_i^{\alpha_5}$$

$$LM_i = \beta_0 \cdot CD_i^{\beta_1} \cdot PE_i^{\beta_2} \cdot UR_i^{\beta_3} \cdot CP_i^{\beta_4} \cdot CE_i^{\beta_5}$$

$$DC = \phi_0 + \phi_1 PE$$

$$DM = PE - \sum_i LC_i - \sum_i LM_i - DC$$

Then to allocate the distance movers among counties in the 70-mile zone

$$DM_i' = \frac{DM_i}{\sum DM_i} \cdot DM$$

where

$$DM_i = \gamma_0 \cdot CD_i^{\gamma_1} \cdot PE_i^{\gamma_2} \cdot UR_i^{\gamma_3} \cdot CP_i^{\gamma_4} \cdot CE_i^{\gamma_5}$$

Taking natural logarithms of the three multiplicative equations, all of the parameters of the above model can be obtained from ordinary least squares estimates of the following four (4) equations:

$$\ln(LC_i) = \ln \alpha_0 + \alpha_1 \ln CD_i + \alpha_2 \ln PE + \alpha_3 \ln UR_i + \alpha_4 \ln CP_i + \alpha_5 \ln CE_i$$

$$\ln(LM_i) = \ln \beta_0 + \beta_1 \ln CD_i + \beta_2 \ln PE + \beta_3 \ln UR_i + \beta_4 \ln CP_i + \beta_5 \ln CE_i$$

$$\ln(DM_i) = \ln \gamma_0 + \gamma_1 \ln CD_i + \gamma_2 \ln PE + \gamma_3 \ln UR_i + \gamma_4 \ln CP_i + \gamma_5 \ln CE_i$$

$$DC = \phi_0 + \phi_1 PE$$

In addition to providing necessary input to the model, the regression coefficients γ_j , β_j , and ϕ_j for all $j = 1, 2, \dots, 5$ have a useful interpretation of their own. They indicate the percentage change in the appropriate dependent variable associated with a one percent change in the corresponding independent variable when other variables are held constant. For example, the numerical value of β_2 would indicate the percentage change in LM_i (the local movers/weekend-travelers from a particular county) associated with a one percent change in project employment.

THE DATA USED IN ESTIMATING THE MODEL

Fortunately, data is available which allows for estimation of the above model. Between 1976 and 1979, twelve separate surveys were administered to workers on three Tennessee Valley Authority nuclear power plant

construction projects. Table 1 gives the dates of the surveys, the surveyed project employment, and the percentage of workers who were local commuters, local movers/weekend-travelers, distance movers/weekend-travelers, and distance commuters. Those surveyed were asked to indicate their residence prior to employment on the project and during employment of the project so it was possible to determine the number of local commuters, local movers/weekend-travelers, and distance movers/weekend-travelers for each county in the commuting zone. In addition, the number of distance commuters from outside the 70 mile zone could be established. Counties were included in the commuting zone if their principal population center was within 70 miles of the construction site.

Values for the independent variables used to estimate the number of commuters and movers were obtained from the following sources:

- CD_i - Commute distance was obtained for each county by computing the mileage between the principal city in the county and the construction site. If roads were particularly bad, some adjustments were made to account for the longer commute time involved.
- PE - Project employment was obtained from TVA and corresponds to the number of workers surveyed at each site
- UR_i - Unemployment rates for each county in the commuting zone are annual averages for the year prior to start of the project and were obtained through telephone contacts with state Employment Security offices. In estimating the model, the percent unemployed times 10 is the form of the data used
- CP_i - Competing population figures indicate total population outside of county *i* but within the commuting zone and are derived from Bureau of Census estimates of 1975 population
- CE_i - Construction employment figures measure, for the county, the number of workers in the construction industry in the year prior to initiating the project and were obtained from state Employment Security offices.

The counties included in the commuting zone for this analysis correspond very closely to TVA's "recruitment counties." The exceptions are counties from which TVA thought they might attract significant numbers of workers but seemed outside of the range for daily commuting to be practical.

Conversations with personnel in TVA's Construction Division gave assurance that nothing atypical has occurred at any of the three construction sites which might affect worker commuter and moving patterns. Car-pooling and bus arrangements were not uncommon for large projects and no excessive overtime was reported. The patterns, it was thought, would be

Table 1. TVA Survey Dates and Distribution of
Commuters and Movers Employed On Site*

TVA Construction Site	Survey Date	Project Employment	Local Commuters	Local Movers/ Weekend- Travelers	Distance Movers/ Weekend Travelers	Distance Commuters
Hartsville, Tennessee	09/76	1,222	1,003	47	143	29
	03/77	1,753	1,367	92	257	37
	09/77	3,233	2,235	192	699	107
	03/78	4,108	2,796	292	886	134
	09/78	5,480	3,662	441	1,170	207
	03/79	6,308	4,028	574	1,420	286
Yellow Creek, Mississippi	06/78	758	630	49	63	16
	12/78	1,333	1,071	81	138	43
	06/79	1,591	1,273	99	174	45
Phipps Bend, Tennessee	05/78	832	718	43	59	12
	11/78	1,231	1,012	91	118	19
	05/79	1,580	1,288	137	142	13

*The project employment figures are the total respondents to each survey. Two differences between the numbers shown in the table and published TVA numbers must be noted.

1. The number of local movers/weekend-travelers and local commuters is based on county-level data, i.e., workers who made an intracounty move are counted as commuters not as movers as done in TVA tabulations.
2. The number of commuters (local and distance) and distance movers/weekend-travelers shown in the tables are slightly different from the TVA figures because the number of employees who did not indicate a residence or who indicated a residence during the work week that was several hundred miles from the project were counted in our study as distance movers.

typical not only for large power plant projects but other large construction projects as well.

ESTIMATED MODEL RESULTS

Because the model is in the early stages of development and is continually being refined, the estimated values of the model's parameters are not reported here.¹ Table 2 does, however, provide the numerical sign of the estimated regression coefficients for three of the equations. These and their level of statistical significance change little with modification of the model or estimation technique. To provide some indication of the accuracy of predictions, summary statistics are also supplied for the estimated regression equations used for the current analysis. It is of interest that the coefficients are all of the expected sign and the equations provide good estimates with low standard errors. The R^2 values range from 0.64 for the equation predicting the number of local commuters from a county within the impact area to 0.78 for the equation estimating the number of distance movers/weekend-travelers. In all but a few cases, the regression coefficients are statistically significant at fairly high levels.

The regression coefficients have a very straightforward interpretation. For example, holding other variables constant an increase in the commute distance between a county and a large construction project will be associated with a decrease in the number of county residents who will commute to the project, a decrease in the number of local movers/weekend-travelers who will relocate to the county to work on the project, and a decrease in the number of distance movers/weekend-travelers into the county. Increases in project employment, on the other hand, are associated with increases in all three categories of workers. Higher unemployment rates represent more local residents available to commute to the project but apparently are related to factors which discourage moving to the county. A large competing population is related to the number of local commuters in an unpredictable manner but clearly decreases the likelihood that project workers will relocate to a particular county. That is, the smaller population counties in the commuting

¹Preliminary values reported in an earlier working paper should be viewed with extreme caution. They do not adjust for a bias introduced by correlation of the regression residual with county size and underestimate the supply of construction workers forthcoming from large counties.

Table 2. Regression Results for Log-Linear Model for Estimating Local Commuters, Local Movers/Weekend-Travelers, and Distance Movers/Weekend-Travelers in Counties within the 70 Mile Commuting Zone Around TVA Nuclear Power Construction Projects

Independent Variables	Dependent Variables		
	$\ln$ (Local Commuters)	$\ln$ (Local Movers/Weekend-Travelers)	$\ln$ (Distance Movers/Weekend-Travelers)
Intercept	(-) ^{***}	(+) ^{***}	(+) ^{***}
$\ln$ (Commute Distance)	(-) ^{***}	(-) ^{***}	(-) ^{***}
$\ln$ (Project Employment)	(+) ^{***}	(+) ^{***}	(+) ^{***}
$\ln$ (Unemployment Rate x 10)	(+) ^{**}	(-) ^{***}	(-) [*]
$\ln$ (Competing Population)	(-)	(-) ^{**}	(-) ^{***}
$\ln$ (Construction Employment)	(+) ^{***}	(+) ^{***}	(+) ^{***}
R^2	0.64	0.75	0.78
F	78.66	137.65	156.14
SEE	1.1870	0.6911	0.8087
n	230	230	230

Using one-tailed tests the coefficients are statistically significant at the following levels:

- *10 percent
- ** 5 percent
- *** 1 percent

region are at a relative disadvantage in attracting movers and will feel less absolute impact from the project. Local commuters are also more likely to be drawn from counties with a large supply of construction workers as represented by the counties' construction employment. As suggested earlier, workers moving into the region are also more likely to relocate to counties in which construction employment (and total population) is greater. So the model not only provides for fairly accurate estimates of the dependent variables, but it describes fairly predictable behavior on the part of workers on large construction projects.

The regression equation for distance commuters was estimated using the data on distance commuters and project employment from the 12 TVA surveys. The results suggest a fairly strong direct relationship between total project employment and the number of distance commuters. The relationship is given by the following linear relationship:

$$\text{Distance Commuters (DC)} = -50.47 + .0507 \text{ PE}$$

$$R^2 = 0.97$$

So each increase in project employment of 1,000 increases the estimated number of distance commuters by approximately 50 people.

TAKING ACCOUNT OF COINCIDENT DEMAND

As formulated, the model discussed above is designed to provide county-level estimates of the number of local commuters, local movers/weekend-travelers, and distance movers/weekend-travelers in the immediate region around a large construction project. The number of distance commuters from outside this normal commuting area is also estimated. In specifying the model, no attempt is made to account for the effect of unusual demand for construction workers generated by other large projects in the area. Other than the project being analyzed, only normal levels of construction activity are assumed throughout the commuting zone. Employment on other large projects, if growing or peaking at the same time, however, will create unusual labor market conditions for locally supplied workers and can be expected to influence local impacts. While it might be expected that coincident demand at a nearby project may represent competition and make it more difficult to attract local construction workers, this is not always the case. Complimentary phasing, particularly among critical craft groups, can be expected to increase the supply of workers to a second project. Even if hiring at the same time, however, the existence of multiple projects can have a joint impact resulting

in a larger than expected supply of local workers. Secondary schools, junior colleges, farm operators and other local employers feel the effects as potential workers temporarily suspend other activities to take advantage of the boom-town-like atmosphere.

When two projects are located very close to one another (within 30 to 40 miles) it is difficult to isolate the effects of one from the other. In such cases it is best to analyze the joint effect of the two projects. Using the model described above, this can best be done by assuming a single project with employment equal to the sum of the two projects combined.¹ Commuting distance can be estimated as the average distance to the two construction sites.² Any county within about 70 miles of either construction site could then be included in the region to be analyzed.

Letting LC_T , LM_T , and DC_T be the total number of local commuters, local movers/weekend-travelers, and distance commuters supplying their labor to the combined projects, the estimates are given for each county by

$$LC_T = a_0 \left(\frac{CD_1 + CD_2}{2} \right)^{a_1} (PE_1 + PE_2)^{a_2} UR^{a_3} CP^{a_4} CE^{a_5}$$

$$LM_T = b_0 \left(\frac{CD_1 + CD_2}{2} \right)^{b_1} (PE_1 + PE_2)^{b_2} UR^{b_3} CP^{b_4} CE^{b_5}$$

where CD_1 and CD_2 are the commuting distance from the county to the two sites respectively, PE_1 and PE_2 are the total employment, and the a_j and b_j are the estimated values of the appropriate regression coefficients. UR , CP , CE are the values of the other independent variables. The county subscript, i , has been eliminated for simplicity.

Having estimated the total number of local commuters and local movers/weekend-travelers for each county in the region impacted by the joint project, the results can be allocated to the separate construction sites. Based on relative commuting distance and employment at each project, the number of local commuters to each project, LC_1 and LC_2 , and the number of

¹The procedure of summing employment on two or more projects is appropriate with this model provided total employment does not greatly exceed 6300 workers, the maximum experienced at any of the TVA sites surveyed.

²Another method which may be preferred in some cases is to compute commuting distance as the minimum distance to either of the sites. This results in somewhat lower estimates of commuting distance and may exaggerate local supply of workers.

local movers/weekend-travelers, LM_1 and LM_2 , can be obtained from the following expressions:¹

$$LC_1 = \left(\frac{CD_1^{\alpha_1} PE_1^{\alpha_2}}{CD_1^{\alpha_1} PE_1^{\alpha_2} + CD_2^{\alpha_1} PE_2^{\alpha_2}} \right) \cdot LC_T$$

$$LC_2 = \left(\frac{CD_2^{\alpha_1} PE_2^{\alpha_2}}{CD_1^{\alpha_1} PE_1^{\alpha_2} + CD_2^{\alpha_1} PE_2^{\alpha_2}} \right) \cdot LC_T$$

$$LM_1 = \left(\frac{CD_1^{\beta_1} PE_1^{\beta_2}}{CD_1^{\beta_1} PE_1^{\beta_2} + CD_2^{\beta_1} PE_2^{\beta_2}} \right) \cdot LM_T$$

$$LM_2 = \left(\frac{CD_2^{\beta_1} PE_2^{\beta_2}}{CD_1^{\beta_1} PE_1^{\beta_2} + CD_2^{\beta_1} PE_2^{\beta_2}} \right) \cdot LM_T$$

¹The first of these expressions is obtained quite easily from the equation for estimating local commuters.

$$LC_1 = \frac{LC_1}{LC_T} \cdot LC_T$$

$$= \frac{LC_1}{LC_1 + LC_2} \cdot LC_T$$

$$= \left(\frac{\alpha_0 CD_1^{\alpha_1} PE_1^{\alpha_2} UR^{\alpha_3} CP^{\alpha_4} CE^{\alpha_5}}{\alpha_0 CD_1^{\alpha_1} PE_1^{\alpha_2} UR^{\alpha_3} CP^{\alpha_4} CE^{\alpha_5} + \alpha_0 CD_2^{\alpha_1} PE_2^{\alpha_2} UR^{\alpha_3} CP^{\alpha_4} CE^{\alpha_5}} \right) \cdot LC_T$$

$$= \left(\frac{CD_1^{\alpha_1} PE_1^{\alpha_2}}{CD_1^{\alpha_1} PE_1^{\alpha_2} + CD_2^{\alpha_1} PE_2^{\alpha_2}} \right) \cdot LC_T$$

The others can be obtained in a similar fashion.

An estimate of the number of distance commuters to the individual construction sites, DC_1 and DC_2 , are best obtained by disaggregating the number of distance commuters to the combined project, DC_T , according to project employment. Thus,

$$DC_1 = \left(\frac{PE_1}{PE_1 + PE_2} \right) DC_T$$

$$DC_2 = \left(\frac{PE_2}{PE_1 + PE_2} \right) DC_T$$

These can be distributed among the counties in the impact area as in the case of a single project.

The result of these calculations is a set of county-by-county estimates of the number of local commuters, local movers/weekend-travelers, and distance movers/weekend-travelers who will work on each of two major construction projects after taking into account the additional employment demand created by the other. The results are based on a disaggregation of the joint impact created by the two simultaneous projects.

CONCLUSIONS

By relying on a county based model of construction labor markets, enough data points are obtained to allow for fairly accurate estimates of commuting and moving patterns among employees on large construction projects. Although the estimates are based on three projects all of which are nuclear plants, the results appear to be fairly general. The twelve surveys cover a wide range of project employment, and variation in other variables is sufficient to provide widely applicable results. What's more, the county based nature of the data when combined to form commuting zone estimates, accounts for a great deal of variation in local characteristics and market conditions.

It should be kept in mind, however, that the model does not take into account a variety of conditions which may be important in a particular area. Union jurisdictions, housing availability and vacancy rates, local codes concerning mobile homes and trailers, and other institutional and legal constraints may alter the actual patterns observed.

It is also important in interpreting results that many large construction projects may have a workforce which differs significantly from that of TVA nuclear power plants. If workers in some crafts are more likely

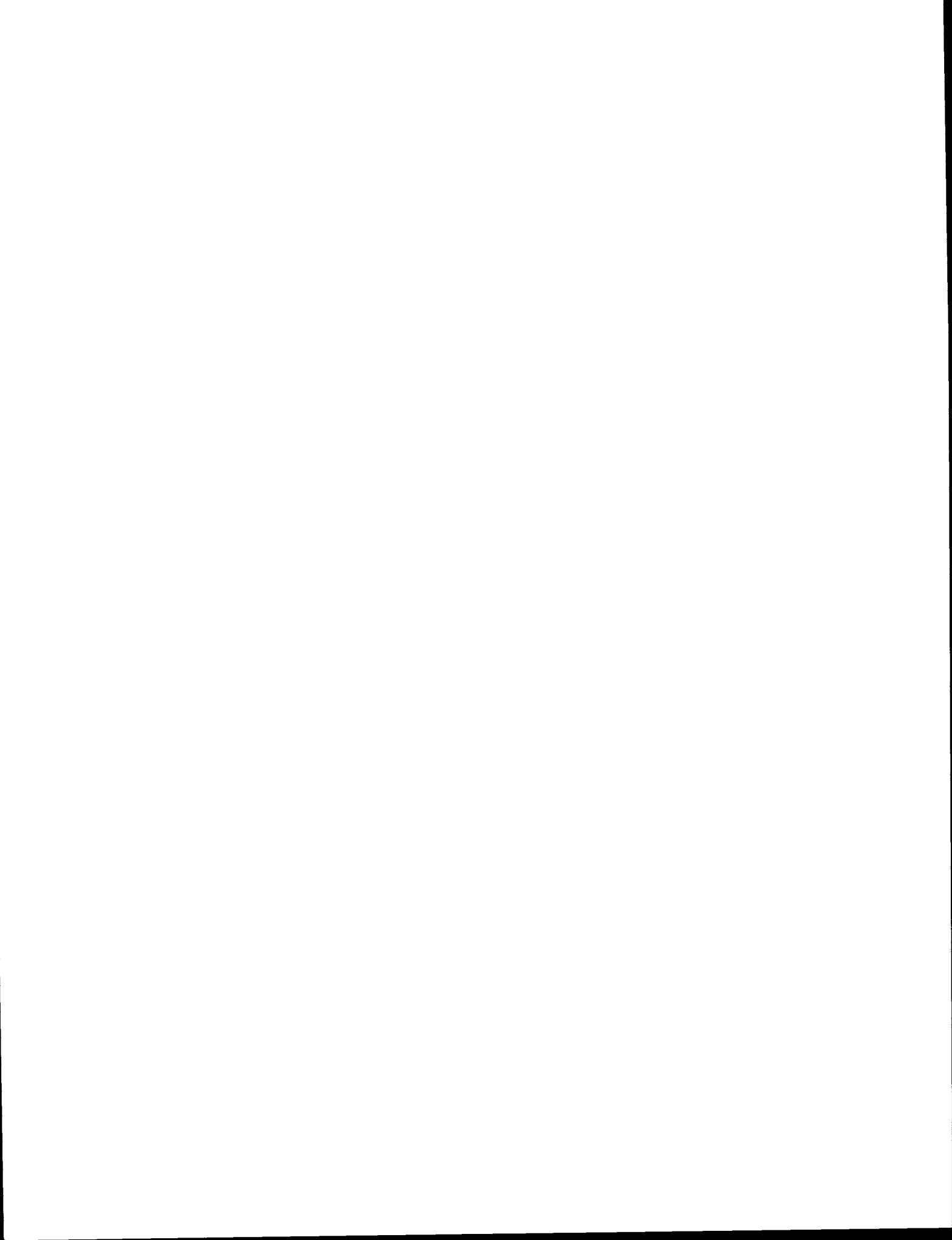
to move or commute long distances than workers in other crafts, then the labor supply pattern will be altered by the composition of craft groups. The labor supply response on nuclear power plant construction projects may also be unique due to the long duration of most such projects. The nature of these and other effects, if they exist at all, are unknown at this time, but they should be kept in mind.

Also important is the region's past, present, and expected future supply and demand for construction workers. Some trends, recent changes, or future developments may not be reflected in the measures used to characterize the area labor market. To the extent that the variables used in the model do not account for such region-specific factors, the results should be qualified.

In conclusion, the econometric model described here can be used to provide some basic estimates of labor market effects. However, whenever such models are used, they cannot be expected to take into account unique features of the region or time period analyzed. Under normal conditions, reasonable estimates can be expected. Analysis is not complete, however, until proper qualitative adjustments have been considered.

APPENDIX DD

TRANSPORTATION SPILLS



Appendix DD
TRANSPORTATION SPILLS

DD.1 INTRODUCTION

The proposed coal liquefaction demonstration plant in Newman, Kentucky, is expected to have a capacity of 5400 t (6000 short tons) of coal per day and will produce energy products consisting of heavy fuel oils, light fuel oils, and solid SRC-I fuel. Final market locations and routes for these products have not yet been established. For the purpose of this analysis of transportation spills, it is assumed that the liquid products will be shipped to two destinations: Pittsburgh, Pennsylvania, and Lake Charles, Louisiana. This appendix selects and describes the rail shipment routes and shipment schedules for heavy oils to Pittsburgh and light oils to Lake Charles and estimates the probabilities of shipping accidents or spills of the SRC-I products.

The SRC-I solid product was not considered in the transportation spill analysis because preliminary laboratory tests on leachates from that product do not appear to present a significant hazard to water quality or to the environment as a whole (see Appendixes C and P). The purpose of this section is to investigate only the worst-case spill, which is considered to be the loss of SRC-I liquids during shipment. A brief analysis of the potential consequences of a worst-case spill is also included.

The rail carrier that will originate and long-haul the SRC shipments is the Louisville and Nashville Railroad (L&N). The L&N and Seaboard Coast Railroad, together with three minor railroads, have merged to form the Family Lines. On November 1, 1980, the Family Lines and the Chessie Rail System merged to form the CSX holding corporation.

The new rail corporation can easily switch traffic within its own system, thus providing through service for shipments of SRC-I heavy liquid to Pittsburgh. Shipments of SRC-I light liquids to Lake Charles require interlining with the Southern Pacific Railroad (SP) in New Orleans. It is assumed that the International Coal Refining Company will own or lease necessary rolling stock (the rail tank cars) and that the railroads will provide locomotives.

In the following sections, route characteristics for both northern and southern shipments are described, and accident spill frequency estimates are developed.

DD.2 PRODUCT TRANSPORTATION

Potential routes for distribution of products from the demonstration plant is still under study. It is thus impossible at this time to specify final transportation routes to be used. The following alternatives are under study and will be used to evaluate the environmental impacts of transporting SRC-I products. This analysis includes the fate of SRC-I products in the event of accidents and resultant spills.

DD.2.1 Description of railroad route from Newman to Lake Charles

For analytical purposes it is assumed that the SRC-I light liquid products will be transported to Lake Charles, Louisiana. Light-oil SRC-I shipments (including the naphtha and middle distillate fractions) will originate on the L&N railroad at the plant's siding in Newman, and shipments are expected to interline with the SP at Avondale Switching Yard in New Orleans for final delivery to Lake Charles.

After originating in Newman, the shipment will proceed through Henderson, Kentucky, and south through Hopkinsville, Kentucky, into Tennessee. The route followed by SRC-I shipments in

Tennessee passes through the city of Nashville before entering Alabama. The shipment will continue south through the major industrial cities of Birmingham, Montgomery, and Mobile before entering Mississippi. The route along the Gulf of Mexico passes through the cities of Biloxi and Gulfport and crosses Lake Pontchartrain into New Orleans. The unit train shipment will probably switch train crews and locomotives before proceeding on SP lines into Lake Charles, Louisiana. Final delivery will be to the Cities Service Refinery at Lake Charles. The SP serves this refinery on a regular basis, and the siding and switching infrastructure are in good operating condition.

The rail route over which this shipment will be hauled is in good condition, and the operation of two additional trains per week presents no capacity problem. The route is designated as an "A" mainline by the Federal Railroad Administration (FRA), which is FRA's highest designation for a rail line.¹ The route on the L&N lines is all single track, with central traffic control (CTC) signaling. CTC is an automatic system with track sensors and safety locks on switches. It is a safe and effective signaling system for controlling multiple trains on a single track. Sidings and yards are adequate to assure increased control of the increased traffic.

The present traffic level is in the range of 18 to 28 annual gross metric tons (20 to 30 million tons), with the route segment from Henderson to Nashville and from Escambia, Alabama, to Mobile exceeding 28 million metric tons. Large amounts of coal are transported along the route segment from Henderson to Nashville. Other prominent commodities on this route are grain, trailers on flat cars (TOFC), automobiles, alumina, contrainers, pulp and paper, and fertilizers. SRC-I liquids shipments would increase the traffic density on this segment by 1.7 to 2.5%.

From the Avondale Switching Yard in New Orleans to Lake Charles, the SP route is also designated as an "A" mainline by the FRA. It is a single track with 80-kmph (50-mph) speeds and train order dispatching. (Central dispatching controls the traffic on this line segment.) This route segment has minimum curvature, a factor which reduces the likelihood of accidents. Extensive rebuilding of this segment of track has already occurred, and after April 1981, slow orders for the New Orleans to Lake Charles route segment will be lifted.

Present traffic on this segment is eight trains per day, moving an average of 16 to 18 million gross metric tons of freight per year. The major commodities shipped on this route are petroleum products, petrochemicals, TOFC, and manifest traffic. SRC-I products would increase traffic density on this track segment by 2.5 to 2.9%.

DD.2.1.1 Towns along the route from Newman to Lake Charles

Trains from Newman to Lake Charles will pass through more than one hundred towns, cities, and communities, having a combined population of over 2.5 million. An accident resulting in an explosion or a spill into the water supply could have adverse effects on these local populations.

The largest cities through which the light oil shipment is transported are New Orleans (555,000), Nashville (461,000), Mobile (368,300), Birmingham (278,000), and Montgomery (189,600). A listing of all towns and cities of more than 100 inhabitants is presented in Table DD.1.

DD.2.1.2 Major water crossings

The described rail route to Lake Charles crosses numerous rivers, creeks, and wetlands. More than 100 water bodies are crossed. Major river crossings are listed in Table DD.2. In Kentucky the rail shipment will cross the Green River at two locations. In Tennessee the major crossing is over the Cumberland River at Nashville. In Alabama the rail route crosses the Tennessee River at Decatur, the Alabama River near Montgomery, and the Mobile River at Mobile. The route will cross the Mississippi River before entering New Orleans and interlining with the SP.

Along the Gulf of Mexico from Mobile to Lake Charles rail shipments pass through bayou terrain. This terrain contains wetlands and sensitive plant and animal species which could be adversely affected by a spill of SRC-I liquid products.

DD.2.1.3 Municipal water intakes along the route and downstream from it

Spilled SRC-I liquid could contaminate both groundwater and surface water supplied to municipal water systems along the route. Spills on land could contaminate groundwater by percolating into aquifers. Soils tend to retard movement and attenuate many chemical species. The role of

Table DD.1. Selected population centers^a on rail route from Newman, Kentucky, to Lake Charles, Louisiana

Kentucky	
Henderson	38,200
Sebree	1,092
Hopkinsville	27,700
Guthrie	1,200
Tennessee	
Springfield	9,720
Nashville	461,200
Brentwood	4,099
Lewisburg	7,205
Alabama	
Athens	14,360
Decatur	39,600
Hartselle	7,355
Cullman	16,800
Birmingham	278,000
Calera	1,655
Jemison	1,423
Clanton	5,868
Montgomery	189,600
Fort Deposit	1,438
Greenville	8,033
Georgianna	2,148
Brewton	6,747
Flomaton	1,584
Atmore	8,293
Bay Minette	6,727
Mobile	368,300
Mississippi	
Pascagoula	31,700
Biloxi	44,700
Gulfport	44,700
Bay St. Louis	6,752
Waveland	3,108
Pass Christian	2,979
Long Beach	6,170
Ocean Spring	9,580
Moss Point	16,500
Louisiana	
New Orleans	555,000
Raceland	4,880
Morgan City	16,500
Franklin	9,325
Jeanrette	6,322
New Iberia	35,400
Lafayette	79,900
Rayne	9,510
Jennings	11,783
Welsh	3,203
Iowa Jct.	1,944
Lake Charles	75,700

Source: *Rand McNally Atlas*, Rand McNally & Co., Chicago, 1980.

^aOnly towns and cities with a population over 1000 are listed.

Table DD.2. Major river crossings on southern SRC-I shipment route to Lake Charles, Louisiana

State	River
Kentucky	Green River (Spotsville) Green River (Smallhaus)
Tennessee	Red River (Adams) Cumberland (Nashville) Harpeth (Arlington) Duck (Chapel Hill) Elk (Fayetteville)
Alabama	Tennessee (Decatur) Mulberry Fork (Bangor) Locust Fork (Trafford) Alabama (Montgomery) Sepulga (Garland) Escambia (Escambia Jct.) Mobile (Mobile)
Mississippi	Pascagoula (Pascagoula) Biloxi Bay (Biloxi) St. Louis Bay (Bay St. Louis)
Louisiana	Lake Pontchartrain (Rigolets) Mississippi (New Orleans) Bayou Lafourche (Raceland) Bayounezipique (Lake Arthur) Calcasieu (Lake Charles)

Sources:

1. *Rand McNally Atlas*, Rand McNally & Co., Chicago, 1980.
2. Telephone conversation with Buck Hord, Manager of Dispatching Operations, Southern Pacific Railroad, Nov. 13, 1980.

the soil in attenuating spilled chemicals is discussed in a later section (see Sect. DD.5.2). There is no such buffer against contamination of surface waters in the event of a spill directly into open water. Spills into open water are particularly serious because many of the streams (listed in Table DD.2) are used for public water supply. For example, the Cumberland River is the water source for metropolitan Nashville, Tennessee.

DD.2.2 Description of the route from Newman to Pittsburgh

The proposed route for heavy oils from the Newman demonstration plant to Pittsburgh follows L&N and Chessie rail lines, both of which are subsidiaries of the CSX rail corporation. Use of a single carrier from plant to destination and infrequency of shipment reduce the probability of an accident or incident in transit.

The shipment will originate on existing L&N rail lines in Newman and will be hauled northeast through Louisville, Kentucky, to Covington, Kentucky. At Covington, the shipment will switch to Baltimore and Ohio (B&O) rail lines, part of the Chessie Rail System, and move through Cincinnati to Columbus. From Columbus it will continue eastward through Ohio to Wheeling, West Virginia, and into Pennsylvania and the Pittsburgh metropolitan area.

The L&N segment of this route is single track into Cincinnati and is designated as a "B" mainline by the FRA.¹ The average annual volume shipped on this rail line is between 5 and 10 million gross metric tons. The increased traffic from SRC-I shipments is approximately 50 thousand metric tons annually, which would increase total traffic by 1% or less.

The 8&0 segment of this route from Cincinnati to Pittsburgh carries annual gross tonnage of 5 to 18 million metric tons. Traffic exceeds the 18-million metric ton average only on a 55-km (34-mi) segment east of Columbus. Annual tonnage traffic on that segment averages less than 28 million metric tons. The proposed SRC shipment from Cincinnati to Pittsburgh would increase traffic density between 0.1% and 1%. The proposed route from the Newman plant to Pittsburgh appears to be adequate to haul the additional tonnage of SRC-I heavy liquids.

DD.2.2.1 Towns along the route

The major cities through which heavy oil SRC-I products pass include: Owensboro (50,700), Louisville (310,000), Covington (43,900), Cincinnati (383,000), Columbus (529,000), Wheeling (42,700), and Pittsburgh (421,000).² A listing of all towns and cities with population over one thousand through which the route passes is presented in Table DD.3.

Table DD.3. Selected population centers^a on rail route from Newman, Kentucky, to Pittsburgh, Pennsylvania

Kentucky	
Newman	
Stanley	350
Owensboro	50,700
East Owensboro	2,500
Maceo	400
Lewisport	1,595
Hawesville	1,262
Cloverport	1,388
Brandenburg	1,637
Louisville	310,000
St. Mathews	13,152
Anchorage	1,477
Crestwood	415
La Grange	1,713
Pendleton	10,500
Campbellsburg	479
Verenoa	300
Walton	1,801
Covington	43,900
Ohio	
Cincinnati	383,000
Loveland	7,126
Wilmington	10,051
Washington Court House	13,600
Mt. Sterling	1,536
Columbus	529,000
Newark	36,900
Zanesville	36,400
Cambridge	12,600
New Concord	2,318
Barnsville	4,292
West Virginia	
Wheeling	42,700
Pennsylvania	
Washington	20,400
Pittsburgh	421,000

Source: *Rand McNally Atlas*, Rand McNally & Co., Chicago, 1980.

^aOnly cities and towns with a population over 1000 are listed.

DD.2.2.2 Water crossings

The route from Newman to Pittsburgh crosses the Ohio River twice, at Covington, Kentucky, and Wheeling, West Virginia. Additional river and creek crossings in Ohio are listed in Table DD.4. Along this route there are relatively few river and stream crossings compared to the southern route by which the light liquids are to be shipped.

Table DD.4. Major river crossings^a on northern SRC-I shipment route to Pittsburgh, Pennsylvania

State	River
Kentucky	Kentucky River (Worthville) Ohio River (Covington)
Ohio	Paint (Washington Court House) Deer Creek (Mt. Sterling) Darby (Harrisburg) Scioto (Columbus) Muskingum (Zanesville) Wills (Cambridge)
West Virginia	Ohio River (Wheeling)

Source: *Rand McNally Atlas*, Rand McNally & Co., Chicago, 1980.

^aThere are possible river crossings in the Pittsburgh metropolitan area, depending on final delivery of SRC shipment.

DD.3 PROBABILITY AND VOLUME OF SPILLS

Because SRC-I liquid fuel is a new energy product, very few shipments have been made, and no accident data have been reported. To measure the probability of a possible accident involving future SRC-I shipments, an analysis of shipments of similar commodities and reported rail incidents involving hazardous materials is presented. The number of spills predicted for the SRC-I demonstration plant is presented in Table DD.5.

DD.3.1 Accident probabilities

SRC-I liquids may be classified as hazardous because they contain naphtha, polynuclear aromatics (PNA), tar, and other chemical compounds previously determined to be hazardous. Three commodity classes from the Standard Transportation Classification Code (STCC) were chosen for analysis: Industrial Inorganic Chemicals, Miscellaneous Chemical Products, and Products of Petroleum Refining. These product groups contain hazardous materials and are considered a valid basis for comparison. The number of shipments for 1976-1978 of each of these product classes is presented in Table DD.6.

DD.3.1.1 Accident and spill frequencies

Accident/spill statistics for shipments of hazardous liquid cargos were determined for the 1976-1978 period using the following data:

1. Carload Waybill Statistics (1976, 1977, and 1978), U.S. Department of Transportation, Federal Railroad Administration, Office of Rail Systems Analyses and Information. The data included aggregate commodity totals for three commodity classes: (a) Industrial Inorganic Chemicals (STCC number 281), (b) Miscellaneous Chemical Products (STCC number 289), and (c) Products of Petroleum Refining (STCC number 291).

**Table DD.5. Predicted accident and spill frequencies
for shipment of SRC-I liquid products**

	Frequency ^a	Derivation ^b
Reportable accidents in terms of:		
No. of shipments		
Heavy products	1,150.0	$i \div b$
Light products	132.2	$i \div f$
Volume shipped		
Heavy products	20.9	$k \div a$
Light products	2.0	$k \div e$
Ton-miles		
Heavy products	24.8	$m \div c$
Light products	1.2	$m \div g$
Car-miles		
Heavy products	23.5	$o \div d$
Light products	1.2	$o \div h$
Reportable spill incidents to water bodies in terms of:		
No. of shipments		
Heavy products	25,786.0	$j \div b$
Light products	2,964.0	$j \div f$
Volume shipped		
Heavy products	465.9	$l \div a$
Light products	44.0	$l \div e$
Ton-miles		
Heavy products	398.8	$n \div c$
Light products	19.8	$n \div g$
Car-miles		
Heavy products	526.5	$p \div d$
Light products	26.3	$p \div h$

^aFrequency is defined in terms of months: for example, 1150 equals 1 occurrence every 1150 months; similarly, 3.1 equals 1 occurrence every 3.1 months.

^bDerivation is keyed to the data elements in Tables DD.10 and DD.11.

2. RYMDSM Data Base, U.S. Department of Transportation, Federal Railroad Administration, Office of Hazardous Materials. Data used include numbers of reported accidents involving shipment of hazardous materials that resulted in losses/damages greater than \$2,900.
3. Pollution Incident Reporting System (PIRS), U.S. Department of Transportation, U.S. Coast Guard. Data used included the number and volume of reported spills of hazardous liquids into bodies of water.

The data are presented in Tables DD.6, DD.7, and DD.8. Calculated accident probabilities are presented in Table DD.9. The following production/transportation assumptions were made:

1. Heavy liquid fuel oils, produced at a rate of 135 tons/d, would be shipped once a month from the plant site at Newman, Kentucky, to Pittsburgh, Pennsylvania (approximately 840 km). This movement is expected to require one train of approximately 60 tank cars.*

*This figure assumes that one ton equals 294 gal and that shipments will be in "average" tank cars of approximately 20,000 gal ($135 \text{ tons} \times 30 \text{ d} \times 294 \text{ gal} \div 20,000 \text{ gal/car} = 59.6 \text{ cars}$).

Table DD.6. Railroad statistics for hazardous commodities

STCC No. ^a	1976				1977				1978			
	Shipments	Tons	Ton-miles ($\times 10^3$)	Car-miles ($\times 10^3$)	Shipments	Tons	Ton-miles ($\times 10^3$)	Car-miles ($\times 10^3$)	Shipments	Tons	Ton-miles ($\times 10^3$)	Car-miles ($\times 10^3$)
281	702,400	55,560,700	38,743,900	484,100	779,200	56,825,500	38,822,800	485,100	759,700	61,628,200	41,940,400	516,500
289	110,900	6,917,400	5,146,800	89,300	110,330	6,848,000	4,851,800	84,200	108,500	6,757,900	4,882,400	82,200
291	315,000	21,522,600	10,930,700	172,600	333,400	22,995,100	11,913,700	183,700	313,800	21,616,800	11,418,600	174,800
Total	1,128,300	84,000,700	54,821,400	746,000	1,222,900	86,668,600	55,588,300	753,000	1,182,000	90,002,900	58,241,400	773,500

^a281, industrial inorganic chemicals; 289, miscellaneous chemical products; 291, products of petroleum refining.

Source: U.S. Department of Transportation, Federal Railroad Administration, *Carload Waybill Statistics*, 1976, 1977 and 1978.

Table DD.7. Reported accidents and spills of hazardous liquids into water bodies

	1976	1977	1978
Accidents ^a			
Number	982	899	1191
Spill incidents ^b			
Number	65	35	37
Volume, ^b tons	801.9	756.2	468.2
Probability of accident occurrence ^c	0.0009	0.0007	0.0010
Probability of spill occurrence ^c	0.0001	0.00003	0.00003

^aAccidents involving loss or damage totaling more than \$2900 as reported in the RYMDSM data base.

^bVolumes of spills into water bodies reported in the PIRS data base and converted to tons based on an average of 294 gal/ton.

^cProbability of accidents is calculated by dividing the number of accidents in a given year by the number of shipments in that year, shown in Table DD.6. Probability of spills calculated in the same manner, using the ratio of spills to shipments in a given year.

Table DD.8. Aggregate accident and spill statistics for hazardous commodity shipments, 1976-1978

(1) Shipments	3,533,200
(2) Tons shipped	260,672,200
(3) Ton-miles	116,234,100,000
(4) Car-miles	2,272,500,000
(5) Reported accidents	3,072
(6) Reported spill incidents (into water)	137
(7) Reported spill volumes (tons into water)	2,026

2. Light liquid fuels, produced at a rate of 1430 tons/d (774 tons/d of naphtha and 656 tons/d of fuel oil), would be shipped twice weekly from the plant site to Lake Charles, Louisiana (approximately 1600 km). These movements are expected to require two trains per week, each with approximately 75 tank cars.* Summary statistics based on these assumptions are presented in Table DD.10.

More recent estimates of production (since the DEIS) indicate that naphtha will be produced in lesser quantities than the figure used in this section. Therefore, probabilities of worst-case spill are somewhat overestimated in this analysis.

Using the universe of accident and spill incident rates from Table DD.9, rates can be expressed in terms of number of shipments, volumes shipped, ton-miles traveled, and car-miles traveled. These data are presented in Table DD.11.

* Figures were derived similarly. Two trains per week were deemed necessary because trains in excess of 75 cars are essentially prohibited. (1430 tons x 7 d x 294 gal ÷ 20,000 gal/car = 147.1 cars.)

Table DD.9. Aggregate accident and spill rates, 1976-1978

Derivation ^a		
No. of reported accidents per:		
Shipment	0.000869	(5) ÷ (1)
Ton shipped	0.0000118	(5) ÷ (2)
Ton-mile	0.000000019	(5) ÷ (3)
Car-mile	0.00000135	(5) ÷ (4)
No. of reported spill incidents into water per:		
Shipment	0.00003878	(6) ÷ (1)
Ton shipped	0.00000053	(6) ÷ (2)
Ton-mile	0.00000000118	(6) ÷ (3)
Car-mile	0.0000000603	(6) ÷ (4)

^aDerivation is keyed to the data elements in Table DD.8.Table DD.10. Summary statistics for projected SRC-I movements per month^a

SRC-I heavy products	
a. Volume shipped, tons	4,050
b. No. of shipments	1
c. Ton-miles	2,126,250
d. Car-miles	31,500
SRC-I light products	
e. Volume shipped, tons	42,900
f. No. of shipments	8.7
g. Ton-miles	42,900,000
h. Car-miles	630,630

^a30 days.

Table DD.11. Aggregate statistics on SRC-I accidents and spills into water

No. of shipments per:	
i. Accident	1,150
j. Spill incident	25,786
Tons shipped per:	
k. Accident	84,746
l. Spill incident	1,886,793
Ton-miles per:	
m. Accident	52,631,579
n. Spill incident	847,460,000
Car-miles per:	
o. Accident	740,741
p. Spill incident	16,587,591

Using Tables DD.10 and DD.11, the frequencies of "reportable accidents" and "reportable spill incidences" for the projected shipments of SRC-I liquids can be determined. These frequencies are presented in Table DD.5.

Reportable accidents (again, defined as resulting in loss or damage in excess of \$2900) can generally be expected much less frequently than every two years for the heavy fuels, while an accident may be expected as often as every six weeks in the case of the light products (see Table DD.5). Reportable spills into bodies of water can be expected to occur only rarely (no more than once every 33 years) in the case of the heavy product, while similar spills for light products can be expected to occur less than every two years.

Track characteristics and traffic conditions are not expected to increase accident or spill risks due to the relatively small volumes of shipments over normally heavily traveled lines. Both routes, however, pass through major population centers, thus exposing the citizens of these cities to the hazardous products. These risks cannot be expected to be significantly different from those of any other comparable petroleum product already moving along those corridors, however. The possibility of contamination of water supplies is expected to be highest along the route from Newman to Lake Charles, especially where the route crosses major water bodies and rivers (i.e., Green River, Cumberland River, Tennessee River, Alabama River, Biloxi Bay, Lake Ponchartrain, and Mississippi River). Significant damage to the bayou wetland en route to New Orleans can also be expected if a major spill occurs.

DD.3.2 Spill volume

The following section presents data on the volume-frequency distribution of rail accidents resulting in spills into water. Rail data were extracted from the Pollution Incident Reporting System (PIRS) for the years 1975 through 1979. Also included in this section is a discussion of the average spill size.

The Federal Water Pollution Control Act of 1970 (Section 311) requires that any discharge of an oil or a hazardous substance in a harmful quantity be reported to the "appropriate agency of the United States Government." Executive Order 11735, 5 March 1970, designated the U.S. Coast Guard as one of the agencies. The PIRS is a computerized data base developed as an adjunct to the Coast Guard's Marine Environmental Protection Program. Initially designed for the collection and maintenance of discharge data, subsequent modifications were made to permit the inclusion of additional data on cleanup (response) activities and penalty actions. The following are data PIRS has collected since 1973 for pollution incidents:

<u>DISCHARGE</u>	<u>RESPONSE</u>	<u>PENALTY</u>
Time of occurrence	Cleanup party	Initiating agency
Location	Equipment used	Authority
State	Personnel	Action against
Waterbody	Cleanup duration	Action date
Source	Amount recovered	Penalty proposed
Cause	Cleanup cost	Penalty collected
Operation		Hearing results
Material		Appeal results
Quantity		Cause status
Affected resources		
Weather		
Notifier		

For a spill to be recorded, it must: (1) be water connected, (2) occur within the territorial boundaries of the United States, (3) be reported by an interested party, and (4) reveal a sheen on the water. (A sheen is generally recorded as a quantity of at least one gallon of material.)

A request was made to the Coast Guard for a comprehensive printout of rail spills of liquid shipments within the states of Pennsylvania, West Virginia, Maryland, and Virginia for the years 1975 to present. Although the total quantity of liquid spilled by rail cars is 655,587 gallons for the period, the largest spill (484,000 gal of kerosene) accounts for approximately 74% of the five-year total.

Table DD.12 presents the frequency of rail spills of hazardous liquids into water for 1975 through 1979 based on PIRS. There were 169 spills reported over the five-year period. In both tables it can be seen that 42% of all spills were less than 1000 gal and over one-half (53%) of the spills recorded were for amounts of less than 2000 gal.

Table DD.12. Frequency and cumulative percentage of rail spills into water, 1975-1979

Spill Volume (gal)	No. of spills	Percentage	Cumulative Percentage
0-250	45	27	27
251-500	14	8	35
501-750	5	3	38
751-1,000	7	4	42
1,001-1,250	2	1	43
1,251-1,500	7	4	47
1,501-1,750	2	1	48
1,751-2,000	7	4	52
2,001-2,500	2	1	53
2,501-3,000	7	4	57
3,001-3,500	4	2	59
3,501-4,000	3	2	61
4,001-4,500	0	0	61
4,501-5,000	4	2	63
5,001-5,500	0	0	63
5,501-6,000	7	4	67
6,001-6,500	2	1	68
6,501-7,000	5	3	71
7,001-7,500	1	1	72
7,501-8,000	5	3	75
8,001-8,500	0	0	75
8,501-9,000	3	2	77
9,001-9,500	0	0	77
9,501-10,000	7	4	81
10,001-10,500	2	1	82
10,501-11,000	2	1	83
11,001-11,500	0	0	83
11,501-12,000	2	1	84
12,001-12,500	0	0	84
12,501-13,000	0	0	84
13,001-13,500	0	0	84
13,501-14,000	3	2	86
14,001-14,500	0	0	86
14,501-15,000	1	1	87
15,001-15,500	1	1	88
15,501-16,000	0	0	88
16,001-16,500	0	0	88
16,501-17,000	0	0	88
17,001-17,500	1	1	89
17,501-18,000	1	1	90
18,001-18,500	0	0	90
18,501-19,000	1	1	91
19,001-19,500	0	0	91
19,501-20,000	6	4	95
20,000	10	5	100

Source: Pollution Incident Reporting System, U.S. Coast Guard.

Calculating a simple arithmetic average shows the average rail spill size to be 8780 gal. The weighted mean size of a spill of hazardous liquids into water is calculated based on the formula:

$$\mu = \frac{\sum_{i=1}^n x_i f_i}{\sum_{i=1}^n f_i}$$

where

- μ = the frequency-weighted mean spill size,
- x_i = the spill gallonage interval midpoint,
- f_i = frequency of the spill which falls into the interval,
- n = number of intervals.

With regard to rail spills, this mean is 5041 gal. The arithmetic average spill size is higher because of the recording of six spills between 19,501 gal and 20,000 gal and of 10 spills with volumes greater than 20,000 gal. Therefore, the worst-case analysis in this EIS considers a spill that is almost four times the frequency-weighted mean spill volume.

DD.4 DETERMINATION OF WORST-CASE SPILL SCENARIO

Spills of liquid SRC-I products in transit will have various levels of environmental impacts, depending on the location of the spill. The degree of concern for individual avenues and locations of release depend upon likelihood of occurrence for the spill event, spatial dimensions of the area affected, and severity of environmental and health effects of the spill.

DD.4.1 SRC-I liquid spilled directly to surface water

As discussed in Sect. DD.3, accidental spills of major and minor varieties may be expected to occur. The focus of the analysis is on SRC-I liquid products because laboratory leaching tests on the SRC-I solid product (Appendix P) suggest that the leachate may be less contaminated than the leachate from raw coal. Liquid products are thus regarded as significantly more hazardous than the solid product. Available information on the organic constituents of the SRC-I liquid product suggests resulting ecological effects greater than those for crude petroleum oil and at least equal to those for No. 2 petroleum distillate fuel oil.³ The light liquids, including naphtha and middle distillate fractions, are considered to be of greater hazard in the event of a spill because of the presence of water-soluble phenols in them. There is potential for water-borne dispersal of these constituents over large areas and for long-term accumulations in bottom sediments. Consequently this route of release is regarded with the greatest degree of concern. The sites at which direct release to surface water is possible are bridge crossings over streams, including major crossings (listed in Tables DD.2 and DD.4), and many smaller streams. Crossings that are viewed with greatest concern are those immediately upstream from municipal water intakes for large cities. On the southern route proposed for shipment of light SRC-I liquids to Lake Charles, Louisiana, the only major crossings less than 80 km (50 river miles) upstream from the water intake of a city with a population greater than 20,000 are the two Green River crossings. Intake for the Evansville, Indiana, municipal water system is on the Ohio only about 15 miles downstream from the Green River crossing at Spotsville. The population of Evansville is approximately 130,000. The Spotsville crossing was, therefore, chosen for the worst-case spill analysis.

Spills into smaller streams could produce similar effects but would generally be less serious because greater opportunity is afforded for arresting the flow to a larger stream by damming (see Sect. DD.6). One such case chosen for examination is the crossing over Love's Creek north of Nashville. Love's Creek flows into the Cumberland River via Cheek Lake at the point where the Madison Suburban Utility District pumps water from the river. The utility serves 12,000 residential and industrial customers in Nashville. Although the probability of a spill at one point such as the Love's Creek crossing is extremely small, consequences of such a spill would be great. Impacts of a spill at that site are considered (see Sect. DD.5).

A spill to the environmentally sensitive bayou wetlands of the Gulf Coast would have serious impacts on the aquatic ecology of the area, although direct health effects on humans would be minor. Effects of a spill into a bayou are, therefore, briefly discussed in a generic sense in Sect. DD.5.

The worst-case spills affecting water supply systems are highly unlikely events because their occurrence requires spillage of the SRC-I product at a specific, vulnerable location (such as the rail barge crossing the Green River). To assess the likelihood of a spill at any such specific location, an estimate is made of the frequency of spills for any 1-mile segment of the 994-mile southern rail route (i.e., it is assumed that the risk of spills is evenly distributed over each mile of the route). Table DD.5 indicates the expected occurrence of spills over the entire route of shipments of hazardous materials. A spill of SRC-I light product (naphtha or middle distillate) to a water body could be expected every 3000 months (250 years). To arrive at the frequency of spill occurrence for each mile of the route, these frequencies are multiplied by 994, the number of miles in the shipment route. Thus for any specific 1-mile segment of the southern route, a spill to water can be expected approximately every 2,900,000 months (250,000 years) in terms of shipments.

DD.4.2 Spills on land

The northern route chosen for shipment of heavy liquids to Pittsburgh also crosses several major streams (see Table DD.4). All of these crossings are at least 80 km (50 miles) upstream from the water intake for a city with a population greater than 20,000. Intakes for Cincinnati and Covington are upstream of the Ohio River crossing, and the intakes for Columbus are upstream from the Scioto and Big Walnut Creek crossings. Therefore, the area that is viewed with most concern is the rail link between Owensboro and Louisville, where the railroad is in close proximity to the river. A spill along this segment could infiltrate and contaminate the alluvial aquifer along the Ohio River or flow overland into the Ohio River. Effects of a spill to an aquifer used for public water supply are discussed in Sect. DD.5.2. In each of the hypothetical spill incidents discussed in Section DD.5, the volume spilled is assumed to be the total contents of one tank car, equaling 75,700 liters (20,000 gal). A spill of this volume exceeds the volume of 95% of all reported spills (see Table DD.12).

DD.5 IMPACTS OF SPILLS

For the purpose of spill analysis, it is assumed that the chemical composition of the SRC-I liquids is similar to that of the SRC-II liquids, which have been much more thoroughly analyzed at this time.⁴ Preliminary examinations of the SRC-I products show them to have the following general characteristics⁵ [International Coal Refining Company (ICRC) telephone conversations with C. Boston, Dec. 8 and 15, 1980].

	Percent by weight	
Phenolic content		
Light and middle fraction	15-25%	
Heavy fraction	15%	
PNA's		
Middle fraction	70%	40% 2-ring 50% 3-ring 10% 4-ring
Heavy fraction	48%	2-3% 2-ring 35% 3-ring 65% 4-ring
Primary aromatic amines	"ppm range"	

If further research indicates the need, hydrotreating of the liquid products may be practiced to reduce the risks associated with transporting and handling the products. The light fraction is considered to be a likely candidate for hydrotreating.

DD.5.1 Surface water and aquatic ecology

Impacts of a transportation spill of SRC-I liquid product are assessed for three cases:

1. a spill into the Green River at Spotsville, Kentucky;
2. a spill into Love's Creek (tributary to the Cumberland River), Nashville, Tennessee; and
3. a spill into a Louisiana bayou.

As discussed in Sect. DD.4.1, these scenarios are believed to illustrate worst-case spills. Cases 1 and 2 represent spills which, although highly unlikely, could pose a threat to the public water supply of major cities. Case 3 is examined because the bayou environment is adjacent to much of the rail line between Mobile, Alabama, and Lake Charles, Louisiana.

A number of assumptions are made to examine the impacts of spills.

Size of spill. Table DD.12 indicates that only 5% of the rail spills into water exceed 75,100 liters (20,000 gal), the capacity of a rail tank car. For this analysis it is assumed that the rupture of a tank car will allow the entire contents to spill into a water body.

Dispersion of spilled materials. The SRC-I product contains three categories of compounds: hydrocarbons (aromatic and aliphatic), phenolic compounds, and basic compounds such as aromatic amines. Some phenolic compounds enter solution fairly rapidly and will be dispersed after dissolution into the water column. Some basic compounds also enter solution readily but are somewhat less soluble than phenolics. Hydrocarbons have low solubilities and enter solution very slowly. Hydrocarbons in the spilled SRC-I product would disperse slowly, forming surface slicks or becoming trapped in the substrate (sand, gravel, and rock) to form a tarlike coating on the bottom and/or shoreline. The rates at which various substances enter solution depend on the turbulence of the water body.

Dissolution of phenolic compounds. A wide range of phenolic compounds is found in SRC product (Table DD.13), and these compounds vary greatly in solubility. The simplest compounds (such as phenol, cresols, and xylanols) enter solution relatively rapidly (within hours), whereas the alkylated phenols enter solution very slowly. Collectively, phenolic compounds are assumed to constitute 25% of the spilled SRC-I product. The short-term impacts to water quality are examined by assuming that phenolic compounds enter solution at a constant rate over a 24-h period. Thus we assume an effective release rate for phenolics of 0.219 kg/s is assumed (Tables DD.14-16).

Spill containment and cleanup. The SRC-I liquid product which will be shipped south is described as a "light fraction" and is assumed to be buoyant. If spilled onto standing water or into a creek, containment of the insoluble material might be possible using booms, but soluble compounds in the product would dissolve and disperse. It is assumed that after 24 h, marginally successful cleanup efforts would recover 50% of the remaining spill material. Containment and cleanup efforts, however, might be hampered by inaccessible location.

To assess the short-term impacts of phenolic compounds on water quality, the conditions for each spill case are defined. For Case 1, the spill into the Green River at Spotsville, Kentucky, the material is assumed to be dispersed in a low flow of 48 m³/s, the mean monthly streamflow which is exceeded 90% of the time, as measured at Lock #2 at Calhoun, Kentucky, on the Green River. This results in a predicted average concentration of phenolics in the Green River of 4.56 mg/liter (Table DD.14). The water supply intake for Evansville, Indiana, is located on the Ohio River several kilometers downstream from the Green River's confluence with the Ohio River. The Green River's low flow is assumed to be diluted in the Ohio River's low flow of 631 m³/s, the mean monthly streamflow which is exceeded 90% of the time as measured at Evansville, Indiana. This produces an estimated concentration of 0.35 mg/liter of phenolics in the Ohio River in the reach where Evansville and Henderson withdraw raw water.

In Case 2, a spill is assumed to occur into Love's Creek in Nashville, Tennessee. Spilled materials are assumed to flow from Love's Creek into Cheek Lake. If the spilled phenolics were to dissolve completely in Cheek Lake (estimated volume of 500,000 m³), a maximum average concentration of 38 mg/liter would occur (Table DD.15). Cheek Lake has a narrow channel opening to the Cumberland River. Blocking this channel might allow containment of the spill, but for this worst-case analysis it is assumed that all the dissolved containments enter the Cumberland River.

Table DD.13. Phenolic compounds identified in the middle/heavy distillate SRC-II product

Compound	Concentration (mg/100 g sample)
Dimethylphenol	33
Phenol	450
<i>o</i> -Cresol	620
<i>o</i> -Ethylphenol	37
<i>m/p</i> -Cresols	95
Dimethylphenol	420
C ₃ -alkyl phenol (isomer 1)	48
2,3-xyleneol and <i>m/p</i> -ethylphenol	960
C ₃ -alkyl phenol (isomer 2)	110
3,5-xyleneol	370
C ₃ -alkyl phenol (isomer 3)	170
C ₄ -alkyl phenol (isomer 1)	13
3,4-xyleneol	91
C ₃ -alkyl phenol (isomer 4)	730
C ₄ -alkyl phenol (isomer 2)	8.8
C ₃ -alkyl phenol (isomer 5)	37
C ₄ -alkyl phenol (isomer 3)	22
C ₄ -alkyl phenol (isomer 4)	130
Methyl indanol (isomer 1)	24
4-indanol	400
Methyl indanol (isomer 2)	55
C ₄ -alkyl phenol (isomer 5)	26
Methyl indanol (isomer 3)	70
5-indanol	40
Methyl indanol (isomer 4)	240
Methyl indanol (isomer 5)	47
<i>o</i> -Phenylphenol	23
1-naphthol	6.4
2-naphthol	19
Methyl naphthalene (isomer 1)	7.2
Methyl naphthalene (isomer 2)	5.1
Methyl naphthol (isomer 3)	5.2
<i>m</i> or <i>p</i> -Phenylphenol	7.6
<i>m</i> or <i>p</i> -Phenylphenol	11
Hydroxyfluorene	3.5

Source: R. L. Spraggins and P. H. Lin, *Analysis of SRC-II Coal Fuel Oil Middle Distillate*, Technical Memorandum 214-029-02, Apr. 29, 1980, Appendix I, Part I, in *Remedial Measures Plan for a Spill of Solvent Refined Coal Liquid at the SRC Pilot Plant, Ft. Lewis, Washington*, prepared by Radian Corp., Austin, Tex., for Gulf Mineral Resources Company, Englewood, Colo.

The water supply intake for the Madison Suburban Utility District withdraws water from the Cumberland River at Cheek Lake. Because the phenolics entering the Cumberland River from Cheek Lake would not be completely mixed, the raw water taken into the filtration plant at Cheek Lake could have an average concentration of phenolics as high as 38 mg/liter. It is assumed that phenolics entering the Cumberland River are diluted by a streamflow of 166 m³/s, the mean monthly low flow for 22 years of record. With complete mixing in the Cumberland River, phenolic concentrations are estimated to be 1.32 mg/liter 10 km downstream where Nashville withdraws raw water for the municipal water supply.

In Case 3 (Table DD.16) a spill is assumed to occur into Bayou Lafourche, Louisiana. Spilled phenolics are assumed to dissolve into the water column over a 24-h period, resulting in an average concentration of 50 mg/liter at the site of the spill. The polluted water than would be

Table DD.14. Assumptions and calculations defining short-term impacts of phenolic compounds on water quality, Case 1

Location of spill	Spotsville, Ky.
Density of spilled material, kg/liter	1 (assumed)
Size of spill, liters	1 tank car = 75,700
Quantity of phenolics released, kg	$75,700 \text{ kg} \times 25\% \times 100 = 18,925$
Period of time for phenolics to enter solution, h	24
Average release rate, mg/s	$18,925 \text{ kg} / 24 \text{ h} = 219,000$
Streamflow of Green River during low flow, m^3/s	48 (48,000 liters/s)
Average concentration of phenolics in Green River, mg/liter	4.56
Streamflow of Ohio River at Evansville, Ind., during low flow, m^3/s	631
Average concentration of phenolics in Ohio River downstream of confluence with Green River, mg/liter	0.346

Table DD.15. Assumptions and calculations defining short-term impacts of phenolic compounds on water quality, Case 2

Location of spill	Loves Creek, Nashville, Tenn. (tributary to Cheek Lake and the Cumberland River)
Density of spilled material, kg/liter	1 (assumed)
Size of spill, liters	1 tank car = 75,700
Quantity of phenolics release, kg	$75,700 \text{ kg} \times 25\% \times 100 = 18,925$
Period of time for phenolics to enter solution, h	24
Average release rate, mg/s	$18,925 \text{ kg} / 24 \text{ h} = 219,000$
Streamflow of Cumberland River during low flow, m^3/s	166 (166,000 liters/s)
Average concentration of phenolics in Cumberland River, mg/liter	1.32
Estimated volume of Cheek Lake, m^3	500,000
Average concentration of phenolics in Cheek Lake, mg/liter	37.9

dispersed into the bayou by the process of diffusion. After seven days of diffusion the concentration of phenolics would exceed 3.4 mg/liter in a zone approximately 3000 m in width. The concentration of phenolics would exceed 0.6 mg/liter in a zone approximately 6000 m in width. After 30 days of diffusion, or 31 days after the spill, the concentration of phenolics would continue to exceed 3.4 mg/liter in a zone approximately 2000 m in width; however, the zone where the concentration exceeded 0.6 mg/liter would extend to approximately 9000 m in width.

Given the above scenarios for serious spills of the SRC-I product, a very rough assessment of impacts can be made. Short-term and long-term impacts are considered separately, and only the most significant impacts are discussed.

Table DD.16. Assumptions and calculations defining short-term impacts of phenolic compounds on water quality, Case 3

Location of spill	Bayou Lafourche, La.
Density of spilled material, kg/liter	1 (assumed)
Size of spill, liters	1 tank car = 75,700
Quantity of phenolics released, kg	75,700 kg × 25% × 100 = 18,925
Period of time for phenolics to enter solution, h	24
Depth of Bayou, m	2 (assumed)
Maximum concentration of phenolics in water column ($C_{\max}$), mg/liter	50 (assumed)
Size of spill	
Area of spill ($Q/C_{\max}d$), m^2	$(18,925 \text{ kg})(1,000,000 \text{ mg/kg}) / (50 \text{ mg/liter})(1,000 \text{ liter/m}^3)(2 \text{ m}) = 200,000$
Width of spill area, m	400
Diffusion coefficient of phenolics into bayou, m^2/s	1 (assumed)
Lateral spread of zone of polluted water ^a (3.4 mg/liter) exceeding EPA maximum concentration for protection of freshwater aquatic life:	
Time after spill	Width of zone
2 (d)	1000 (m)
8 (d)	3000 (m)
31 (d)	2000 (m)
Lateral spread of zone of polluted water ^a hazardous to aquatic life (0.6 mg/liter):	
Time after spill	Width of zone
2 (d)	2000 (m)
8 (d)	6000 (m)
31 (d)	9000 (m)

^aZone of polluted water determined from

$$\frac{c}{C_{\max}} = \frac{1}{2} \left[\operatorname{erf} \left(\frac{w+x}{4\sqrt{\alpha\theta}} \right) + \operatorname{erf} \left(\frac{w-x}{4\sqrt{\alpha\theta}} \right) \right],$$

where c = concentration of water at time θ (mg/liter)
 $C_{\max}$ = maximum concentrations of pollutants (53 mg/liter)
 w = width of spill area (400 m)
 α = diffusion coefficient ($1 \text{ m}^2/\text{s}$)
 θ = time after diffusion of phenolics begins or time after spill minus 1 d (s)
 x = width of zone of contaminated water (m)

Short-term impacts. The spills into the Green and Cumberland rivers would cause water supply emergencies for Evansville, Indiana; Henderson, Kentucky; Nashville, Tennessee; and the north-east suburbs of Nashville, Tennessee, served by the Madison Suburban Utility District (MSUD). The most serious problems would clearly occur in the Nashville area. At the MSUD water supply intake in the Cumberland River near Cheek Lake, the filtration plant would temporarily discontinue operations to avoid the possibility of withdrawing grossly contaminated water. It is not known whether MSUD could continue to supply water through interconnections with other water supply systems. The contaminated slug of water would probably reach the city water intake within several hours, although contaminants would be somewhat less concentrated at this point. The draft EPA criterion for phenol for protection of human health is 3.4 mg/liter. If concentrations

of phenolics in the Cumberland River did not exceed the projected 1.32 mg/liter, Nashville might be able to continue supplying water for nonpotable uses only. Phenolics in the water supply would cause taste and odor problems; other soluble compounds in the SRC-I product (such as aniline and other basic compounds) would also pose a possible threat of toxicity to humans. Following the passage of the most contaminated slug of water, public health assessments would be needed to determine the risks associated with residual contamination levels.

Because of the dilution capacity provided by the Ohio River, Evansville and Henderson would experience less severe impacts than those projected for Nashville. The estimated worst-case concentration of phenolics in the Ohio River is 0.346 mg/liter. The spill site is roughly 20 km upstream from the water intakes, so the time of transit would allow at least several hours for advance preparation. Households could be instructed to store drinking water. The presence of phenolics and other soluble contaminants would cause taste and odor problems and the risk of exposure to undesirable organic compounds, so during the period when Ohio River water was most contaminated, only nonpotable use should be made of the water.

With respect to aquatic organisms, impacts would be most severe close to spill sites. For spills into the Green or Cumberland Rivers, a slug of highly contaminated water would form and be carried downstream. Contaminants in solution would be rapidly carried downstream at roughly the velocity of streamflow, while insoluble material might contaminate a limited area (perhaps 1 to 2 km of river channel). The combination of many dissolved contaminants would be acutely toxic, killing many or most of the organisms in the immediate spill area. Phenolic compounds (such as phenol, cresols, and xylenols), basic compounds (such as the aromatic amines), and the small amounts of hydrocarbons which would dissolve would all contribute to the toxicity. As the contaminated slug of water moved downstream, the concentration of pollutants would be reduced by dilution, uptake by organisms, and adsorption to sediments. Hydrocarbons would also decline in concentration due to volatilization and photolysis.

Downstream from the zone of massive mortality would be a zone of selective mortality in which only the more sensitive species would be killed. Further downstream, organisms would suffer sublethal effects of contamination rather than outright mortality. As the contaminated slug moved downstream, the decline in concentration of contaminants would depend on many unknown factors. Therefore, the size of the above zones of impacts cannot be estimated.

In the case of the spill in the bayou, the contaminants were assumed to be dispersed not by flow but by diffusion alone. This would produce an area of massive mortality with concentric zones of lesser impact surrounding that area. Table DD.16 indicates an estimate that after one week the lateral spread of contaminants could produce an area 3 km in width in which phenol concentrations would exceed the draft EPA criterion level of 3.4 mg/liter. Within this area, large-scale mortality could be expected. Within one month the lateral spread of contaminants would produce an area approximately 9 km in width in which the concentration of phenolics would exceed 00.6 mg/liter, the EPA draft criteria level for a 24-h average maximum. Selective mortality and sublethal effects would be expected in this area.

Long-term impacts. Long-term impacts would result largely from the less soluble compounds in the SRC-I product. Close to the spill site, the gross contamination would cause significant aesthetic damage. Oil-covered water and shoreline could cause limited mortality to birds and other riparian organisms. Substantial quantities of spilled produce would be mixed with gravel, sediment, and other debris in the river. Contaminants mixed with substrate could pose a long-term hazard as toxic compounds leached out. Contaminants adsorbed on fine sediment and organic detritus could be transported downstream, thus allowing dispersion of low-solubility PNA.

Because of their high molecular weight, PNAs, although unlikely to enter solution in sufficient quantities to be acutely toxic, are susceptible to bioaccumulation and bioconcentration. Because some PNAs are carcinogenic (Sect. 4.1), these could become serious contaminants in downstream ecosystems, possibly affecting sport fish. Some of the basic compounds are also suspected carcinogens, and further analysis of these is under way by DOE (Sect. 4.1). Both the soluble and the less soluble phenolics might cause taste and odor problems in water supply systems for several weeks or perhaps longer. Recreational fishing in the Green River, Cumberland River, or bayou could be affected for one or more years, and contamination of bayou wetland ecosystems could cause economic impact. Because of the many unknown factors affecting the distribution of organic contaminants in aquatic ecosystems, it is not possible to estimate the severity of these impacts.

DD.5.2 Groundwater quality impacts

Potential effects on groundwater quality of an SRC-I liquid spill depend on the spill volume, location, nature of the substrate under the spill, and cleanup timing. Phenolic compounds and PNAs are of concern because of their carcinogenic and mutagenic character.

Phenolics are water soluble, and their solubility varies with variation in molecular structure (Table DD.13). PNAs have very low solubilities in water and when dispersed to the environment tend to form microdroplets which adhere to soil or sediment particles.

There are a number of possible ways for spills of these liquids to affect groundwater. Spilled liquids seep into soils at a rate determined by local soil characteristics such as content of sand versus clay, and moisture content. Poorly soluble fractions of SRC-I liquids are expected to be retained near the soil surface due to physical attenuation on soil particles. The more soluble phenolics, however, will migrate with infiltrating precipitation and will follow the normal groundwater flow rate. Results of site monitoring conducted for planning remedial measures following the SRC-II liquid spill at Fort Lewis, Washington, exemplify the ability of phenols to reach the groundwater systems.⁴

The transportation routes for SRC-I liquids have been described in Sect. 2.0 of this appendix. The rail line over which heavy liquid will be transported to Pittsburgh crosses regions with varied conditions with respect to groundwater resources. Between Newman and Covington, Kentucky, the rail route generally follows the Ohio River and directly overlies the alluvial aquifer. The transportation route south to Louisiana crosses several areas in Tennessee and Alabama underlain by cavernous limestone aquifers. The route also crosses recharge areas for freshwater aquifers of the Gulf Coastal Plain region. The rural character of these areas and resulting difficult access for cleanup activities would favor infiltration of contaminants into groundwater systems. Contaminant transport in solution cavities is rapid and, in most cases, unpredictable rendering aquifer reclamation extremely difficult.

The city of Owensboro obtains its municipal water supply from a well field east of town. The wells are located between the railroad line and the Ohio River, and water is pumped from the alluvium. In the event that a railroad accident occurred near the municipal well field there would be a threat to the water supply. The SRC-II liquid spill at Fort Lewis, Washington, serves as a scenario for contamination of an alluvial aquifer.

The following paragraph summarizes information obtained by Radian Corporation during their investigations at Fort Lewis.⁴

In the Fort Lewis spill, 8842 liters (2336 gal) of SRC-I liquid spilled and seeped into the gravelly alluvial soil. The spill occurred on 19 December 1979, and groundwater sampling is reported from late January to early June. Phenolic compound concentrations were determined to be in excess of the 3.4 mg/liter human criterion on several occasions during February and March 1980 in downgradient wells within 53 m (175 ft) of the spill. The human health criterion was also exceeded in a well located 152 m (500 ft) downgradient of the spill. Phenol concentrations gradually declined in the downgradient wells and at the end of the reported monitoring period (six months after the spill) ranged from 0.01 to 1.0 mg/liter. Recommended remedial measures included excavation and disposal of approximately 69 m³ (90 cubic yards) of contaminated soil, pumping of wells, treatment of discharged water to remove as much of the contaminant plume as possible, and a long-term monitoring program. No existing public water supplies were affected by the spill, however. It was recommended that "the upper aquifer in the vicinity of the spill site probably should not be considered for use as a public or private water supply for the foreseeable future."

Each railroad tank car will carry 75,680 liters (20,000 gal) of liquid, or 8.5 times as much as was spilled at Fort Lewis. If spills of these liquids are not cleaned up rapidly, groundwater quality in potable aquifers may be adversely affected. Owensboro is one of many cities which derive municipal water supplies from well fields that could be contaminated by transportation spills of SRC liquids.

SRC liquid spills' impact on soils depends on soil texture (infiltration characteristics), elapsed time between the spill event and cleanup, and rate of attenuation or natural degradation of the hydrocarbons. The phenolic compounds in SRC liquids are acutely toxic to microorganisms. (Personal communication R. F. Strager, Oak Ridge National Laboratory, Dec. 12, 1980). Infiltration of the phenolics is expected to eradicate microbes which might otherwise aid in biodegradation of the heavier hydrocarbons. It is expected that spilled SRC liquid which is not cleaned up

would remain in the soil for a long period of time. Phenolics would gradually leach out, leaving the less soluble hydrocarbons. When phenolic concentrations diminish to the level at which hydrocarbons metabolizing bacteria can survive, biodegradation of the spill would begin. The time periods involved depend on spill configuration, ambient temperature, rate of leaching activity, and other factors and would be entirely site specific.

Effects of a spill of SRC-I liquids on groundwater quality would depend on the spill volume, location, nature of the substrate at the spill site, and cleanup timing. Because phenolic compounds are water soluble, they have the greatest potential for groundwater contamination. Effects of the spill of SRC-II liquid at the Fort Lewis pilot plant on nearby aquifers exemplify this potential.⁴ PNAs have very low solubilities in water and tend to form microdrops which adhere to soil or sediment particles when dispersed to the environment. PNAs would thus be retained in the soil near the spill site.

Proposed transportation routes for shipment of SRC-I liquids pass over numerous aquifers which could be contaminated by a spill. One area of particular concern is the well field for the city of Owensboro, Kentucky. Groundwater pumped from an alluvial aquifer between the L&N railroad and the Ohio River could be contaminated by a spill near the well field.

DD.5.3 Impacts on air quality

Spills on land or water, either at the storage sites or while in transit in unit trains, would immediately release high concentrations of nonmethane hydrocarbons into the atmosphere. Those light, insoluble distillates that would remain above the water surface would evaporate. Some of the vapors released are known toxic gases, such as the vapors from naphthalene and phenol portions of the SRC-I product, and proper protective respiratory equipment should be worn when near such spills.

Effects to air quality are likely to be temporary because the liquid would be rapidly absorbed into the soil and the remainder would be cleaned up as quickly as possible. Spills on water would also temporarily affect air quality, because they will be contained, recovered, and cleaned as soon as possible. Another temporary effect could result if the vapors of a spill were to ignite. Additional substances, such as carbon monoxide (CO) and sooty particulates would result from incomplete combustion of organics. Because of the unpredictability of such accidents, the unknown components released by the uncontrolled combustion of SRC-I liquid, and the temporary nature of such accidents, it is not possible to quantify the releases of pollutants and their effects on air quality. It is reasonable to assume that emissions would be large until the spills are absorbed or recovered and until any fire associated with the spill is extinguished.

DD.6. CONTROL OF LIQUID SPILLS

DD.6.1 Introduction

Techniques used to clean up an SRC spill would be similar to those techniques used for petroleum fuel oil. For the purpose of this analysis, it is assumed that the composition SRC-I liquid product is similar to that of SRC-II liquid fuels (see Appendix Z, SRC-II Final EIS).

Because SRC-I has not been commercially produced, there is no history of spills. When oil is spilled on water, a variety of processes occur such as weathering dissolution, emulsification, chemical reaction, biological degradation, and formation of tar lumps. Collectively, these tend to disperse the oil into a thin film. SRC-I liquid is a complex mixture of varying compounds of varying densities; however, the average density would most likely be less than water.

If the SRC-I liquid were floating and spreading in water, light-end naphthas and single-ring phenolic compounds would probably evaporate quickly. This evaporation would be enhanced by higher wind speeds and temperatures. Some of the heavier naphthas which evaporate slowly may mix with the water to form an emulsion and some may undergo oxidation under the influence of the ultraviolet band of sunlight. Oxidation would also be enhanced with wave action or swift currents. The remainder of the naphthas would probably remain mixed with the heavier phenolics, polynuclear aromatics, and tar compounds.

Biological degradation may occur with the phenolic compounds but probably would take months or years with the polynuclear aromatics, if they would deteriorate at all. In any case, cleanup

operations would be undertaken. This remaining mixture of the heavier naphthas, phenolics, polynuclear aromatics, and tar compounds could combine under oxidation or polymer formation to form "tar balls," which would create a serious problem when they reached the shore. It is assumed that some of the SRC-I liquid would settle to the bottom of a river or other water body, but the chemical fraction and quantity that would settle cannot be identified at the present time.

Spills of hazardous materials on land have received considerably less legislative and programmatic attention than spills into water bodies, but the potential for significant contamination of soil, groundwater, and air in the vicinity of a spill are of concern as well. The surface spill of SRC fluid that occurred at Fort Lewis, Washington, on Dec. 19, 1979, provides valuable insight into the effects of a spill on land. The measures developed to counteract the effects of that spill will be of help in designing spill mitigation procedures for other sites, although site-specific differences in soil, geology, and groundwater conditions will require variations in the mitigation plans.⁴

The Remedial Measures Plan for treatment of the Fort Lewis spill site included the following:

1. excavation of contaminated soil,
2. sealing of the land surface at the spill site to prevent further infiltration of precipitation,
3. pumping of groundwater near the spill site to control transport of contaminated groundwater, and
4. implementation of a long-term surface and groundwater monitoring program.

DD.6.2 Oil spill control

This section presents general information on corrective action to be taken on an oil spill. SRC-I liquid is essentially an oil and is considered to be responsive to normal oil spill treatment. No single system or procedure for cleaning up oil spills can be applied in all locations regardless of the characteristics of the waterbody and terrain. Geographic differences, exposure, ease of access, and other variables require that each system be carefully designed for a specific area.

An oil spill initiates certain responses basic to all spills. The phases of an oil spill are:

1. discovery and notification,
2. evaluation and initiation of action,
3. containment and countermeasures,
4. recovery, mitigation, and disposal,
5. cleaning and repositioning equipment,
6. documentation and cost recovery.

This EIS cannot address all of the operational phases of oil spills but will concentrate on the state of the art of oil spill removal equipment which have possibilities for use on inland waterways for containment, countermeasures, and recovery.

To reduce one possible impact of public exposure due to releases resulting from transportation accidents, a program will be instituted to provide fast response for containment, treatment, and cleanup of materials from such spills. The program presently being evaluated will include at least the following elements:

- A telephone response system operated by the industrial partners, located at the plant site and capable of providing information regarding the properties, hazards, recommended containment, and cleanup procedures for SRC products.

- Participation in the CHEMTREC program sponsored by the Manufacturing Chemists Association. This will provide an alternate source of the same information and assistance as the response system indicated above.
- Direct assistance to the local emergency response personnel when requested.
- Maintenance of a rapid-response assistance capability including trained personnel, transportation, and funding necessary to provide this immediate advice and assistance in the event of a spill.
- Training and information on emergency procedures for personnel involved in the transportation of SRC products by unit trains or highway trailers that are wholly utilized for SRC product transport.

In addition, the criteria used to select transportation modes will include minimization of public health impact should spills occur, provided that this procedure is consistent with the requirements of adequate transportation to end users. Products could be shipped by multiple-car trains, barge, or unit train over specified chosen routes. Personnel associated with shipping or handling operations could be given special training in handling procedures and using the telephone response system outlined above. In addition, the distribution of products from the initial operation of the demonstration plant could be limited to a selected group of users to minimize possibility of spills.

In the event that research indicates the hazards of SRC products to be much more serious than currently anticipated, hydrotreating of all the liquid product might be practiced to reduce the hazards associated with transportation and handling of the materials.

DD.6.2.1 Containment and countermeasures

Containment and countermeasures are perhaps the most important action in the removal of an oil spill. They are the first corrective actions taken and should be initiated as soon as possible. Countermeasures are usually of four types:

1. isolation and evacuation of the spill area to protect life or health,
2. shutting off the source of the spill,
3. placing booms or other physical or adsorbent barriers to prevent contamination of surrounding terrain or adjacent waterways by spreading the spill, and
4. preplanned construction of trenches or ditches to isolate potential spill areas on land.

Containment is the critical first step of any coordinated spill cleanup activity. Quick response time is important and depends on variables such as terrain characteristics, equipment design and availability, personnel capability, size, physical and chemical properties of the oil spill. Containment is accomplished through four principal methods: booms, containment dams, air barriers, and surface tension modifiers. For a summary of containment methods, see Table DD.17.

DD.6.2.2 Removal

Removal of an oil spill can be accomplished in several ways including:

1. evaporation (gasoline, jet fuel, light distillates),
2. physical removal (mechanical equipment such as skimmers),
3. biodegradation,
4. burning,
5. dispersion (emulsification), and
6. pumping into landfills.

Table DD.17. Summary of containment methods

Type of system	Principle of operation	Advantages	Disadvantages
Air barriers	Subsurface bubbling to create upswelling of water surface	Do not impede vessel movement	Costly to install and maintain; limited by environmental factors (wind, current)
Piston film or Herder chemicals	Surface tension phenomenon	Easily applied; small dose required	Only provide limited containment for a matter of hours; government approved products must be used
Booms	Physical barrier	Quickly deployed; are physical barriers	Work best in calm waters; may be used in limited currents and waves
Hose spray	Turbulent barrier to oil	Rapidly applied	Limited to use in confined areas and calm water; temporary method only
Sorbent barrier	Both physical barrier and absorbent surface for oil pickup	Easily deployed; can be used for both containment and pickup	Works best in calm water; oil is not effectively contained; slows spreading

Methods (4), (5), and (6) are not desirable because of their adverse effects on to the environment and hazard to life and property. Reliance on method (3) is not recommended because of its lengthy reaction time and the possibility of toxic products. Method (1) is a naturally occurring phenomenon for light, high volatile products. Method (2) is most extensively used and is benefiting from intensive research.

The principal methods of mechanical removal of oil spills is by vacuuming and by skimming. The types utilized include vacuum units and skimmers (mechanical and suction).

DD.6.2.3 Site-specific cleanup and containment procedures

Authority for cleanup and containment procedures used in case of a spill along the proposed route are found in the National Oil and Hazardous Substances Pollution Contingency Plan. The plan provides for coordinated Federal action to prevent discharges of oil and hazardous substances and to protect the environment from damage when discharges occur. The plan, developed in compliance with Sect. 311(c)(2) of the Clean Water Act, promotes Federal-State coordination and encourages local governments and private firms to build capabilities for cleaning up spills. Depending on where a spill of SRC-I liquid occurs along the proposed route, either EPA or the U.S. Coast Guard would oversee the procedures. The Coast Guard would respond to spills in the Lake Charles area and the EPA would respond to spills along the Mississippi River. The plan provides for:

1. assignment of responsibilities among Federal agencies, in coordination with State and local agencies;
2. identification, procurement, maintenance, and storage of equipment and supplies;

3. establishment or designation of a strike force to carry out the plan; trained and adequately equipped emergency task forces at major ports;
4. a system of surveillance and reporting to give responsible Federal and State agencies the earliest possible notice of discharges of oil and hazardous substances or imminent threats of such discharges;
5. establishment of a national center to provide for coordination and direction of operations in carrying out the plan;
6. procedures for identifying, containing, dispersing, and removing oil and hazardous substances;
7. a schedule, prepared in cooperation with the states, to identify any dispersants or other chemicals that may be used in carrying out the plan;
8. a system for reimbursing states for reasonable costs incurred in removing discharges.

Five sequential steps are to be taken by Federal authorities once the spill is reported. These steps are to:

1. investigate the report to determine pertinent information such as the threat posed to public health or welfare, the type and quantity of material discharged, and the source of the discharge;
2. notify Regional Response Teams (RRT) and the Scientific Support Coordinator, in accordance with the applicable regional plan;
3. determine whether the person or activity responsible for the pollution is properly carrying out removal actions;
4. officially classify the severity of the discharge and determine the course to be followed;
5. determine whether State action to effect removal is necessary within the meaning of the Clean Air Act.

In general, according to the plan, the company spilling the hazardous substance is fined \$5000 (regardless of the amount spilled) and is responsible for timely and effective cleanup. In addition, the company is required to call the National Response Center at (800) 424-8802. Once the center is notified, actions must be taken both to assure a proper cleanup and to assess possible environmental damage (e.g., contamination of the water supply). In the event that the company does not satisfactorily clean up the spill, Federal, State, or local authorities would intervene by cleaning up the spill. The responsible company would then be charged for these cleanup costs.

Regional Coast Guard and EPA officials, asked to discuss the response they would execute in the event of an SRC-I liquid spill, offered two site-specific criteria for determining cleanup and containment procedures. These criteria are climatic conditions (season and geographic setting) and type of water body. (The basic assumption in these discussions was that when spilled, SRC-I liquids will behave like petroleum fuel oil.)

DD.7 TRANSPORTATION REGULATIONS

The U.S. Department of Transportation (DOT), Office of Hazardous Materials (OHM), regulates hazardous materials while they are in transport. The OHM is the agency within DOT that handles the transportation of materials similar to SRC-I liquid. An extensive set of regulations covering all phases of transportation, from the time the material leaves the shipper to the time it reaches the consignee, have been created by OHM to protect the public interest. The following section presents regulations pertinent to SRC-I liquid shipments, as well as the most likely mode of transport.

Because the primary transport for SRC-I liquid shipments is rail tank cars, a description of the unit tank car train is presented in the second part of this section.

The DOT regulations applicable to transport of SRC-I liquid products are not explicit because SRC-I liquids are new products, and amended regulations do not yet include SRC-I products. The miscellaneous category, not other specified (NOS), would apply to SRC-I liquid transport at this time. The literature indicates that component elements of SRC-I liquid are similar to both the middle and heavy petroleum distillates. For the purpose of this preliminary analysis, Federal regulations for distillate transport can be assumed to be applicable for SRC-I liquid shipments.

DOT regulations dealing with the shipment of hazardous materials are stated in Title 49 Code of Federal Regulations Part 100.000-177.000. Five subsections of the Federal Code are applicable to shipments of SRC-I products:

1. Subsection 172.100 for Proper Shipping Name;
2. Subsection 172.200 for Description of Hazardous Materials on shipping papers;
3. Subsection 172.300 for marking and labeling requirements;
4. Subsection 172.400 for Packaging Specifications;
5. Subsection 173.119 for specification of tank cars.

Each tank car will be marked with either the proper shipping name or the common name of the chemical. The markings must be of a specific size, four inches or more in height with a minimum of three-fourths of an inch between each letter. They must be affixed to both sides of the tank car and in plain view. Finally, any tank car marked in this way may not be used to transport any other material unless the markings are removed.

The last regulation that would apply to SRC-I shipment liquid is the use of placards. Placarding only applies to volumes over 640 cubic feet and/or 1200 pounds and requires that the shipper identify the hazardous material by means of the appropriate placard. The placard must be displayed at each end and at each side of the shipping container. For SRC-I liquid shipments, the placard would post either "combustible" or "flammable," depending on the exact chemical composition of the product.

DD.8 DESCRIPTION OF TRANSPORTATION EQUIPMENT

The transportation analysis is based on specific assumptions regarding production and shipping quantities of SRC-I liquid products. Although the proposed SRC-I demonstration plant is capable of producing a mix of usable energy products, analysis of transportation requirements is based on the largest possible quantity (11,000 barrels per day). It has been established, however, that the actual production rate during the first 4-5 years of operation will be considerably less than 100% of full plant capacity. During the first three years of operation, the plant is expected to operate at or below 50% capacity. Because of the limited production rate, transportation requirements considered in this section are exaggerated.

DD.8.1 Unit tank-car train

The specific transportation requirements of the Newman plant suggest the utilization of tank car unit trains for the shipment of SRC-I liquid. The current state of the art for the shipment of homogenous bulk liquids is a system of interconnected tank cars developed by General American Transportation Corporation (GATX). (Personal communication with Dominic Conova, GATX Terminal Corporation, Chicago, Illinois, Oct. 28, 1980.) The system, whose registered trade mark name is "TankTrain," offers a wide range of advantages over conventional unit train design. The unique interconnected system of elbow pipes and flexible hose enable the unit train to be loaded and unloaded from an individual tank car, an appreciable improvement over the conventional method of loading and unloading each car individually.

This modification should have a positive impact both on the human environment and on the environment in general. It will also provide cost advantages to the shipper. Because of the single product line connection feature, the number of persons handling loading and unloading operations is greatly reduced. The harmful effects of climbing on cars, opening manways, handling fittings, and exposure to commodity, including harmful vapors, are all minimized. The single product line connection feature also allows direct transfer of the liquid commodity to holding facilities or subsequent transportation modes, thereby reducing the possibility of spillage or vapor loss which is usually associated with conventional unit trains.

DD.8.2 Specification for rail tank car construction and design and required safety features

The Code of Federal Regulations, CFR 49, Part 179, Subparts (A), (B), and (D) deals exclusively with design requirements for rail tank cars. Several tank car design features must meet specifications outlined in these regulations. The most important features are the thickness of the tank walls, type of wall materials, and types of loading/unloading and safety relief valves.

A major manufacture of rail tank cars was contacted to determine which DOT specifications are the current standard for petroleum tank cars and would therefore be acceptable for SRC-I liquid products. The manufacturer identified three designs that are in use today for petroleum products. The DOT specifications for these three designs are 103W, 11A60W1, and 11A100W1 (see Table DD.18). The 103W rail cars are heavier and costlier than those cars built in accordance with the other two specifications. Either of the two remaining designs are acceptable for SRC-I liquid shipments, a factor which increases the availability of rail tank cars. The majority of petroleum rail cars are built to meet specification 11A100W1. DOE will specify use of the safest equipment available.

Table DD.18. Individual rail tank car specification requirements

	103W	11A60W1 ^a	11A100W1 ^a
Material (see 179.200-7)	Steel	Steel	Steel
Insulation (see 179.200-4)	Optional	Optional	Optional
Bursting pressure, psi (see 179.200-5)	240	240	500
Minimum plate thickness, in.			
Shell (see 179.200-6)	170.201-2	7/16	7/16
Heads (see 179.200-6 and 179.200-8)	179.201-2	7/16	7/16
Dome	Required	None	None
Minimum expansion capacity (see 179.200-14) ^b	2% in dome	2% in tank	2% in tank
Test pressure, psi (see 179.200-22)	60	60	100
Safety relief devices (see 179.200-18)	Valve or vent	Valve or vent	Valve or vent
Valve start-to-discharge pressure, psi (± 3 psi)	35	35	75
Valve vapor tight pressure (minimum psi)	28	28	60
Valve flow rating pressure (maximum psi)	45	45	85
Vent bursting pressure, psi ^b	60	60	100
Gaging devices (see 179.200-16)	Optional	Required	Required
Top loading and unloading devices (see 179.200-16)	Optional	Optional	Optional
Bottom outlet [see 179.200-17(a)]	Optional	Optional	Optional
Bottom washout [(see 179.200-17(b))]	Optional	Optional	Optional
Closure for manway (see 179.200-15)	179.201-6(a)	179.201-6(a)	179.201-6(a)
Postweld heat treatment (HT) (see 179.200-11)	HT	HT	HT
Special references	179.202-1 179.202-2 179.202-3 179.202-4 179.202-6 179.202-19	179.202-2 179.202-3 179.202-5 179.202-6	179.202-1 179.202-2 179.202-5 179.202-6

^aTanks converted to DOT-111A series from existing forge-welded specification. DOT-105A300, 400, or 500 tanks, by modification using conversion details complying with DOT-111A specification requirements, shall be stenciled by substituting the letter "F" for the letter "W" in the specification designation.

^bMandatory compliance with 49 CFR Part 179.201-1 is Jan. 1, 1979.

Source: *Hazardous Materials Regulations of the Department of Transportation*, Tariff No. BOE-600, Association of American Railroads, Dec. 3, 1979, p. 453.

DD.9 FATE AND EFFECTS OF COAL LIQUEFACTION PRODUCTS IN AQUATIC ECOSYSTEMS

This section presents experimental results specific to the SRC-II liquid product. This program has not conducted experiments with SRC-I material. However, the processes are similar and the results give a perspective on the SRC-type materials relative to other petroleum oils.

D.D.9.1 Introduction

Spills of liquid products are among the major potential environmental hazards of coal liquefaction technologies. It has been estimated that a commercial liquefaction industry producing 500,000 barrels per day of synthetic oil would result in accidental releases of from 1000 to 150,000 barrels per year into aquatic ecosystems.⁵ Based on these considerations, the Advanced Fossil Energy Program (AFEP) of Oak Ridge National Laboratory's Environmental Sciences Division has been conducting research on the transport, fate, and effects of synthetic oils in freshwater ecosystems. This section presents the major results to date from the AFEP research.

Objectives of the synthetic oils research program are: (1) comparison of the toxicity of coal liquefaction products, shale oils, and petroleum products to aquatic plants and animals; (2) identification of the principal water-soluble toxic constituents of synthetic oils, (3) examination of the effects of refining and process conditions on the toxicity of synthetic oils, (4) examination of the influence of weathering processes (especially dissolution, photodegradation, and evaporation) on the toxicity of synthetic oils, and (5) investigation of the long-term fate, and the possible effects on aquatic organisms, of synthetic oil residues incorporated into sediments.

Objectives (1) through (3) have been investigated to some depth to date. Preliminary results have been obtained which address objective (4); work on objective (5) has not yet been initiated.

DD.9.2 Experimental approachDD.9.2.1 Water-soluble fractions (WSFs)

The first two years of this research have focused on water-soluble fractions (WSFs) of oils for several reasons. (1) Studies with petroleum products indicate that the water-soluble components of oils are responsible for most of the oil's acute effects on phytoplankton, zooplankton, and fish.^{6,7} (2) The components of an oil that dissolve rapidly into water after a spill are liable to affect a larger area than the oil slick itself. (3) Exposure of organisms to dissolved oil components will occur even if the undissolved oil is recovered. (4) Bioassays with WSFs avoid the experimental difficulties inherent in tests with insoluble and immiscible materials.

After a review of the literature, a procedure was selected that has been widely used in studies on petroleum for WSF preparation. Oil is floated on water in a closed glass vessel at a ratio of 1:8, a ratio widely used in petroleum toxicity testing. The mixture is stirred gently for a predetermined length of time, and the aqueous phase (the WSF) is then separated from the oil and filtered to remove oil droplets. Except in experiments on photodegradation, WSFs are prepared in the dark (or under gold fluorescent lights) to avoid photochemical changes in the oils or WSFs. This procedure results in reproducible, easily handled solutions that can be compared with many published studies on petroleum.

A similar experimental apparatus has been used to quantitate concentrations and rates of dissolution of synthetic oil contaminants. Oil is layered onto water in a closed glass vessel at a volumetric ratio of 1:140 to permit the oil added (25 ml) to spread to a thickness of no more than 2 mm to simulate a thin oil slick in the environment. A reciprocating stirrer is used to prevent vortex formation. At intervals water samples are withdrawn, and dissolved contaminants are extracted with solvents into acid/neutral and base fractions. Contaminants are quantified after gas chromatographic separation; identifications are made by co-chromatography of standards and by GC-mass spectrometric analysis.

Gentle equilibration of petroleum with underlying water in a closed system may not model accurately either the mode of toxicant introduction into seawater or the final contaminant compound distribution.⁸ However, oceanic turbulence is far greater than that of most navigable rivers, where synthetic oil spillage is most likely, and dissolution of synthetic oil toxicants is far more rapid than toxicant dissolution from petroleum (as will be presented in later

sections of this appendix). Therefore, the experimental dissolution system employed is more likely to simulate correctly contaminant movement from oils into fresh water than is an experimental system dominated by emulsification (i.e., rapid and violent agitation). Further modeling of actual synthetic oil spills may be required to demonstrate conclusively the validity of this assumption.

DD.9.2.2 Oils tested

Most of the oils used in this research were received from the Fossil Fuels Research Materials Facility of the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE) located at the Oak Ridge National Laboratory. These oils and their EPA/DOE identification numbers are listed in Table DD.19. Further information can be found in Griest.⁹

Table DD.19. Oils tested

Oil	EPA/DOE No.
SRC-II product	CRM-1
SRC-II fuel oil blend	1701
Coal liquid A	^a
Coal liquid B	1116
Coal liquid C	1101
Coal liquid D	130B
Coal liquid E	1309
Coal liquid F	1310
Coal liquid G	1312
Coal liquid H	1313
Coal liquid I	1314
Coal liquid J	1601
Coal liquid K	1602
Coal liquid L	1603
Coal liquid M	1604
Coal liquid N	^a
Petroleum crude oil	CRM-3
Petroleum No. 2 diesel fuel	^b
Petroleum marine diesel fuel	4616
Petroleum JP-5 jet fuel	4614
Petroleum residual A	5401
Petroleum residual B	5402
Petroleum residual C	6101

^aObtained from producer.

^bObtained from local distributor.

Table DD.20 shows densities and viscosities of the oils used in dissolution studies. Two SRC-II products were tested as well as three other coal-derived liquids and a petroleum crude oil. The SRC-II products (which were collected from different pilot plant production runs) are intermediate in viscosity between a raw coal liquid (A) and light and heavy distillates of a hydro-treated oil (B and C, respectively); they are considerably less viscous than the petroleum crude tested. The SRC-II products were the densest of the six oils. At 5°C the densities are greater than that of water, while at 25°C the densities are less; thus at temperatures below about 15°C the SRC-II oils sink, while at higher temperatures they float.

Table DD.20. Characteristics of oils tested for dissolution of water-soluble contaminants

Oil	Viscosity at 25°C (cS)	Density	
		5°C	25°C
Coal liquid A	2.82	0.9168	0.9111
Coal liquid B	1.23	0.8276	0.8125
Coal liquid C	21	0.9731	0.9581
Petroleum crude	202	0.9453	0.9320
SRC-II product	7.42	1.0088	0.9940
SRC-II fuel oil blend	7.09	1.0094	0.9950

DD.9.3 Comparative toxicology of oils**DD.9.3.1 Algae**

Water-soluble fractions (WSFs) of natural and synthetic oils were tested for their effects on photosynthesis by freshwater algae. The test organisms were *Selenastrum capricornutum*, a unicellular green alga that has been recommended by the EPA for chemical hazard assessment,¹⁰ and *Microcystis aeruginosa*, a nonnitrogen-fixing unicellular blue-green alga. The bioassays measured effects of WSFs on organic carbon uptake in 4-h exposures.^{11,12} Results are expressed as percentages of controls. In some experiments, EC₂₀ values (WSF concentrations causing 20% inhibition of photosynthesis) were estimated by interpolation on a plot of photosynthesis versus log concentration.

Table DD.21 lists EC₂₀s for all WSFs tested.¹³ Values for coal liquid WSFs were one to two orders of magnitude below those for petroleum WSFs. Crude petroleum was not tested, but petroleum crudes are generally less toxic than refined petroleum products.^{7,14,15}

Table DD.21. Acute toxicity of WSFs to freshwater algae

Oil	EC ₂₀ ^a	
	<i>Selenastrum capricornutum</i>	<i>Microcystis aeruginosa</i>
SRC-II fuel oil blend	0.83	0.63
Coal liquid A	0.29	
Coal liquid D	0.25	0.46
Coal liquid E	0.30	0.26
Coal liquid F	0.063	0.13
Coal liquid G	0.019	1.4
Coal liquid H	0.16	0.15
Coal liquid I	0.019	0.13
Coal liquid J	0.42	0.91
Coal liquid K	0.57	0.75
Coal liquid L	0.68	1.4
Coal liquid M	0.60	1.6
Coal liquid N	0.63	1.1
Petroleum No. 2 diesel fuel	15	25
Petroleum marine diesel fuel	13	
Petroleum JP-5 jet fuel	>100	
Petroleum residual A	>100	14
Petroleum residual B	>100	>100
Petroleum residual C	>100	63

^a WSF concentration (percent dilution) causing 20% inhibition of photosynthesis.

DD.9.3.2 *Daphnia magna*

Water-soluble fractions (WSFs) of oils derived from coal and petroleum were tested for acute toxicity to the freshwater crustacean *Daphnia magna* in standard 48 bioassays.¹⁶ Several of the WSFs were also examined in 28 static-renewal experiments to measure chronic effects on *D. magna*. The responses measured in the chronic tests included life span, day of first brood release, number of broods per female, number of young per female, and number of young per brood. Results are summarized in Table DD.22. WSFs of two refined petroleum products were slightly toxic to *D. magna* with 48-h LC₅₀ values of 30 and 67% respectively. Petroleum residual C was nontoxic. In contrast, the WSFs of the coal liquefaction products had LC₅₀s ranging from 0.2 to 4.6%. The SRC-II fuel oil blend was the second most toxic product tested with an LC₅₀ of 0.3%.

Table DD.22. Acute and chronic toxicity of WSFs to *Daphnia magna*

Oil	48-h LC ₅₀ ^a	28-d LOEC ^b
SRC-II fuel oil blend	0.3	
Coal liquid A		
Coal liquid E	4.6	0.58
Coal liquid F	2.5	0.92
Coal liquid G	0.24	0.016
Coal liquid H	1.0	0.25
Coal liquid I	2.5	
Coal liquid J	0.4	
Coal liquid K	0.5	
Coal liquid L	1.5	
Coal liquid M	1.7	
Petroleum No. 2 diesel fuel	30	20
Petroleum marine diesel fuel	67	
Petroleum residual C	>100	

^aWSF concentration (percent dilution) that killed 50% of the test organisms in 48 h.

^bLowest WSF concentration (percent dilution) at which significant effects on reproduction were observed in 28 d.

At much lower WSF concentrations, more chronic effects than acute effects were observed. The number of young produced per female (over her entire lifetime) was the most sensitive parameter measured in the 28-d tests. Coal Liquid G affected reproduction at a concentration of 0.016% WSF. Petroleum No. 2 diesel fuel produced no chronic effects below 20% WSF. Thus, the differences between the toxicities of coal liquids and petroleum were greater in the chronic bioassays than in the acute bioassays. In separate studies, low concentrations of Coal Liquid A WSF reduced respiration rates and grazing rates in *D. magna*.

DD.9.3.3 *Sediment microbial communities*

Sediment microbial communities in laboratory microcosms were treated with Coal Liquid G and petroleum marine diesel fuel semi-continuously for three months. Dehydrogenase activity (a measure of microbial respiration) and adenosine triphosphate (ATP, a measure of microbial biomass) were significantly reduced by the liquefaction product; only dehydrogenase was affected by the marine diesel fuel. At the end of the experiment, four other structural features and seven other microbial functions were assayed in the microcosm sediments. None of the structural measurements showed significant effects from the oil treatments. However, many of the microbial functions (mineralization of glucose, protein, starch, lipid, and naphthalene) were significantly higher in the microcosms treated with the liquefaction product than in the controls. Starch, protein, and lipid mineralization were also stimulated by the marine diesel fuel.¹⁷

DD.9.3.4 Pond ecosystems

The WSF of the SRC-II fuel oil blend was applied to two 80-liter pond microcosms containing water, sediment, and a complex biotic community. The WSF concentration immediately after treatment was 1%, near the threshold for photosynthetic inhibition as determined by algal bioassays (Sect. DD.9.3.1) and approximately three times the 48-h LC₅₀ for *Daphnia magna* (Sect. DD.9.3.2). The treatment resulted in a gradual decline in primary production to very low levels over a two-week period. A large portion of the dominant plant population (the pondweed *Elodea*) was destroyed, and the major algal taxa (*Spirogyra* and benthic diatoms) were eliminated; zooplankton disappeared. Snails moved out of the water and remained above the waterline on the walls of the microcosms. For two to four weeks after the WSF was added, the systems were nearly anaerobic. A gradual recovery ensued. *Elodea* resumed growth, and blue-green algae replaced the benthic diatoms. The snails returned to the water and began producing egg masses. Primary production rebounded, reaching pretreatment levels after 6 to 8 weeks. These experimental ecosystems thus responded more dramatically than the simple algal bioassays to this WSF, but the major effects were transient. Ecosystem function (energy and nutrient flow) recovered from the treatment, but certain changes in community structure (such as the replacement of diatoms by blue-green algae) persisted until the experiment was terminated at eight weeks.¹⁸

DD.9.3.5 Summary

Water-soluble fractions (WSFs) of the SRC-II product and other coal liquids were toxic to freshwater algae and invertebrates at much lower concentrations than WSFs of petroleum products. Effects on *Daphnia magna* reproduction occurred at WSF concentrations as low as 0.016% for coal liquids, compared with 20% for petroleum No. 2 diesel fuel. Coal liquids and their WSFs produced significant effects on primary production, microbial activity, and other functions of aquatic ecosystems.

DD.9.4. Composition of water-soluble fractions (WSFs)

DD.9.4.1 Chemical analyses

In contrast to the well-known complexity of synthetic oils, water-soluble fractions are relatively noncomplex; more than 99% of the total water soluble material (on a mass basis) consists of about 30 compounds. Analyses of water-soluble fractions of several oils are shown in Table DD.23. Major constituents include phenol, cresol isomers, CH₂-phenols, aniline, toluidines, and C₂-anilines; C₃- and C₄-phenols and aniline isomers have also been detected at low concentrations. In contrast, virtually no phenolic or basic compounds were measured in water equilibrated with a petroleum crude oil (consistent with reports by other investigators). Gas chromatographic scans of the WSFs of coal liquids were nearly identical, indicating little qualitative difference among the various synthetic oils. In no case was chromatographic or mass spectrometric evidence for naphthols or polyhydric phenols (e.g., resorcinol or catechol) found, although these compounds may be present at concentrations below the procedural detection limit (1 mg/liter). In the Coal Liquid A base fraction, pyridine and alkylpyridines were tentatively identified on the basis of elution position but at concentrations of less than 0.1 mg/liter; they were not observed in the SRC-II fuel oil blend.

Although m- and p-cresol isomers are not distinguishable under the gas chromatographic conditions employed, the two compounds partition to similar extents between oil and water and thus should be present in water in the same proportions as in the oil. In Coal Liquid A, relative concentrations of m- and p-cresol isomers were approximately 3:2 (M. R. Guerin, ORNL, personal communication), which implies a similar ratio between m- and p-isomers in the WSF.

Both SRC-II product oils tested produced concentrations of phenolics in underlying water three- to five-fold higher than for either Coal Liquid A or B. Similarly, levels of anilines were several-fold greater in the SRC-II fuel oil blend WSF than in that of Coal Liquid A. Concentrations of mono- and diaromatics were an order of magnitude lower in the SRC-II WSFs than in either of the other coal liquids.

DD.9.4.2 Contribution of WSF constituents to toxicity

As a first step towards identifying the principal toxic constituents of WSFs, acute bioassays were conducted with algae and *Daphnia magna* on the ether-soluble acid, ether-soluble base, and

Table DD.23. Concentrations (mg/liter) of contaminants in 3500 milliliters water equilibrated with 25 milliliters of oils in laboratory extraction apparatus at 22° C

	Coal liquid A	Coal liquid B	SRC-II product	SRC-II fuel oil blend	Petroleum crude
Acids					
Phenol	39	35	175	210	<1
o-Cresol	26	48		456	<1
m-/p-Cresol	57	62	260		
2-ethylphenol	1.6	5.2			
2,4-/2,5-dimethylphenol	16	31		178	<1
4-ethyl-/3,5-dimethylphenol	27	24	140		
2,3-dimethylphenol	1.8	2.9			
C ₃ -phenols (2 isomers)	13	17	46	58	<1
Indole	0.2	1.8	a	21	<1
C ₄ -phenols (2 isomers)	<0.1	1.1	a	15	<1
Neutrals					
Toluene	2.6	9.2	0.5	<0.1	0.2
Xylenes	1.6	3.9	<0.1	0.6	0.1
Naphthalene	5.1	1.5	a	a	0.03
Methylnaphthalenes	0.3	0.7	a	a	<0.03
Bases					
n-Ethylaniline	1.5	a	a	1.6	<0.03
Aniline	5.3	a	a	13.6	<0.03
o-Toluidine	4.6	a	a	35	<0.03
m-/p-Toluidine	8.0	a	a	23	<0.03
2,4-dimethylaniline	1.5	a	a	6.9	<0.03
2,3-/3,5-dimethylaniline	3.2	a	a	7.6	<0.03
m-Ethylaniline	1.1	a	a	4.4	<0.03
C ₃ -anilines (5 isomers)	3.9	a	a	8.0	<0.03

^aNot determined.

neutral subfractions of WSFs (prepared using an oil:water ratio of 1:8) from Coal Liquids E, F, G, H, and I, and Petroleum No. 2 diesel fuel. Table DD.24 presents the results of the algal bioassays. Photosynthetic inhibition of the two test species was most severe during exposure to the ether-soluble bases; the neutral subfractions were the least toxic, except in the case of petroleum diesel fuel. These trends were less consistent in the *D. magna* bioassays, but the basic components were still the most toxic subfraction in three of the WSFs (Table DD. 25). The neutral subfraction was the most toxic to *D. magna* in one WSF, and in one case the fiducial limits for the 48-hr LC₅₀s of the three subfractions overlapped completely.

To test for loss of toxicity during the fractionation procedure, the subfractions were combined to form a reconstituted WSF and assayed with *D. magna*. For all five Coal Liquids, the 48-h LC₅₀s of the reconstituted WSFs were not significantly different from those of the original WSFs. These results confirmed earlier findings that the fractionation process does not significantly alter the toxicity of the individual subfractions.¹⁶

Further insight into the relative contributions of WSF constituents to WSF toxicity comes from a comparison of the concentrations of organic compounds in WSFs with the acute toxicities of these compounds to algae and *Daphnia magna* (Table DD.26). The concentrations of phenols and anilines in these WSFs are in most cases higher than the 48-h LC₅₀ for *D. magna* or the EC₂₀ for algae. Of the neutral WSF components, only naphthalene approaches the acute toxicity concentrations for these organisms. These data are incomplete, but they are consistent with the acid-base fractionation results in identifying the acids and bases rather than the neutral compounds as the major toxic constituents of synfuels' WSFs.

Table DD.24. Acute toxicity of acid, base, and neutral subfractions of WSFs to two freshwater algae^a

	<i>Selenastrum capricornutum</i>	<i>Microcystis aeruginosa</i>
Coal liquid E		
Acids	66	89
Bases	22	43
Neutrals	88	(98)
Coal liquid F		
Acids	(87)	50
Bases	25	30
Neutrals	(90)	(97)
Coal liquid G		
Acids	32	8
Bases	21	34
Neutrals	44	60
Coal liquid H		
Acids	17	33
Bases	4	9
Neutrals	94	(94)
Coal liquid I		
Acids	56	(100)
Bases	23	41
Neutrals	(103)	(98)
Petroleum No. 2 diesel fuel		
Acids	(97)	(99)
Bases	71	88
Neutrals	87	91

^a Photosynthesis (as percent of controls) in two algal cultures exposed for 4 h to acid, base, and neutral subfractions of WSFs prepared from five unrefined coal liquids and one refined petroleum product. Each fraction was tested at one-tenth its concentration in the original WSF. Numbers in parentheses indicate photosynthetic rates not significantly different from controls ($P = 0.05$) (from K. E. Cowser, *H-Coal Pilot Plant Project Quarterly Progress Report for Period Ending June 30, 1980*, ORNL/TM-7469. Oak Ridge National Laboratory, Oak Ridge, Tenn., 1980).

Table DD.25. Acute toxicity to *Daphnia magna* of acid, base, and neutral subfractions of water extracts of five coal liquids

Subfraction	Acute toxicity (LC ₅₀ ^a)		
	Acids	Bases	Neutrals
Coal liquid E	6.4 (5.6-7.4)	2.74 (2.3-3.3)	4.60 (3.5-7.0)
Coal liquid F	11.4 (10.2-13.5)	5.6 (4.8-6.8)	7.0 (6.2-8.0)
Coal liquid G	0.48 (0.42-0.56)	0.18 (0.03-0.28)	2.70 (2.44-3.00)
Coal liquid H	1.96 (1.80-2.16)	4.14 (1.46-13.4)	2.08 (1.58-2.50)
Coal liquid I	2.62 (2.26-3.08)	3.84 (3.24-4.62)	0.62 (0.32-1.2)

^a The percentage of the fractionated material from 1 liter of water extract that, when dissolved in 1 liter of dilution water, was estimated to have killed 50% of the test animals in 48 h. Numbers in parentheses are 95% fiducial limits (from K. E. Cowser, *H-Coal Pilot Plant Project Quarterly Progress Report for Period Ending June 30, 1980*, ORNL/TM-7469. Oak Ridge National Laboratory, Oak Ridge, Tenn. 1980).

Table DD.26. Concentrations of organic compounds in WSFs compared with acute toxicity concentrations for algae and *Daphnia magna*

Values are in mg/liter

Compound	Concentration in WSF ^a		Acute toxicity		
	Coal liquid A	SRC-II fuel oil blend	<i>Selenastrum capricornutum</i> ^b	<i>Microcystis aeruginosa</i> ^b	<i>Daphnia magna</i> ^c
Phenol	39	210	174	54	30
o-Cresol	26	456		25	16
m-Cresol	57			46	18
p-Cresol				251	1.4
2,4-dimethylphenol	16	178		21	2.3
2,5-dimethylphenol					
C ₃ -phenols	13	58		148 ^d	0.28 ^d
Toluene	2.6	<0.1	115	80	646
Naphthalene	5.1	0	5.7	0.85	8
			3.8	3.6	1.2
1-methylnaphthalene	0.1	0.7			
2-methylnaphthalene	0.2				
Anilines	29.1	100	21 ^f	24 ^f	0.54 ^f

^aData from Table DD.23.

^b4-h EC₂₀ [J. M. Giddings, "Acute Toxicity to *Selenastrum capricornutum* of Aromatic Compounds from Coal Conversion," *Bull. Environ. Contam. Toxicol.* 23: 360-364 (1979); and unpublished data].

^c48-h LC₅₀ (Parkhurst, unpublished data).

^dData for 2,4,6-trimethylphenol.

^eNot determined.

^fData for aniline.

DD.9.4.3 Summary

Chemical analyses of WSFs from several synthetic oils were qualitatively very similar. Major constituents in each case were phenol, aniline, and their C₁-, C₂-, and C₃-substituted derivatives. The two SRC-II WSFs contained substantially higher concentrations of phenols and anilines than did two other coal liquid WSFs tested. Neither phenols nor anilines were detected in the ESF from a petroleum crude WSF. Consistent with the high degree of toxicity of anilines and phenols, these two fractions accounted for nearly all the toxicity observed in coal liquid WSFs to aquatic organisms.

DD.9.5. Dissolution of oil constituents

DD.9.5.1 Dissolution kinetics

Three factors largely control the rates at which compounds in an oil layer dissolve into underlying water: Characteristics of the oil (primarily viscosity), characteristics of the water (primarily turbulence), and the equilibrium partition coefficient of the compounds between oil and water. In laboratory studies, water turbulence was essentially held constant for all oils (by use of the same stirring speed); dissolution rates were thus controlled primarily by oil viscosity and the oil-water partition coefficient of each contaminant.

Table DD.27 summarizes dissolution rate data for several phenolic compounds for the different oils tested. Dissolution rates are indicated by the time required for 50% approach to equilibrium ($t_{1/2}$), (i.e., for the contaminant concentration in underlying water to reach 50% of its final value). Thus a small $t_{1/2}$ indicated rapid dissolution of a contaminant. Several trends are apparent in Table DD.27. For each oil, phenol dissolves most rapidly; substituted phenols of increasing molecular size dissolve more and more slowly. This trend is due to the tendency of larger phenols to partition increasingly into the oil phase. For the one oil (SRC-II Fuel Oil Blend) for which dissolution rates of anilines were measured, they followed the same pattern as phenols but dissolved somewhat more slowly: $t_{1/2}$ values for aniline and C₁-, C₂-, and C₃-anilines were 2.6, 4.6, 6.0, and 12 h respectively. The second apparent trend in

Table DD.27. Time (in h) required for dissolution of phenolics from oils to reach 50% of equilibrium concentrations in underlying water in laboratory extractor (22° C, reciprocating stirrer speed: 800 rpm)

	Oil viscosity at 25° C (cS)	Phenol	C ₁ -Phenols	C ₂ -Phenols	C ₃ -Phenols
Coal liquid A	2.82	0.3	0.8	2.0	6.7
Coal liquid B	1.23	0.10	0.25	0.9	2.3
Coal liquid C	21	2.3	3.4	3.4	4.1
Petroleum crude	202	4.4 ^a	<i>b</i>	<i>b</i>	<i>b</i>
SRC-II product	7.42	0.4	0.7	1.7	5.2
SRC-II fuel oil blend	7.09	1.2	3.1	5.7	9.1

^aObtained from ¹⁴C-labeled phenol added to oil.

^bNone detected.

Table DD.27 is that phenol dissolution rates are inversely related to oil viscosity; thus, phenol dissolves most rapidly from the light distillate oil B and most slowly from the highly viscous petroleum crude. Third, differences in dissolution rates among oils are most readily apparent for phenol (the most water-soluble compound) and become smaller as the phenols become more highly alkylated (and thus less water soluble): while $t_{1/2}$ values for phenol differ forty-fourfold among the oils tested, corresponding ranges for C₁-, C₂-, and C₃-phenols are fourteenfold, sixfold, and fourfold respectively.

DD.9.5.2 Dissolution and WSF toxicity

Formal studies of the influence of differential dissolution rates on the toxicities of WSFs have not yet been undertaken, but results of several preliminary experiments were consistent with other findings relative to the dissolution and toxicity of specific compounds. Comparisons of compound concentrations in WSFs with acute toxicity concentrations for algae, together with bioassays on acid, base, and neutral subfractions of WSFs, pointed to anilines and phenols as the principal toxic constituents of synfuels' WSFs (Sect. DD.9.4.2). Because these classes of organics dissolve out of soils rapidly, it would be expected that the toxicity of a WSF should increase relatively rapidly at first, and then increase slowly or not at all with continued extraction time. Two experiments with Coal Liquid A were performed to test this hypothesis. In one experiment, an oil:water ratio of 1:8 was used in WSF preparation, and algal bioassays were run after 2, 4, and 8 h of extraction. In the second experiment, the oil:water ratio was 1:140, and extraction times ranged from 1 to 6 days. In both experiments, the toxicity of the WSF with the shortest extraction time was nearly as great as that with the longest extraction time (Table DD.28). Thus, results were consistent with the hypothesis of rapid, rather than gradual, initial increase in WSF toxicity.

Another implication of the solubility data is that successive extractions of the same oil should produce WSFs that decrease in toxicity as phenols and (to a lesser extent) anilines are depleted from the oil. This was in fact observed in four successive 2-h extractions of Coal Liquid A (using a 1:8 ratio). Photosynthesis by *Selenastrum capricornutum* in 10% WSFs of the first, second, third, and fourth extracts was 10, 27, 29, and 37% of the controls respectively. These WSFs were not analyzed chemically, but on the basis of the kinetic studies it may be inferred that the concentrations of unsubstituted and C₁-anilines and phenols in the fourth extract were much lower, perhaps by an order of magnitude, than the concentrations in the first extract. The fact that considerable toxicity remains in the fourth extract is consistent with the supposition that more highly substituted anilines and phenols (whose concentrations would decline more slowly than unsubstituted aniline and phenol in successive extractions) are important contributors to the toxicity of the WSF.

Table DD.28. Influence of extraction time on the toxicity of coal liquid A WSF to *Selenastrum capricornutum*

Tabulated values are relative photosynthesis expressed as percentages of controls

	WSF concentration (%)		
	0.1	1	10
Experiment 1 (oil:water = 1:8)			
2-h extraction	98	71	4.1
4-h extraction	103	62	3.7
8-h extraction	99	58	6.1
Experiment 2 (oil:water = 1:140)			
1-d extraction			63
2-d extraction			53
4-d extraction			52
6-d extraction			48

DD.9.5.3 Summary

In five coal liquids tested, dissolution rates of phenols decreased as the compounds increased in molecular size (and decreased in water solubility). The dissolution rate of phenol was most rapid for a light distillate and decreased as oils increased in viscosity. The toxicity of the WSF of two coal liquids increased rapidly during the initial period of extraction and only slowly thereafter, which suggests that the major components of coal liquids causing acute toxicity would dissolve during the period immediately following a spill in a river.

DD.9.6 Effects of weathering

DD.9.6.1 Evaporation

Preliminary experiments to determine losses of compounds from synthetic oils were undertaken by exposing a 2-mm thick oil film (identical to the dissolution rate experiment) on a 30- by 30-cm glass plate to a wind of constant velocity (approximately 1 m/sec) and measuring both weight loss from the film and loss of added ^{14}C -labeled compounds. SRC-II product lost 10% of weight within 6 h; contaminants continued to evaporate at a decreasing rate until after 70 h over 37% had evaporated. When radiolabeled benzene was added to a film, 50% evaporated within 6 min; evaporation half-times for phenol, naphthalene, and aniline were 6, 16, and 68 h. Although more studies are needed to examine effects of wind speed, temperature, and oil film thickness and viscosity, the initial results indicate that under gentle wind conditions benzene (and probably toluene) would evaporate far too rapidly to permit dissolution into underlying water. In contrast, phenol and aniline dissolve sufficiently rapidly that evaporation would probably not substantially reduce expected concentrations in the water.

The influence of evaporation of components of oils on the toxicity of WSFs to algae was examined by extracting the SRC-II fuel oil blend in open and sealed flasks using a 1:8 oil:water ratio. The extractions were performed in the dark and in the light. Exposure to light had a dramatic effect on WSF toxicity (see Sect. DD.9.6.2), but there were no differences between WSFs prepared in open or closed flasks. Evaporation was therefore apparently not significant in reducing the toxicity of the WSFs, as anticipated from the measured evaporation rates of aniline and phenol.¹⁸

DD.9.6.2 Sunlight

To assess the effect of sunlight on contaminants dissolved from coal liquids into the underlying water, oils were layered onto water (1:140 volume ratio) in the laboratory extraction apparatus, covered with quartz glass to permit transmittance of ultraviolet radiation, and exposed to midsummer sunlight on the laboratory roof for periods of up to seven days. A circulating cooling bath maintained the oil-water temperature below 28°C. Samples were collected at intervals

and tested for formation of oxidants using an amperometric technique. Additional samples were analyzed for dissolved contaminants using ultraviolet, visible, and infrared spectrophotometry, and gas chromatography.

As found previously for No. 2 fuel oil, oxidants were observed by amperometry to accumulate in the water below each coal-derived oil tested.¹⁹ Oxidant formation occurred only during daylight and was most pronounced during clear, bright days. As reported previously no oxidants were measured in water underlying the petroleum crude oil.¹⁹

Although oxidant levels increased linearly in water underlying a Coal Liquid A sample when tested, few other chemical changes were observed. Gas chromatographic scans of acid, base, and neutral fractions of light-exposed and nonexposed water samples collected each day over seven days were identical, although infrared scans indicated the presence of carbonyl functionality in the light-exposed samples which was not present in the dark controls.

Two experiments were performed to measure the effect of sunlight on the toxicity of WSFs to algae. The experiments are summarized in Table DD.29. In both cases, exposure of the oil to sunlight during WSF extraction caused the toxicity of the WSF to increase, although the magnitude of the increase was different in the two experiments. Toxicity of the Coal Liquid A WSF to *Daphnia magna* was also about two-fold greater after eight days' exposure to sunlight; the LC₅₀ declined steadily from 2.85% dilution on day 2 to 1.60% on day 8. The effect of sunlight on the WSF of a petroleum crude was considerably more pronounced. The LC₅₀ was decreased sevenfold below that of a dark control after five days' exposure.

Table DD.29. Influence of sunlight on the toxicity of WSFs to algae

Oil	Oil:water	Extraction time	Test organism	EC ₂₀ ^a (%)	
				Light	Dark
SRC-II fuel oil blend	1:8	7 h	<i>Microcystis aeruginosa</i>	0.17	1.3
Coal liquid A	1:140	8 d	<i>Selenastrum capricornutum</i>	3.3	5.6

^aWSF concentration (percent dilution) causing 20% inhibition of photosynthesis, estimated by interpolation on a plot of photosynthesis vs log concentration.

Further studies are underway to characterize oxidants produced by irradiation of coal liquids by sunlight. Rates of reaction with iodide indicate that at least two different oxidants are produced in water underlying irradiation Coal Liquid A, of which only the minor constituent appears to be organic. Hydrogen peroxide appears to be the dominant oxidant produced, comprising about 75% of total oxidant in the water. The organic hydroperoxides produced by action of sunlight on fuel are considerably more toxic than hydrogen peroxide, which may explain at least in part why exposure to sunlight appears to have relatively less effect on toxicity of coal liquid extracts than on toxicity of petroleum products during the initial stages of weathering.¹⁹

DD.9.6.3 Summary

In initial experiments, evaporation of benzene from an SRC-II product film was sufficiently rapid to prevent benzene from dissolving into underlying water. Phenol and aniline, however, dissolved considerably more rapidly than they evaporated, and thus at least under gentle wind conditions evaporation would not be expected to reduce their toxicity to aquatic organisms substantially. Bioassays of SRC-II fuel oil blend WSFs prepared under sealed and open conditions support this conclusion. Although WSF toxicities of several coal liquids were increased several-fold by exposure by sunlight, apparently caused by formation of water-soluble oxidants (and possibly quinones), the relative toxicity increase is not as great as has been reported previously for petroleum oils.

DD.9.7 Implications

Oil spilled onto a body of water will spread over the water's surface; less viscous oils (such as SRC-II produce and light distillates) spread more rapidly than more viscous oils (such as many petroleum crudes and heavy distillates). If the density of the oil is near that of the water, substantial mixing of oil into water will occur. Water turbulence or river traffic will also promote the mixing of oil into water.

Phenols and anilines, which are highly toxic to aquatic life, are present in substantial amounts in coal liquids but are not abundant in petroleum. These compounds will dissolve from light oils within minutes after a spill has occurred. Dissolution will be slower from raw synconides or heavy distillates; but aniline, phenol, and their C_1 -substituted derivatives will still dissolve within several hours. Dissolution will be more rapid in well-mixed areas and slower in poorly mixed environments such as impoundments. Mono- and diaromatic hydrocarbons (such as toluene and naphthalene), which are the major soluble components of petroleum, dissolve much more slowly and reach lower equilibrium concentrations than anilines and phenols and are therefore less important contributors to the toxicity of water in contact with spilled coal liquids. The rapid dissolution of toxic components from coal liquids suggests that clean-up efforts would have to be undertaken immediately to mitigate the impacts of a spill.

Although wind will cause evaporative losses of nonaromatic hydrocarbons from oils, phenols and anilines will not be substantially reduced. Therefore, the influence of evaporation on the toxicity of coal liquids will be much smaller than is the case with petroleum spills. Sunlight will cause chemical changes in coal liquids that may slightly increase the toxicity of water under a spill during the initial several days.

Depending on the initial density of the oil, the temperature of the water, and rates of dissolution and evaporation of the lighter oil constituents, some or all of the spilled product may eventually sink and become incorporated into the sediments. The chemical nature of this material, its fate in natural sediments, and the long-term consequences for aquatic life and for human health are matters that urgently need investigation.

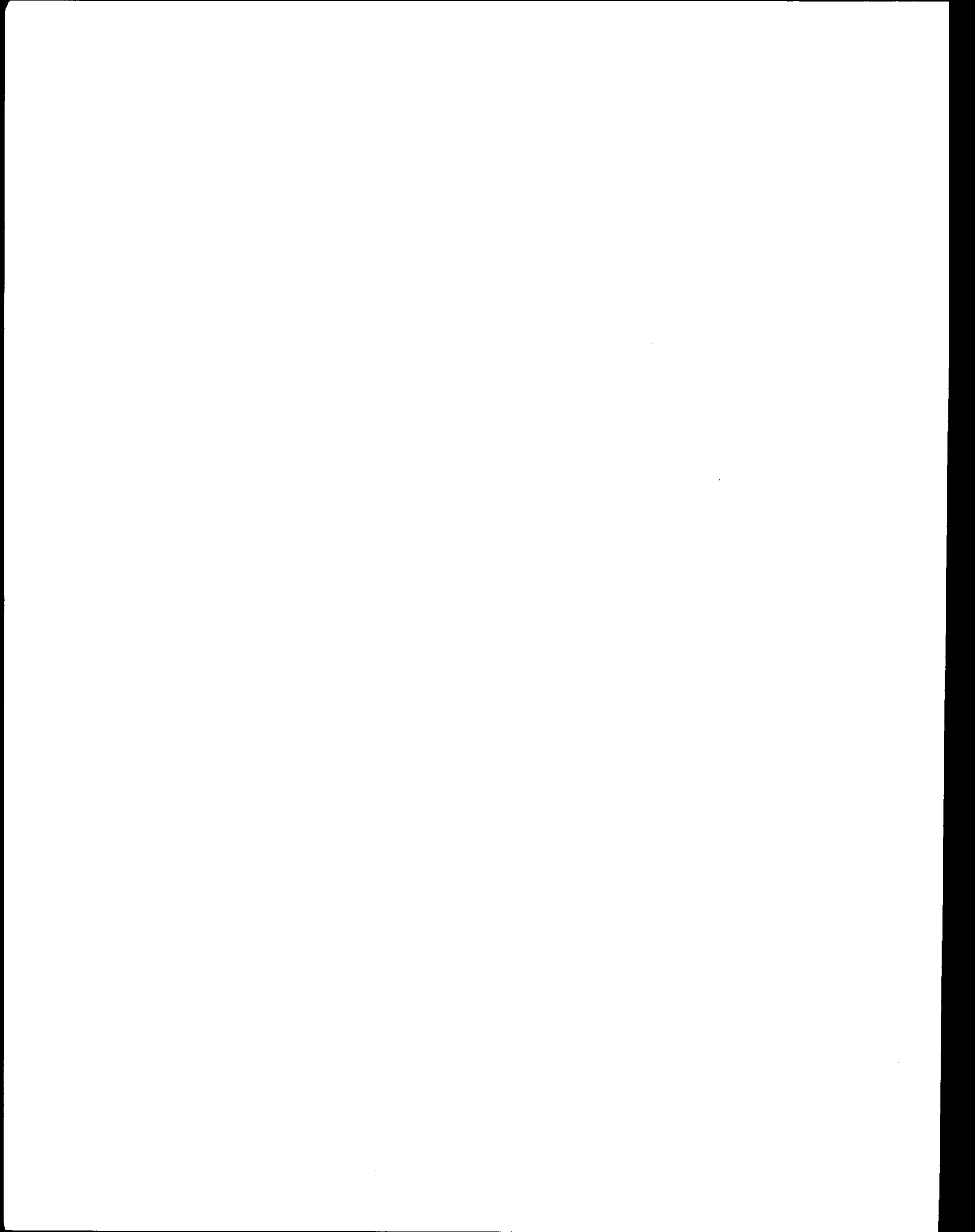
The physical and chemical differences between coal liquefaction products and petroleum have important implications in the event of an oil spill in an aquatic environment, as described above. One potential strategy for reducing the impact of liquefaction product spills would be to remove anilines and phenols (by hydrotreating, for example) before transporting the products from the liquefaction site. Since the concentration of phenols and anilines in liquefaction products are partially dependent on coal type and on plant operating conditions, these factors might also be manipulated to reduce the hazards of product transportation. The feasibility of mitigation strategies such as these is another topic for further research.

REFERENCES FOR APPENDIX DD

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Appendix EE

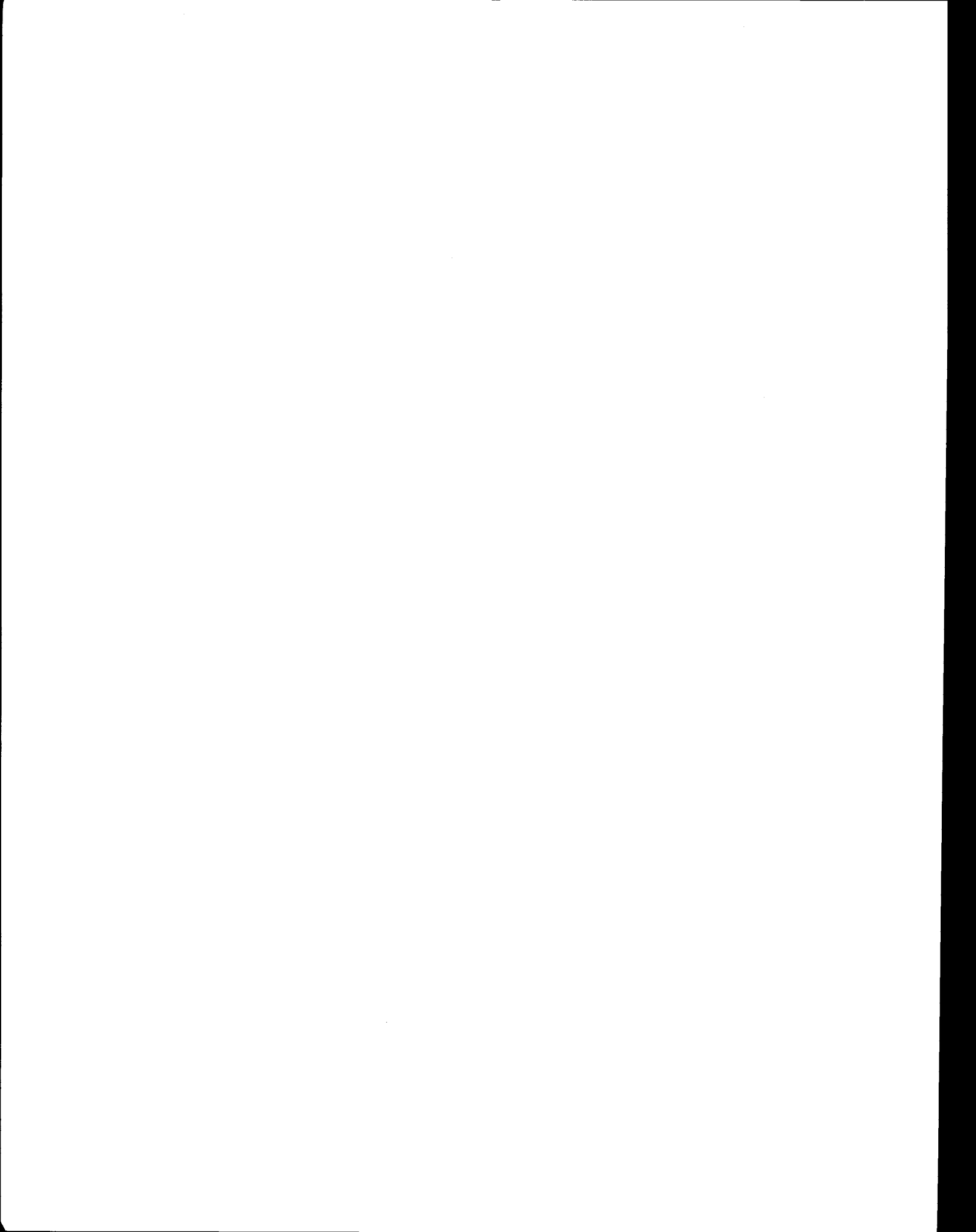
U.S. DEPARTMENT OF ENERGY, U.S. ENVIRONMENTAL PROTECTION AGENCY, AND KENTUCKY
DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL PROTECTION WORK PLAN TO
ASSURE ENVIRONMENTAL ACCEPTABILITY OF THE SRC-I PROJECT



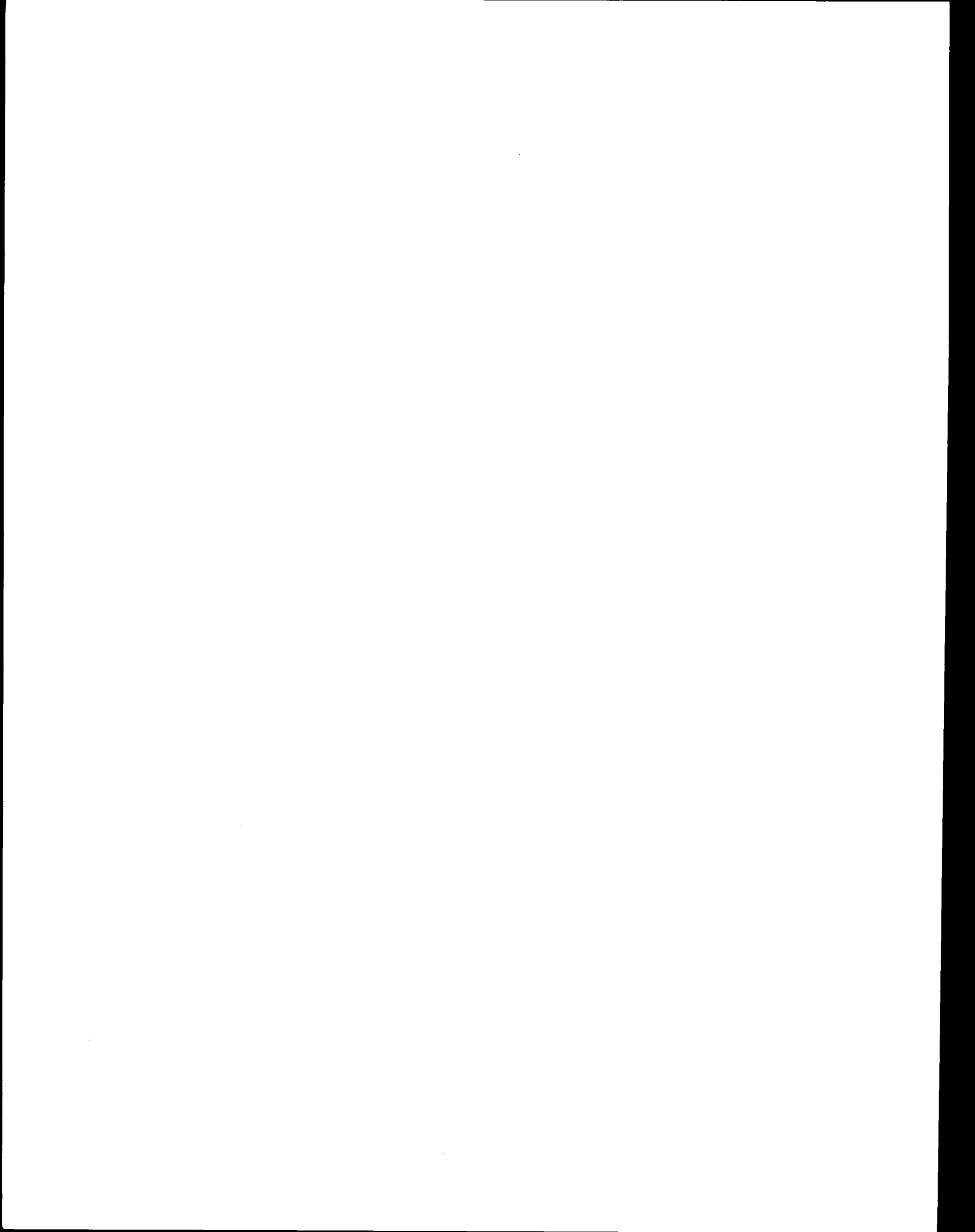
Appendix EE

U.S. DEPARTMENT OF ENERGY, U.S. ENVIRONMENTAL PROTECTION AGENCY, AND KENTUCKY
DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL PROTECTION WORK PLAN TO
ASSURE ENVIRONMENTAL ACCEPTABILITY OF THE SRC-I PROJECT

The subject work plan was jointly prepared by the U.S. Department of Energy (DOE), U.S. Environmental Protection Agency (EPA), and the Kentucky Department of Natural Resources and Environmental Protection (KDNREP) and finalized on December 5, 1980. A copy of the work plan was presented in the DEIS and is also included as part of this Appendix. The work plan presents DOE's commitments to ensure environmental acceptability of the SRC-I project and the responsibilities of EPA and KDNREP to review project activities and to participate in development of project monitoring plans.



EE.1 ORIGINAL WORK PLAN





Department of Energy
Oak Ridge Operations
P.O. Box E
Oak Ridge, Tennessee 37830

December 12, 1980

Ms Rebecca Hanmer, EPA
Ms Jackie Swigart, KDNREP

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cc: John Hagan, EPA, EIS Branch, Atlanta, GA
Russell Barnett, KDNREP, Frankfort, KY

Rebecca Hanmer,
Administrator
EPA, Region IV
345 Courtland Street
Atlanta, GA 30308

Jackie Swigart,
Secretary
Kentucky Department of Natural
Resources and Environmental
Protection
Capital Plaza Tower
Frankfort, KY 40601

Dear Ms. Hanmer and Ms. Swigart:

DOE/EPA/KDNREP WORK PLAN TO ASSURE ENVIRONMENTAL ACCEPTABILITY OF THE
SRC-I PROJECT

Attached for your review and concurrence is a copy of the subject work
plan which was reviewed and finalized by our staffs on December 4, 1980.

It is our intent to include the work plan in the Draft EIS for the pro-
posed SRC-I Demonstration Plant, which is to be issued within a few
weeks. Thus, your early review and concurrence of the work plan would
be appreciated.

Sincerely,

John F. Pearson, Jr.
Assistant Manager for Solvent
Refined Coal Projects

SR-74:JAR

Enclosure:
As stated

EE-7

DOE/EPA/KDNREP WORK PLAN TO ASSURE ENVIRONMENTAL ACCEPTABILITY OF
THE SRC-I PROJECT

December 5, 1980

As cooperating agencies, the U. S. Department of Energy, the U. S. Environmental Protection Agency, and the Kentucky Department of Natural Resources and Environmental Protection have reviewed environmental issues pertinent to the proposed SRC-I demonstration plant to be constructed near Newman, Kentucky. The environmental issues of interest to EPA and KDNREP are presented in the Draft EIS and, where data are available, the expected environmental impacts are noted. The Draft EIS is being issued early in the design phase of the project with the intent of completing the public review and incorporating responses to all public comments in the Final EIS prior to any decision to proceed with the major detailed design efforts or to commence construction of the SRC-I facility. It is DOE's position that the Final EIS should be completed prior to any significant financial commitments to the SRC-I project such as would be incurred by the completion of final design, currently projected to cost \$171 million. The Draft EIS assesses environmental impacts based on the best available design description and data and where design decisions are not yet available, a worst case is assumed for the environmental impacts analysis. DOE, utilizing the tiering approach for NEPA, will perform supplemental NEPA reviews should further design or other factors identify significant environmental impacts not within the scope of the Final EIS. Significant issues raised by EPA and KDNREP with respect to a preliminary Draft EIS are noted below with identification of the process required for resolution, the time frame within which the information will be available to EPA, KDNREP, and the public, continuing EPA and KDNREP involvement, and respective DOE, EPA, and KDNREP responsibilities for resolving the issues and assuring environmental acceptability of the SRC-I demonstration plant. Additional issues may be identified during the continuing review process of this project, necessitating periodic work plan modifications.

A. Issue

The completion of the NEPA responsibilities prior to commercialization.

Process to Resolve

Written commitments to comply with NEPA requirements prior to transferring the Demonstration Plant to the industrial partner for possible commercial expansion have been made in the U. S. Department of Energy, Solvent Refined Coal Demonstration Project (SRC-I) Contract No. DE AC05 78OR03054, August 7, 1980, Article XXXVII, Environmental Review Before Buyout, p. 67 (cost-shared agreement). In the event modifications to the Demonstration Plant are necessary to meet NEPA requirements, the cost of such modifications shall be deducted from the buyout price of the Plant.

Prior to the decision on what NEPA action is appropriate, DOE will consult with EPA and KDNREP concerning the appropriate action and scope of the NEPA review.

Time Frame:

Prior to the NEPA decision on commercialization, so as to give cooperating agencies sufficient advanced notice to be able to participate meaningfully in defining the scope of the NEPA review and in any subsequent NEPA actions taken.

Continuing EPA and KDNREP Involvement

EPA and KDNREP will participate in defining the scope of the NEPA review and will review any NEPA document prior to a final decision being made by DOE on transfer of the demonstration plant to the industrial partner for possible commercial expansion.

Responsibility:

DOE is responsible for initiating contact with EPA and KDNREP prior to finalizing the scope of the NEPA review and prior to the final NEPA determination.

EPA and KDNREP are responsible for prompt and meaningful participation in defining the scope of the NEPA review and in the final NEPA determination.

EPA is responsible for determining whether the expansion of the demonstration plant to commercial scale would constitute a new source under NPDES with attendant NEPA responsibilities.

DOE will make the final NEPA determination available for public review.

B. Issue

Assessment of the effects of a flood on construction and operation of the facility.

Process to Resolve:

In compliance with Executive Order 11988 and DOE regulations contained in the March 7, 1979, Federal Register, (Vol. 44, No. 6), DOE will provide a description of the direct and indirect, long- and short-term effects of the proposed action on the floodplain in the Final EIS. The Final EIS will also contain an analysis of alternatives to the proposed action which could be implemented to avoid or mitigate any adverse impacts.

DOE will provide a general description of the effects of a 100-year flood on the construction and operation of the facility in the Final

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EIS. During detailed design, a more detailed assessment of the 100-year flood impacts on construction activities and plant operations, including equipment and production losses and impacts on supporting facilities such as wastewater treatment systems and residual waste disposal areas, will be performed.

DOE will provide maps delineating the location of the floodway, 20 percent (5-year) flood, and the historic high flood prior to submittal of the Final EIS. During detailed design and prior to application for a Floodway Construction Permit, DOE will delineate encroachments within the floodway and will describe how such encroachments will be minimized.

Time Frame:

The floodplain assessment will be included in the Final EIS. Detailed assessment of the project's impact on flood flows will be prepared during final design and prior to the application for a KDNREP Floodway Construction Permit.

Continuing EPA and KDNREP Involvement:

EPA and KDNREP will review and make comments on the floodplain map delineations. EPA and KDNREP will review the Final EIS to assess impacts of flood flows on the project. KDNREP will review the assessment of the impact on the project of flood flows prior to issuing a Floodway Construction Permit.

Responsibility:

DOE will conduct the floodplain assessment as described above.

DOE will provide EPA and KDNREP the opportunity for review of the detailed assessment.

EPA and KDNREP will review/comment on the detailed assessment, as appropriate, in a timely manner.

KDNREP will process a Floodway Construction Permit in a timely manner.

C. Issue

Residual Waste Disposal (Hazardous and Non-Hazardous)

Process to Resolve:

During detailed design, DOE will conduct geotechnical evaluations of the solid waste disposal sites to insure their adequacy to contain hazardous and non-hazardous materials. The evaluation will include hydrologic information; e.g., floodplain delineation and groundwater elevations, geologic and soils information;

e.g., soil types, foundation stability and potential for soil liquefaction, and seismic activity; and any other information deemed necessary to assure the suitability of the proposed sites for waste disposal.

An evaluation of alternative waste management practices; e.g., waste reduction, chemical fixation, incineration, etc., with supporting data will be provided by DOE to EPA and KDNREP at a sufficiently early stage to allow for adequate and meaningful review and comment prior to submittal of Federal and Commonwealth permit applications.

Time Frame:

Based on existing studies and/or preliminary results of the new geotechnical site studies a more complete evaluation of the feasibility of alternative on-site residual waste disposal sites, identification of constraints to those sites and alternative means of disposing of residual wastes materials will be presented in the Final EIS. The Final EIS will also present the ongoing geotechnical study and RCRA and Commonwealth permitting activities being performed to determine final siting and the preferred alternative for disposal.

Geotechnical site and alternative analysis to be completed prior to submittal of applications for Federal and Commonwealth permits.

RCRC and Commonwealth permitting completed prior to the initiation of construction of residual waste treatment facilities.

Continuing EPA and KDNREP Involvement:

EPA and KDNREP will provide guidance to DOE concerning the most environmentally sound residual materials handling, treatment, and disposal methods. EPA and KDNREP will process permit applications in a timely manner.

Responsibilities:

DOE will perform a RCRA evaluation in accordance with EPA and KDNREP guidance to determine classifications for each solid waste process stream and will submit a RCRA permit application for approval prior to initiation of construction of residual waste facilities.

EPA will process RCRA permit applications in a timely manner.

KDNREP will expedite any Commonwealth hazardous and non-hazardous waste disposal permits.

DOE will contact and receive approval from the Daviess County government to construct and operate a hazardous waste disposal facility.

D. Issue

Selection of detailed processes, pollution control designs, and maintenance procedures for the protection of air and water, and hazardous waste disposal through the determinations of best available control technologies (BACT) consistent with appropriate permitting regulations.

Process to Resolve:

EPA has provided detailed comments concerning the design of the demonstration plant, many of which cannot be resolved until detailed design is undertaken. DOE and EPA will identify significant detailed design, maintenance, or other concerns not addressed in the Draft EIS due to the preliminary status of projects activities. The Final EIS will include a list of these concerns and estimated time frame for availability of project data and decisions for EPA review either through environmental permits, reports, or separate briefings. BACT will be determined by KDNREP and EPA, and the demonstration facility will utilize such technologies.

Time Frame:

Identification of outstanding needs in the Final EIS. Assessment of alternate technologies, development of maintenance programs, and reporting of results during detailed design. Selection of BACT will be made prior to finalization of design.

Continuing EPA and Kentucky DNREP Involvement:

EPA will provide guidance and up-to-date advice on pollution control technologies to DOE upon request.

KDNREP will incorporate BACT determinations into the PSD and Hazardous Waste Permits to be issued by the Department, and will evaluate in a timely manner future technology applications. KDNREP and EPA will make the BACT determinations.

EPA will develop BACT determinations to be incorporated into the NPDES and RCRA permits to be issued by the agency. EPA will retain oversight authority to review the PSD determination.

Responsibility:

DOE will provide a list of outstanding detailed design data, maintenance programs, or other needs in the Final EIS, perform necessary assessments, and report results.

KDNREP and EPA will further review the Draft EIS, identify significant concerns, and review results of detailed evaluations. EPA and KDNREP have responsibility for BACT determinations.

E. Issue

Erosion and Sedimentation Control Plan

Process to Resolve:

The plan is a requirement of DOE Contract No. DE AC05-78OR03054 and is the responsibility of Construction Manager Contractor to prepare. The plan will be prepared and submitted by DOE to EPA and KDNREP for review and comments.

Time Frame:

Control plan developed prior to initiation of onsite construction activity.

Continuing EPA and KDNREP Involvement:

Review of the control plan.

Responsibility:

DOE is responsible for developing and submitting the plan to EPA and KDNREP for review and comment.

EPA and KDNREP are responsible for submitting any significant comments to DOE in a timely manner.

F. Issue

Socioeconomic - Transportation Impacts

Process to Resolve:

DOE is funding studies to evaluate further the socioeconomic impacts of the Demonstration Plant and to identify mitigative measures that are available to affected communities. Available results from these studies will be included in the Final EIS and presented to affected communities.

Continuing EPA and KDNREP Involvement:

Review/comment on Final EIS.

Responsibility:

DOE is responsible for performing studies on the socioeconomic and transportation impacts of the demonstration plant and providing copies of the report to the affected local governments and Green River Area Development District for their review and comment. A summary of the final report will be incorporated into the Final EIS. DOE will identify mitigating measures and assist affected communities in securing Federal/State aid.

G. Issue

Monitoring

Process to Resolve:

A comprehensive monitoring program for system performance, ambient environmental quality, and health effects will be developed. Elements of this program will include environmental (atmospheric, hydrologic, biologic), health, and pollution control efficiency monitoring. The program will be designed to provide an overall, integrated assessment of the impacts of the project. DOE will develop, implement and evaluate results of the program. EPA and KDNREP will actively participate in the development of the monitoring program and in the review and evaluation of monitoring results. EPA and KDNREP will cooperate with DOE in redefining monitoring program data needs and/or identifying measures to mitigate adverse environmental impacts. Mitigation measures may entail changes in process or control design or in operations.

Time Frame:

A conceptual outline of the monitoring program will be included in the Final EIS. The implementation schedule will be identified and specified during development of the monitoring program.

During detailed design, the monitoring program will be developed with the cooperation of EPA and KDNREP.

Continuing EPA and KDNREP Involvement:

EPA and KDNREP will assist DOE in developing the monitoring program.

EPA and KDNREP will assist DOE in evaluating monitoring results throughout the life of the monitoring program.

Responsibility:

DOE is responsible for developing and issuing a report describing the monitoring program. The monitoring program and monitoring results will be made available to the public and local governments through established reporting procedures. Should there be significant public interest in the monitoring program results, DOE will conduct public briefings.

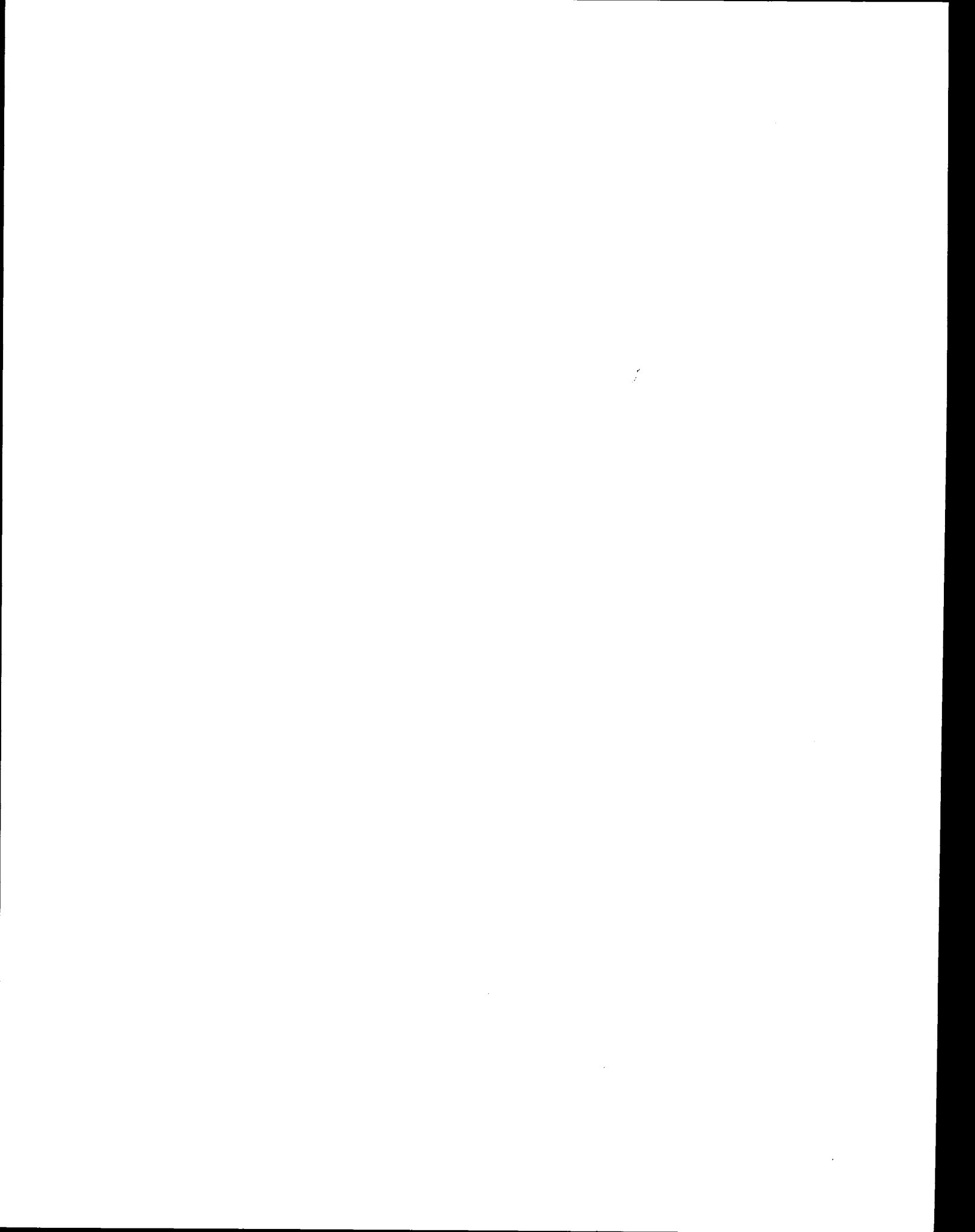
EPA and KDNREP will assist DOE in the development of the monitoring programs. EPA, through permitting actions, will require implementation of an approved program for monitoring of regulated pollutants.

DOE is responsible for implementing and evaluating the results of the monitoring program and coordinating with EPA and KDNREP on

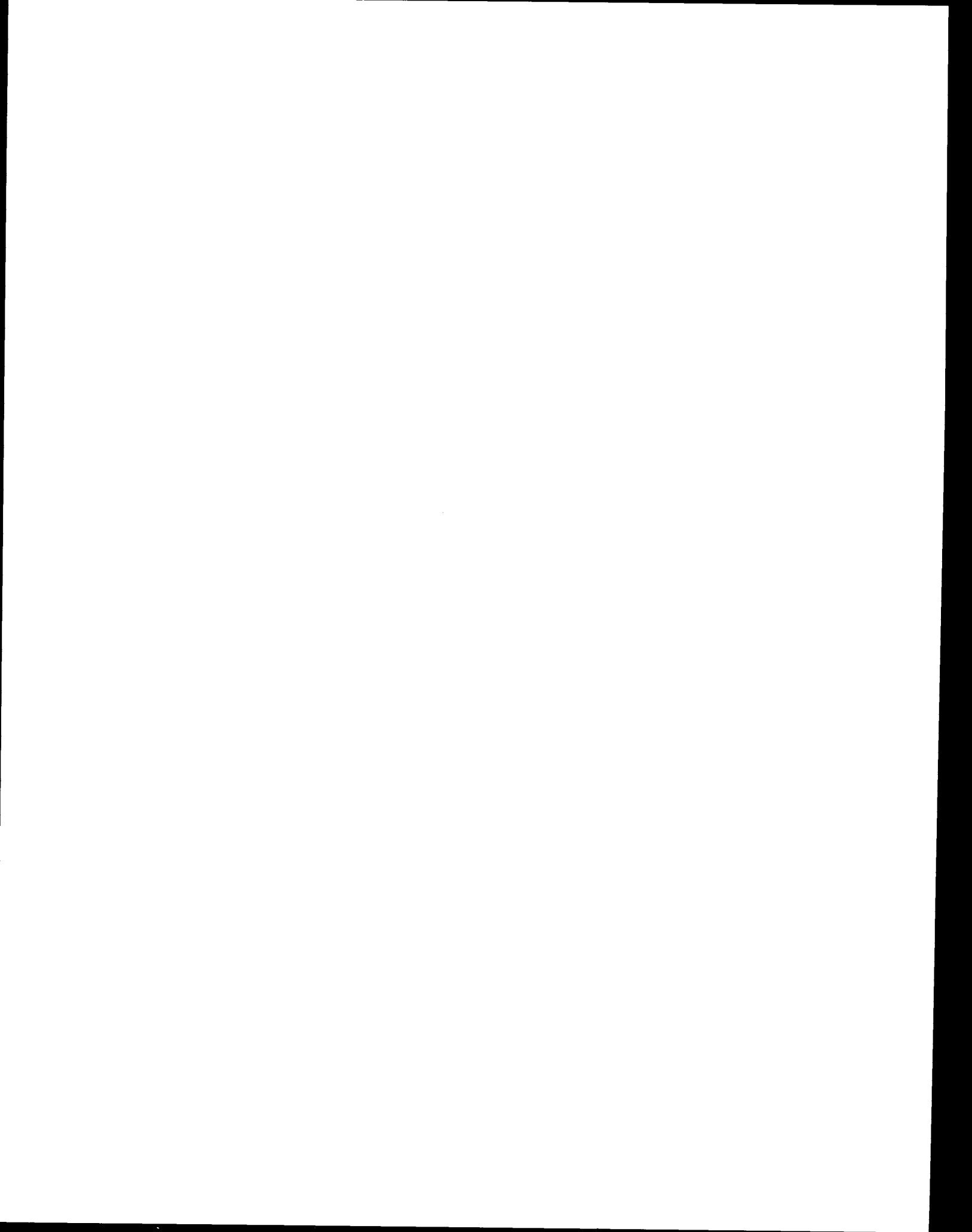
mitigating adverse environmental impacts identified through the monitoring program.

EPA and KDNREP will review monitoring program results and cooperate with DOE in redefining the monitoring program data needs and in mitigating adverse environmental impacts.

EE-11



EE.2 STATUS OF THE WORK PLAN



EE.2 STATUS OF THE WORK PLAN

The DOE has initiated the commitments made in the work plan through incorporation of additional information and schedules requested by EPA and KDNREP in this FEIS. Following is a status for each work plan element, an identification of information DOE has provided in the FEIS, and the DOE-prepared schedules for providing additional detailed design and monitoring information after the FEIS:

- A. Issue. The completion of the National Environmental Protection Agency (NEPA) responsibilities prior to commercialization.

Status. No action is required at this time. The scope of the NEPA review will be defined during the operations phase of the demonstration plant in coordination with EPA and KDNREP.

- B. Issue. Assessment of the effects of a flood on construction and operation of the facility.

Status. Appendix D of this FEIS provides the SRC-I floodplain/wetlands review, containing a preliminary floodplain/wetlands determination and a floodplain/wetlands assessment. The floodplain/wetlands assessment describes floodplain and wetland impacts of the proposed action and an evaluation of alternate site layouts and designs. Appendix E, "Impacts on Flood Elevation," presents results of the Newman site floodplain encroachment study.

A general description of the effects of a 100-year flood on construction and operation of the Demonstration Plant is presented in Appendix C.6.

A map delineating the location of the 5-year floodway is presented in Appendix F. During detailed design, a detailed assessment of the impacts of a 100-year flood on construction and operation of the demonstration plant and a delineation and assessment of 5-year floodway encroachments will be performed and presented to EPA and KDNREP.

- C. Issue. Residual waste disposal (hazardous and nonhazardous).

Status. The FEIS presents available design information and solid waste management alternatives in Appendix C, Sects. C.2.3 and C.3.2, respectively. Because of a delay in initiation of more detailed geotechnic site studies and unavailability of results from ongoing research and development (R&D) studies, a more comprehensive study of final siting of each hazardous and nonhazardous waste storage area and alternative means of waste disposal is not available. The statement of work for the planned geotechnic study has been prepared and is awaiting ICRC and DOE approval for implementation. Results of the geotechnic work and R&D studies will provide information required for the hazardous waste permit applications. A schedule of project tasks for preparation of the hazardous waste permit applications follows:

	<u>Start</u>	<u>Complete</u>
R&D studies	1/81	12/81
Approval of research purchase req.		
Confirmation of waste composition		
Preliminary leaching results		
Final lab results		
Waste inventory	1/81	3/81
Inventory from area contractors		
Review with ICRC		
Preliminary siting submission	1/81	5/81
Meeting with KDNREP		
Rust prepares geotechnical data		
Dames & Moore prepares hydrogeological data		
ICRC reviews and assembles submission		
DOE submits to KDNREP		
KDNREP reviews siting information		

Development of design guidelines	1/81	6/81
Formation of permit review team		
Evaluation of base plan by Fred C. Hart Assoc.		
Modeling of base design by Dames & Moore		
Modeling of alternate designs by Dames & Moore		
Receipt of preliminary R&D results		
Contingency plan preparation	3/81	1/82
Review of emergency procedures		
Review of process safety program		
Interfacing with governmental bodies		
Compilation of plans		
Incorporation into application		
Implementation of plan		
Process design	6/81	1/82
Guidance from ICRC		
Rust prepares process design		
Application preparation	1/82	3/82
Incorporation of design and drawings		
Inclusion of contingency plans		
Completion of application		
Application review and approval	3/82	1/83
ICRC reviews and forwards to DOE		
DOE reviews and submits to EPA/KDNREP		
EPA/KDNREP review and approve		
Contingency plan implementation		1/83
Start of construction of hazardous waste facilities		1/83

- D. Issue. Selection of detailed processes, pollution control designs, and maintenance procedures for the protection of air and water, and hazardous waste disposal through the determinations of best available control technologies (BACT) consistent with appropriate permitting regulations.

Status. The FEIS presents an enhanced description of the proposed controlled combustor and flare system and alternate designs being evaluated for controlling emissions of nonmethane hydrocarbons in Appendix C.2.2.6 and C.3.1.5. Design alternatives for control of other emissions and effluents are essentially the same as those presented in the DEIS. Additional information provided in the FEIS is noted in the schedule below, which presents specific comments of EPA and KDNREP and presents DOE's schedule for providing requested information. Schedules for detailed engineering have been prepared by ICRC but are subject to change because of recent funding limitations that have resulted in a delay in detailed engineering activities. Once the government decision on final funding of the project is obtained, the detailed engineering schedule will be revised and specific dates provided for availability of the design information discussed below:

1. DOE/ICRC should advise EPA regarding the tests for hydrocarbon emissions from the coal dryer/pulverizer, and regarding any planned adjustments to dryer temperature/residence time in order to reduce these emissions. Also, hydrocarbon emissions from this source should then be added to Table C.7.

Schedule: Testing - late 1981.

2. The DOE should assess the worst-case sulfur emissions that might result if the Beavon unit is not operating properly. If these potential emissions are considered too high, some appropriate course of action should be agreed upon in the event that these worst-case levels are indeed observed during operation.

Schedule: Completed. See Appendix C.4.1.4 and Sect. 4.2.3.1.

3. Page C-40, last paragraph. The DEIS describes some aspects of the proposed directed maintenance protocol in general terms: for example, "valves . . . will be inspected regularly." More details should be provided — source type by source type — regarding the nature of the inspection and the actual frequency. It is recognized that details on the directed maintenance protocol will not be completed until after the FEIS is submitted; the FEIS should indicate the schedule by which the information, if not currently available, might be expected.

DOE/ICRC should provide the information requested above regarding the detailed monitoring plan for tracking fugitive organics emissions/control performance after plant operation begins, to the extent that the plan is not available for inclusion in the FEIS.

Schedule: The directed maintenance protocol is discussed in Appendix C, Sect. C.3.1.5. The final detailed directed maintenance and monitoring plans are scheduled to be available in June 1982.

4. DOE/ICRC should provide further details regarding the directed maintenance protocol, to the extent that this information is not available for inclusion in the FEIS. (The details should also include monitoring plans for identifying the presence of fugitive organics from aerial coolers.)

Schedule: June 1982 (air coolers monitoring is discussed in Appendix C.3.3.1 and Sect. 4.2.5).

5. An expanded directed maintenance protocol should be agreed upon for the first year or two of plant operation, as supplemented and guided by a more extensive fugitive organics monitoring effort. This expanded protocol could then possibly be relaxed after operating experience is gained, based upon the results from the first year or two of operation; however, the ultimate relaxed protocol would not be less stringent than the refinery volatile organic compound (VOC) leak guidelines.

Schedule: Six months prior to operation.

6. The ultimate directed maintenance protocol should be agreed upon after the results from the first year or two of plant operation become available.

Schedule: During the demonstration plant operations phase.

7. Page C-40, Sect. C.3.1.5. The FEIS should indicate the schedule by which refined performance estimates, feed stream composition estimates, and controlled combustor/flare system design information will be provided after the FEIS.

Schedule: Appendix C, Sects. C.2.2.6 and C.3.1.5 expand on the description of the controlled combustor/flare system. The other items will be addressed during detailed engineering.

8. DOE/ICRC will revise the controlled combustor/flare performance estimate, and will estimate the composition of the gas stream to the elevated flare, under routine operation and for various upset conditions.

Schedule: During detailed engineering.

9. DOE/ICRC should provide specifications and design information regarding the controlled combustor/flare system, confirming the ability to achieve the performance goal.

Schedule: During detailed engineering.

10. DOE/ICRC should estimate the schedule by which they should be able to provide the specific key combustion modification design information on individual in-plant heaters and boilers.

Schedule: During detailed engineering.

11. DOE/ICRC should provide the key combustion modification design information and manufacturer guarantees concerning NO_x emissions in order to confirm anticipated reductions in NO_x from individual units.

Schedule: During detailed engineering.

12. The PSD application indicates scrubber design for 85% SO₂ removal and 92% particulate removal. The FEIS should present the rationale for not designing for higher removal efficiencies, especially since the coker-calciner is such a major contributor of SO₂. If the selection of the scrubber system and its performance is less finalized than inferred from the PSD application, then the FEIS should indicate the schedule by which the decision on scrubber design/performance will be made. The FEIS presents the worst-case removal efficiency for assessment of environmental impacts.

Schedule: The requested information will be provided during detailed engineering.

13. Page C-36, paragraph one. The DEIS indicates that the hydrocarbons and reduced sulfur species in the coker/calciner off-gas will be incinerated. If at all possible, the FEIS should indicate a performance goal for this incinerator. As a minimum, the FEIS should indicate on what assumptions (stream composition and incinerator performance) the coker/calciner emissions in Table C.7 were estimated and the schedule by which further information will be available concerning incinerator design, feed-gas composition, and performance.

Schedule: During detailed engineering.

14. DOE/ICRC should identify the schedule by which the decision will be made whether or not to employ incineration, and — if incineration is to be used — the schedule by which information on incinerator design and tail-gas cleanup will become available. If this information becomes available prior to the FEIS, it should be included in the FEIS (in particular, any tail-gas treatment performance goals and emission factors would be of interest).

Schedule: During detailed engineering.

15. DOE/ICRC should provide information regarding any envisioned wastewater-related incinerators, including key design information, estimated feed-stream composition, and estimated emissions. DOE/ICRC should provide key design and performance information for incinerator tail-gas treatment systems. DOE/ICRC should prepare a monitoring plan to monitor emissions from any incinerators.

Schedule: During detailed engineering. Monitoring plan by June 1982.

16. Page C-48, last paragraph. The DEIS indicates that phenol recovery is under consideration as an alternative for inclusion in the wastewater treatment plant. The FEIS should include the results of this assessment of phenol recovery, or else should indicate the schedule by which the decision will be made as to whether or not to include phenol recovery.

Schedule: Completed (results of the assessment are provided in Appendix C.3.4).

17. DOE/ICRC should provide estimates of wastewater stream compositions throughout the treatment plant and key design information on individual treatment plant components (e.g., manufacturer performance guarantees, residence time, etc.) This information would enable confirmation that the performance goals are likely to be met.

DOE/ICRC should provide the results of experimental work confirming the estimates of treatment performance and effluent concentrations to the extent that this information is not included in the FEIS.

Schedule: Experimental work is currently in progress (Appendix C, Sect. C.4.2). Final results will be provided in the NPDES application.

18. The FEIS should indicate the schedule by which a decision is expected regarding liner material/design for runoff collection and regarding estimation of runoff composition and treatment step design.

Schedule: During detailed engineering and with hazardous waste permit applications.

19. DOE/ICRC should provide further details regarding landfill design.

Schedule: During detailed engineering and with hazardous waste permit applications.

20. DOE/ICRC should provide the information supporting the ultimate decision regarding liner material identity, permeability, and thickness.

Schedule: During detailed engineering and with hazardous waste permit applications.

21. DOE/ICRC would provide additional details in the SPCC plan.

Schedule: With NPDES permit application.

22. DOE/ICRC would advise EPA of any decision regarding the stabilization of waste brines.

Schedule: One month after completion of study or with RCRA permit application, whichever is sooner.

23. DOE/ICRC would provide the results of any groundwater modeling.

Schedule: One month after completion of study or with hazardous waste permit applications, whichever is sooner. Preliminary screening with a rough model has been carried out and is described in Appendix R.

24. DOE/ICRC would indicate corrective actions that might be taken in the event that groundwater does become contaminated.

Schedule: Completed. The groundwater contamination contingency plan is presented in Appendix HH.

25. DOE/ICRC will advise EPA, after operation of the landfills begins, if the gasifier slag/ash is concluded to no longer require treatment as a hazardous waste.

Schedule: The monitoring results for the gasifier wastes will be provided with other monitoring data on a regular basis.

E. Issue. Erosion and sedimentation control plan.

Status. A preliminary erosion control plan is presented in Appendix GG of this FEIS. The construction manager contractor will modify and finalize the plan as necessary prior to initiation of on-site construction activities.

F. Issue. Socioeconomic — transportation impacts.

Status. DOE has funded additional socioeconomic studies performed by Dames & Moore under contract to the ICRC and by the Green River Area Development District. Results of these studies have been included in Sects. 3.2.4 and 4.2.4 of this FEIS. Proposed socioeconomic mitigation actions, including a mitigation plan for transportation problems during construction, are provided in Sect. 4.6.

G. Issue. Monitoring.

Status. Section 4.5 of this FEIS presents the proposed monitoring program for this project. "The Preconstruction Environmental Monitoring Plan," most of which is currently under way, is summarized in Sect. 4.5 and was transmitted to EPA, KDNREP, and others for review and comment on April 14, 1981. A general description of the monitoring program to be conducted during the construction and operation phases is also provided in Sect. 4.5. The construction-phase monitoring plan will be prepared and submitted for EPA and KDNREP review prior to initiation of construction. The operations phase monitoring plan will be prepared and submitted for EPA and KDNREP review in June 1982. Specific items identified by EPA for inclusion in the plan are presented below:

1. The plan for monitoring sulfur recovery plant tail-gas — including extended-term monitoring and more frequent monitoring during the first year or two of plant operation — should be provided.
2. A monitoring plan should be prepared, indicating how controlled combustor/flare performance will be determined during the first year or two of plant operation, and routinely thereafter.
3. The monitoring plan should include coker/calcliner off-gases monitoring and monitoring of the wastewater treatment plant.

Appendix FF

IMPLICATIONS OF THE TOXIC SUBSTANCES CONTROL ACT FOR
SOLVENT REFINED COAL PROCESSES

Appendix FF

IMPLICATIONS OF THE TOXIC SUBSTANCES CONTROL ACT FOR SOLVENT REFINED COAL PROCESSES

FF.1 TOXIC SUBSTANCES CONTROL ACT

FF.1.1 Description

The Toxic Substances Control Act (TSCA), enacted in 1976, protects human health and the environment by authorizing the Administrator of EPA to obtain information from industry on the production, use, disposal, and health effects of chemical substances and mixtures.¹ Under TSCA, EPA's authority centers around four activities:

1. collecting basic information on chemical substances from manufacturers and processors, including importers;
2. identifying potentially harmful substances and requiring that industry test them for adverse health and environmental effects;
3. reviewing all new chemicals for potential health and environmental risks before they are manufactured for chemical use; and
4. controlling unreasonable risks stemming from the manufacturing, processing, distribution, use, or disposal of a chemical substance.¹

The law divides chemicals into "existing" chemicals and "new" chemicals. "Existing" chemicals are those listed in the Chemical Substances Inventory. This inventory is not a list of hazardous or toxic chemicals; rather, it is a list of all chemicals that were manufactured, imported, or processed for a commercial purpose between January 1, 1975, and June 1, 1979. EPA has also collected information on these chemicals to determine which chemicals pose an unreasonable risk to human health or the environment. Testing of these chemicals may be required to further define their persistence, environmental fate, ecological effects, and such health effects as carcinogenicity, mutagenicity, teratogenicity, or behavioral toxicity.

TSCA established an Interagency Testing Committee (ITC) to identify and recommend to EPA chemicals for priority testing. Within 12 months of an ITC recommendation, EPA must either initiate rulemaking proceedings to require testing or publish reasons for not doing so.

A "new" chemical substance is a chemical not listed in the inventory or an existing chemical for which a significant new use has been proposed. These chemicals are subject to a 90-day premanufacturing notification review by EPA. Manufacturers and importers of "new" chemicals must submit a premanufacturing notice (PMN) to EPA. The PMN requires the following information:

- common or trade name,
- chemical identity and molecular structure or the general composition of a mixture of variable composition,
- estimated production amounts,
- proposed use categories,
- methods of disposal,
- workplace exposure levels,

- description of by-products, impurities, and other related products, and
- all test data on health and environmental effects of the substance (see Table Z.9 in Appendix Z).

During the review period, if EPA determines that a substance may present an unreasonable risk (or that the substance will be produced in substantial quantities and may lead to significant human or environmental exposure), EPA may require additional data to determine what risks are presented.

After review of the PMN and all available data, EPA may prohibit or limit the manufacture, processing, distribution, use, or disposal of a chemical or mixture. Action under TSCA can range from a complete ban to a simple labeling requirement. If the manufacturer objects to the order, EPA can go to a Federal District Court and seek an injunction.

FF.1.2 General DOE compliance

DOE projects that result in the production of a new chemical or mixture are impacted by the requirement for submitting a PMN. The PMN must undergo a 90-day review by EPA. If EPA requires additional testing or studies, DOE will have to perform the additional studies. In addition, DOE will have to comply with testing standards developed by EPA.

TSCA will also impact DOE projects that might require the use of chemicals or mixtures that are or will be limited by TSCA. If a chemical essential for a DOE project is limited by EPA, the size or productivity of the project may be limited.

FF.2 REGULATIONS IMPLEMENTING TSCA

Almost all the regulations (40 CFR Part 720) implementing TSCA are in draft form at this time.² EPA estimates that most of its draft rules and guidelines will be finalized soon.² Because TSCA is so complex, there are numerous draft regulations published in the *Federal Register* (FR). The regulations may be divided into the following categories:

- premanufacturing notification,
- information gathering/inventory reporting, and
- testing.

FF.2.1 Premanufacture notification

The PMN program officially began July 1, 1979. Proposed rules and notice forms for the PMN program were published in the January 10, 1979 FR. A statement of interim policy on PMN requirements and review procedures was published in the May 15, 1979 FR. Revised PMN forms were repropounded on October 16, 1979 (45-day comment period). Industries submitting PMN forms at this time should use the form published in the October 16, 1979 FR.

FF.2.2 Information gathering/inventory reporting

Regulations governing the reporting and compilation of chemical substances, as required by TSCA Section 8(b), were promulgated in December 1977. The official publication date for the initial chemical inventory was June 1, 1979. A special 210-day reporting period has been added to the June 1 deadline to permit processors to review and add to the inventory.

EPA is developing a comprehensive plan for reporting and recordkeeping on chemical production, use, by-products, exposure, and disposal. These rules must first be coordinated with other EPA rules to avoid duplicating requirements; they are expected to be published in draft form.

In July 1978, a security procedures manual was published so that contractors and federal agencies could submit confidential information to EPA.

FF.2.3 Testing

Testing standards will be directed at specific characteristics and effects including oncogenicity, teratogenicity, mutagenicity, as well as environmental fate, persistence, and ecological effects. EPA plans to make these consistent with standards being established under its pesticide program.

The first standards, oncogenicity and other chronic effects, were proposed in the May 9, 1979 FR. Additional standards for acute and subchronic toxicity, mutagenicity, teratogenicity, reproductive effects, and metabolism studies were proposed on July 26, 1979. Additional health effects testing standards, as well as the first environmental testing standards, were to be proposed in early 1980.

FF.2.4 Summary

During 1980, all aspects of the TSCA program were to be in operation, although not at full capacity.

Initially, more emphasis will be placed on obtaining and analyzing information than on writing specific regulations. Activities in 1980 concentrated on:

- premanufacturing notification system,
- developing testing standards and rules,
- making information systems operational,
- conducting risk assessments, and
- promulgating reporting and recordkeeping requirements.

FF.3 THE SRC PROCESS AND DOE TOXICITY STUDIES

FF.3.1 SRC processes (SRC-I and SRC-II)

Solvent refined coal (SRC) processes convert high sulfur and ash coal into cleaner burning gaseous, liquid, and/or solid fuels by noncatalytic hydrogenation. Hydrogenation involves direct conversion of coal to improved fuels through the addition of hydrogen to coal at elevated temperatures and pressures, with the amount of hydrogen determining the final form of the fuel — liquid (SRC-II) or solid (SRC-I). SRC-II utilizes about twice the amount of hydrogen as the SRC-I process.

SRC-I primarily produces a solid, coal-like product of less than 1% sulfur and 0.2% ash. SRC-II primarily produces a low-sulfur (0.2-0.5% by weight) fuel oil and naphtha. Both SRC-I and SRC-II also produce significant quantities of gaseous hydrocarbons that are further processed to synthetic natural gas (SNG) and liquefied petroleum gas (LPG) products.

Except for the last stages in production, the processes are essentially the same. SRC-I relies on solvent recovery and solidification functions to produce a solid fuel; SRC-II uses a fractionation function to produce a liquid fuel. Because the processes are very similar, most of the potential toxicants and carcinogens should be common.³ The SRC-II products (light, middle, and heavy distillate) are similar to the SRC-I products of light oil, wash solvent, and process solvent.⁴

At present, there is a lack of definitive data on the chemical constituents in synfuel products, including SRC. Several known or suspected carcinogens are present in products, by-products, and waste streams of synthetic fuel conversion processes. These include polynuclear aromatic hydrocarbons (PAH), naphthalenes, aromatic amines, and inorganic trace elements (selenium, boron, cadmium, lead, and antimony).¹

FF.3.2 DOE toxic substances research on SRC materials

Pacific Northwest Laboratory published a report entitled *Biomedical Studies on Solvent Refined Coal (SRC-II) Liquefaction Materials: A Status Report*.⁴ This report, published in October 1979, is the most complete and reliable DOE source of information on toxicity of SRC products.

Studies on toxicity of the SRC-II products — heavy distillate (HD), middle distillate (MD), and light distillate (LD) — indicate that HD is the most toxic. Of the SRC-I products, the process solvent appears to be the most toxic. In general, results of all tests show SRC products to have variable toxicity. The results are summarized below.

1. Microbial mutagenicity appears to be caused primarily by aromatic amines. HD is mutagenically active; LD is not mutagenic.
2. Toxicity studies on monkey kidney cells indicate that both the HD of SRC-II and the process solvent of SRC-I are highly toxic and are similar in degree of toxicity.
3. Mice were used for studies of epidermal carcinogenesis. HD and LD SRC-II products were compared. High doses [approximately 20 mg per application (3 times per week)] and medium doses (2 mg per application) resulted in 100% of the mice treated with HD developing tumors within several months. A light dose of HD (0.2 mg per application) resulted in tumor growth in 6 of 48 mice. High and medium doses of LD resulted in tumors in 1 of 44 and 1 of 46 mice respectively. Light doses of LD did not cause tumor growth in any of 41 mice after 465 days. These dose studies are continuing. The majority of tumors were malignant.
4. Initial oral toxicity studies on rats indicate that SRC-I wash solvent is highly toxic, with an LD₅₀* of 0.57. The other fractions of SRC-I and SRC-II had LD₅₀ values from 2.30-3.75. (To compare, LD₅₀ of crude petroleum is >12.)
5. Developmental toxicity studies indicate that risk for a fetus is only slightly greater than for the mother.

Studies on the ecology/transport effects of SRC materials indicate that SRC water soluble components are 450 times more toxic than similar components in No. 6 fuel oil; phenols are the major toxic compounds of untreated wastewater; ammonia is the major toxic compound in treated wastewater.⁵

FF.3.3 DOE toxicity studies planned

The following are planned to more fully define the toxic nature of SRC materials:

1. continue generation of analytical characterization data for SRC liquefaction;
2. continue comparisons of environmental effects of liquid effluents and solid wastes;
3. continue biomedical evaluation program;
4. provide information on chemical methods for eliminating the mutagenic hydrocarbons in SRC product;
5. validate carcinogenic activity of aromatic amines;
6. evaluate effectiveness of serum enzyme tests for early detection of health effects in workers; and
7. continue inhalation studies on animals to determine adverse health effects in worker populations.

* LD₅₀ is defined as the dose in grams per kilograms of body weight required to kill 50% of the animals.

The studies performed thus far by DOE are essential for making the risk assessment required by TSCA. Because EPA has not yet published standards and rules for testing, the studies proposed by DOE should be initiated or continued. At the time EPA publishes standards, these standards should be examined in light of the studies already done or anticipated by DOE.

FF.4 SPECIFIC REQUIREMENTS FOR SRC UNDER TSCA

EPA's Office of Toxic Substances (OTS) has set up the Synfuels/Toxic Work Group, a committee comprised of OTS representatives and technical experts on synthetic fuel processes. This committee provides a forum for the exchange and review of information during the premanufacture notice development process and will serve as a source of guidance for the synfuel industry. The intent is to minimize the potential for unnecessary regulatory constraints and delays.

EPA has determined that synthetic fuels are "new" chemical substances and are subject to the provisions of Section 5 of TSCA. The Synfuels/Toxic Work Group will work with synfuel developers in developing their premanufacture notices. This interaction should eliminate the uncertainty TSCA imposes on the synfuel developer.

TSCA also regulates waste products, by-products, and disposal of toxic substances. EPA realizes that the potential for overlap and conflict with other agency regulations, particularly RCRA, NPDES, and Clean Air, is great. The committee discussed previously may also provide EPA with guidance on how TSCA should regulate synfuels throughout the life-cycle of the materials.

If a PMN is required, the SRC product may be classed as a mixture of variable composition so that specific identification and analysis of each chemical component may not be necessary. DOE would be required to submit results of all tests so that EPA could make a reasonable risk assessment. It is suggested that before DOE submits a PMN, the project officer should write EPA a letter setting forth the known facts of the SRC-I process and presenting some analysis of tests of the toxic nature of the product. EPA personnel could then sit down with the project officer and a member of NAD to discuss specific requirements of the PMN.

FF.5 CONCLUSIONS

1. SRC liquid products are generally toxic; they are definitely more toxic than conventional fuel oils as tested in microbial and cellular systems.
2. Specific TSCA requirements for SRC liquid remain unknown. EPA intends to resolve the issue of how synfuels should be controlled under TSCA.
3. Studies concerning the toxic nature of SRC materials should continue so that a reasonable risk assessment may be made if a PMN is required.
4. No permit is required; however, after review of a PMN, EPA may limit production or require labeling of the materials. Review should be limited to 90 days.
5. The PMN review must be completed before operation begins.
6. Prior to submitting a PMN, DOE should send a letter describing the project and its toxic nature to EPA. Arrangements should be made to confer with EPA so that potential problems may be identified. In addition, a conference early in the planning stages of a project will enable DOE and EPA to identify the types of toxicity studies that should be initiated, and EPA may be able to assess the need for limiting or controlling the material. In addition, a date for submittal of a PMN may be established at this time.
7. Regarding the SRC-I Environmental Compliance Schedule, a time line reflecting compliance with TSCA need not be added at this time because the relationship of TSCA regulations to alternate fuels in general has not yet been defined by EPA. Because EPA can extend its review period by 90 days, a PMN should be submitted at least 6 months before operation begins. EPA regulations do state that early submission of a PMN is acceptable if accompanied by a statement of the fact that commercial processing of the material is a certainty.

REFERENCES FOR APPENDIX FF

1. EPA, *Toxic Substances Control Act: An Overview of Its Authorities and Major Activities*, September 1979.
2. EPA, *Implementing the Toxic Substances Control Act: Where We Stand*, Nov. 1, 1979.
3. J. R. Simons, The Aerospace Corporation, *Coal Conversion and Toxic Substances*, November 1978.
4. Pacific Northwest Laboratory, *Biomedical Studies on Solvent Refined Coal (SRC-II) Liquefaction Materials: A Status Report*, October 1979.
5. *OHER Program Plan for 1980* (unpublished).

Appendix GG

PRELIMINARY EROSION CONTROL PLAN

(Adapted from Rust Engineering study, No. 21-1997F)

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Appendix GG

PRELIMINARY EROSION CONTROL PLAN

GG.1 INTRODUCTION

GG.1.1 Purpose

The purpose of an erosion control plan in land-disturbing activities is to provide suitable sites for buildings and roadways, improve surface drainage, and control soil erosion and sediment deposition. This plan will specify the requirements and procedures during the construction period that will be used to minimize soil erosion and to prevent sedimentation.

GG.1.2 Planning criteria

The planning criteria for an erosion control plan includes the following:

1. construction of sedimentation basins,
2. construction of storm drainage channels and velocity protection,
3. temporary sediment barriers,
4. removal and storage of topsoil,
5. temporary protection on areas that need immediate vegetation, and
6. permanent vegetation on disturbed areas.

The disturbed areas and the duration of exposure to erosion elements will be minimized. Clearing of natural vegetation will be limited to those areas of the site to be developed at a given time. Natural vegetation will be retained, protected, and supplemented with the scheduling of construction to limit the duration of soil exposure. Any major land clearing and grading will be scheduled, where permitted, during seasons of low potential runoff.

The stabilization of disturbed areas will be effected as soon as possible after the land is disturbed. This stabilization will be accomplished by permanent structures, temporary or permanent vegetation, mulch, or a combination of any of these measures. Temporary vegetation will be utilized (1) in disturbed areas where permanent vegetation is not practical to bring an area to final grade and finish so that permanent seeding and protection work can be performed without subsequent serious disturbance by additional grading, (2) when soil erosion occurs or is considered to be a potential problem on construction areas that are temporarily suspended, or (3) when an immediate cover is required to minimize erosion, siltation, or pollution of any area. Permanent vegetation will be utilized on all disturbed areas as soon as final grading operations are complete.

Control of runoff will be accomplished by construction of storm drains and stable waterways, such as unpaved and paved ditches and pipes; by temporary diversion; or by other types of structures that will prevent runoff in areas of erodible soils or decrease runoff velocities. The installation of sedimentation basins will be constructed to prevent flooding, siltation, and damage to downstream facilities. These facilities will be operational as soon as possible after the start of construction.

Sediment will be controlled by providing sediment basins, temporary silt fences and sediment barriers, and related structures. These sediment-retention structures will be planned to retain sediment in conjunction with other erosion control methods mentioned previously.

GG.2 SEDIMENTATION BASINS

GG.2.1 Purpose

Sedimentation basins will be installed to prevent sediment from leaving the site or entering natural or constructed drainageways or storm drainage systems prior to permanent stabilization of the disturbed area. The basins will also permit the use of more economical channel improvement or stabilizing structures in the channel downstream and reduce environmental hazards and pollution. The sedimentation basins will be utilized only during the construction phase.

GG.2.2 Design criteria

The storage volume will be based on a 10-year, 24-h frequency rainfall. The peak release rate will not exceed the peak storm-water runoff rate from the area in its natural undeveloped state for a 10-year storm frequency. An emergency spillway will be provided and designed to safely convey runoff from storms of greater than 10-year frequency without damaging the structure. Any structure that will have a water storage of 0.3 m (1 ft) deep or greater will be totally surrounded by a 1.8-m (6-ft)-high, chain link security fence. The basin will be designed for removal of oil and will include such devices as fitted oil brooms and inverted pipe dams or their equivalent.

GG.2.3 General requirements

The temporary sedimentation basin will be located so that it will not interfere with construction operations. The structure will be constructed on natural ground surface, excavated surface, machine-compacted fill, or on all of the previously mentioned areas. Any compacted fill slopes will have 3:1 minimum side slopes. All erodible areas will receive temporary seeding where vegetative cover is impossible or impractical to establish.

GG.3 STORM DRAINAGE CHANNELS

GG.3.1 Purpose

Storm drainage channels will be constructed to be nonerosive and to provide adequate capacities of projected peak flows and velocities.

GG.3.2 Design criteria

Storm drainage channels will be designed with a trapezoidal cross section and a minimum 2-ft flat bottom. The grade, capacities, and velocities will be determined by Manning's formula for open channel flow. The n values for use in this formula shall be estimated by using currently accepted guides, along with knowledge and experience regarding the conditions. The capacities will be based on a 25-year, 1-h frequency rainfall with a ϕ value of 0.5 as established in the "Mechanical Design Criteria" provided by the International Coal Refining Company. The maximum allowable velocity for unpaved channels is 1.5 m/s (5 ft/s). Unless the channels are paved, all of them will be at a slope of 3:1.

Where channel velocities exceed safe velocities for vegetated lining because of increased grade or a change in channel cross section or where durability of vegetative lining is adversely affected by seasonal changes, channel linings of rock, concrete, or other durable material will be used. Channels may be stabilized by the placement of rock riprap lining or concrete lining. Channel linings will also be utilized at channel intersections where two or more channels combine to form one flow.

GG.3.3 General requirements

Weather permitting, all channels will be seeded, fertilized, or mulched immediately after construction. If weather conditions cause a delay in establishing vegetation, the area will be mulched. Construction operations will be carried out in such a manner that erosion and air and water pollution will be minimized. There will be compliance with applicable laws concerning pollution abatement. Seeding, fertilizing, and mulching will conform to the standard for vegetative cover.

GG.4 STORM DRAIN OUTLET PROTECTION

GG.4.1 Purpose

Storm drain outlet protection will be provided at any culvert drainage pipe that requires a reduction in the velocity of flow to prevent erosion and scouring of downstream facilities during projected peak flow discharges. The purpose of outlet protection is to convert pipe flow to channel flow and reduce the velocity of the water consistent with the strength of the channel lining in order to convey the flow of water to a stable existing downstream channel without causing erosion.

GG.4.2 Design criteria

Each pipe outlet shall have a structurally lined apron where the water can change from pipe flow to channel flow. The structurally lined apron will meet the following criteria:

1. The bottom grade will be 0.0%.
2. The side slopes will be 3:1 or flatter.
3. The top of the sidewall will extend at least one-foot above maximum tailwater but no lower than two-thirds of the vertical conduit dimension above the conduit culvert.
4. The invert elevation at the end will be equal to, or lower than, the lowest elevation on the cross section immediately downstream from the end of the apron.
5. The size of riprap and length of apron will be determined by acceptable methods.

Riprap is a layer of loose rock or aggregate placed over an erodible soil surface. The purpose of riprap is to protect the soil surface from the erosive forces of water. Riprap is used where the soil conditions, water turbulence and velocity, expected vegetative cover, and groundwater conditions are such that the soil may erode under the design flow conditions. The minimum design discharge for channels and ditches will be the peak discharge from the design storm. The toe of the riprap will be entrenched in stable channel bottoms for a depth of 0.5 to 1 m (1.5 to 3 ft), depending on the size of the riprap. If the channel bottom is not stable, the design will incorporate other requirements needed to stabilize the riprap toe. The channel side slope will be no steeper than 1.5:1. A blanket of filter material will be placed underneath the riprap, except under the following conditions:

1. The soil material in the bank has a P.I. of at least 10 or is a sand-gravel mixture.
2. The stream transports a full load of sediment at flood stage as evidenced by sand deposits on channel banks.

The riprap will extend up the bank to an elevation where vegetation will provide adequate protection. Riprap will be reasonably well graded within the following limits:

Velocity	Maximum-minimum stone sizes
up to 1.8 m/s (6 ft/s)	4.5-22.7 kg (10-50 lb)
1.8-2.4 m (6-8 ft/s)	9.1-45.4 kg (20-100 lb)
2.4-3 m (8-10 ft/s)	11.3-113 kg (25-250 lb)

Material will be hard, durable rock; concrete rubble; or similar substance weighing at least 2400 kg/m^3 (150 lb/ft^3). Filter material can be either a mixture of hard, durable sand and gravel or a single layer of plastic filter cloth manufactured for that express purpose. Maximum gravel size will be 3.8 cm, 7.6 cm, and 11.4 cm (1.5 in., 3 in., and 4.5 in.), respectively, for each of the above riprap sizes. The plastic filter cloth will be woven of polypropylene monofilament yarns.

GG.4.3 General requirements

The channel side slope and the toe excavation will be prepared to the required lines and grades. The subgrade for the riprap or filter will be prepared to the required lines and grades. Any fill required in the subgrade will be compacted to a density that is approximately that of the surrounding undisturbed material. The plastic filter cloth will be protected from punching, cutting, or tearing. Any damage other than an occasional small hole will be repaired by placing another piece of cloth over the damaged part or by completely replacing the cloth. Whether for repairs or joining two pieces of cloth, all overlaps will be a minimum of 0.3 m (1 ft). The rock or gravel will conform to the grading limits when installed, respectively, in the riprap or filter.

The stone for the filter and riprap may be placed by equipment. Both the filter and riprap will each be constructed to the full course thickness in one operation in a manner that will avoid displacement of the underlying material. The stone for filter and riprap will be delivered and placed in a manner that will ensure that the filter and riprap each will be reasonably homogenous with the smaller stones and spalls filling the voids between the larger stones. Riprap will be placed in a manner that will prevent damage to the filter blanket. Hand placing will be required to the extent necessary to prevent damage to the permanent work.

GG.5 TEMPORARY SEDIMENT BARRIERS

GG.5.1 Purpose

Temporary sediment barriers are used to prevent sediment from leaving the site and entering natural drainageways or storm drainage systems by slowing storm-water runoff and causing the deposition of sediment at the structure.

GG.5.2 General requirements

GG.5.2.1 Temporary silt fences

A temporary silt fence is constructed of woven wire fencing with commercial filter fabric securely attached to the upper face. The bottom edge of the filter fabric should be installed in a trench 30 to 46 cm (12 to 18 in.) in depth. Fence posts of adequate strength and spacing will be installed to ensure stability under maximum loading conditions. Frequent inspections will be required to ensure prompt repair or replacement. Trapped sediment will be cleaned out and disposed of when required.

GG.5.2.2 Temporary straw bales

A straw bale dike is a temporary barrier constructed out of straw bales which is installed across or at the toe of a slope. These straw bales intercept and detain small amounts of sediment from unprotected areas. Locations for these barriers are at all storm drain inlets, across minor swales and ditches, and at other temporary structures where structures are temporary. The bales are placed in a single row, lengthwise, on the contour and embedded in the soil to a depth of 7.6 cm (3 in.). Bales must be securely anchored in place by stakes or bars driven through the bales or by other acceptable means to prevent displacement. Inspections will be frequent, and repair or replacement will be made promptly as required.

GG.6 DISTURBED AREA STABILIZATION

GG.6.1 Purpose

Disturbed area stabilization involves the establishing of vegetative cover on disturbed areas. Temporary vegetative cover provides fast-growing seedlings on disturbed areas. Disturbed area stabilization reduces erosion, sediment, and runoff damages to downstream resources and improves aesthetics, safety on road rights-of-way, and wildlife habitat.

GG.6.2 General requirementsGG.6.2.1 Disturbed area stabilization with temporary vegetation

Temporary vegetation is utilized where permanent vegetation is not practical or final grade lines have not been established. This condition is applicable where water runoff is controlled by ditches, dikes, and diversions. Areas to be temporarily seeded will require the preparation of a seedbed only when the surface of the soil is hard and crusty. The seedbed will not be required when the soil surface is in an acceptable condition from the normal grading operations. The disturbed area will first receive an application of fertilizer. The method of application can be either conventional or hydraulic. The fertilizer should be a 10-10-10 analysis and applied at a rate of 5.4 kg/93 m² (12 lb/1000 ft²). Only rye grain or annual ryegrass seed will be used. Rye grain will be sowed at the approximate rate of 11.3 kg/93 m² (25 lb/1000 ft²) during the period of September 1 through November 30. Annual ryegrass will be sowed at the approximate rate of 0.4 kg/93 m² (0.8 lb/1000 ft²) during the period of March 1 through August 31.

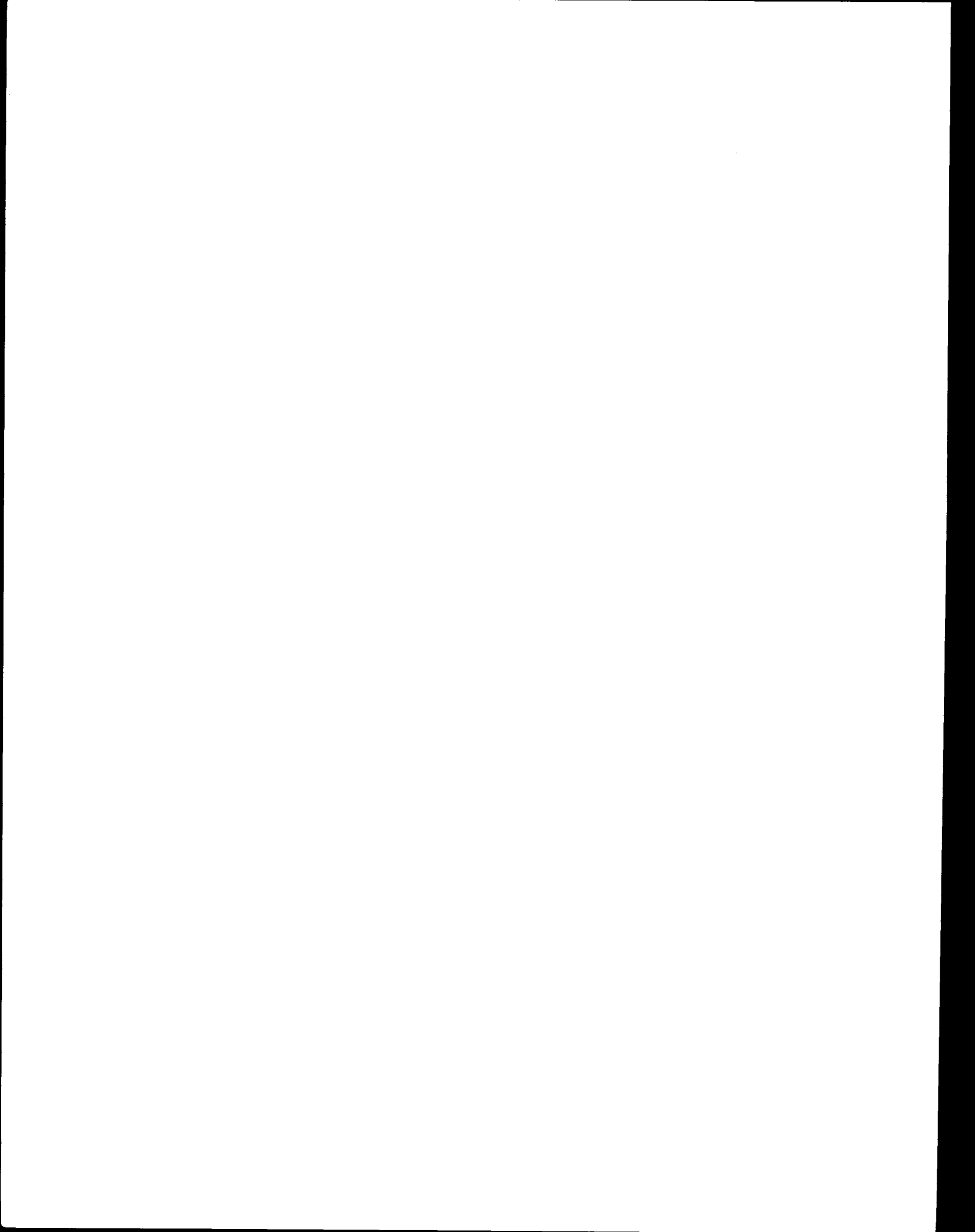
All seeded areas will be promptly protected with a straw mulch or an erosion control fabric. The straw mulch will be uniformly applied to the seeded areas at the approximate rate of 2 t/acre and tacked down with approximately 306.5 liters/ha (200 gal/acre) of bituminous material. The erosion control fabric will be installed according to the manufacturer's recommendations. Areas requiring temporary erosion control measures during the period of December through February, when seeding is not permitted, will receive only an application of straw mulch held in place with bituminous material. The approximate rate of application of the straw mulch will be 1.2 t/ha (3 t/acre), and the approximate rate of application of the bituminous material will be 460 liters/ha (300 gal/acre) for this type of protection.

GG.6.2.2 Disturbed area stabilization with permanent vegetation

All areas disturbed by construction operations will be promptly protected with permanent vegetation. The disturbed areas will receive a 10-cm (4-in.) layer of topsoil after grading operations are complete. If hydraulic seeding and fertilizing equipment is used, then seedbed preparation will be required. All areas with 10-cm (4-in.) topsoil will receive a fertilizer (15-15-15) analysis that will be spread at a rate of 119 kg/ha (650 lb/acre). Also, agricultural limestone will be spread at a rate of 367 kg/ha (2000 lb/acre). After seedbed preparation and fertilization operations are complete, these areas will be seeded. Seed will be sowed only at specified times of the year. Normal application dates for seed are between March 1 and May 31, and between August 10 and September 30. After seeding operations are complete, the areas will be mulched. Mulching protection will be either a bituminous-treated mulch or an erosion-control-mulching fabric. The bituminous-treated mulch will uniformly spread from the jet nozzles at the discharge spout of the equipment that will blow or eject the mulch material uniformly over the seeded area at the rate of 383 liters/ha (250 gal/acre). The erosion-control-mulching fabric will be applied in accordance to the manufacturer's recommendations.

Appendix HH

GROUNDWATER CONTAMINATION CONTINGENCY PLAN



Appendix HH

GROUNDWATER CONTAMINATION CONTINGENCY PLAN

HH.1 INTRODUCTION

This Groundwater Contingency Plan is for International Coal Refining Company's (ICRC) solvent refined coal demonstration plant (SRC-I) located at Newman, Ky. The plant site consists of 600 ha (1484 acres) on the Green River floodplain. The SRC-I process converts high-sulfur coal into a low-sulfur, low-ash solid fuel product, secondary gaseous and liquid products, and by-product elemental sulfur. A preconstruction groundwater monitoring plan has been formulated to detect contaminants or pollutants that may have migrated into aquifers or saturated zones before initiation of active coal processing.

This plan is written in accordance with the provisions of 40 CFR 265.93, which mandate that the owner or operator must prepare an outline of a groundwater assessment program.

This Groundwater Contingency Plan does not address spills that would be covered by a Spill Prevention Control and Countermeasures (SPCC) Plan.

HH.1.1 Purpose of the plan

The objective of this Groundwater Contingency Plan is to provide information and guidance for remedial action in the event that contaminants or pollutants are detected in either saturated or unsaturated zones beneath the plant property. Unsaturated zone monitoring is designed to detect local soil contamination for each process, handling, or storage location. Saturated zone or aquifer monitoring is designed to detect contamination from all site holding ponds and landfills. Lysimeters will be used for unsaturated zone monitoring; wells will be used for saturated zone monitoring.

HH.1.2 Groundwater contingency plan management

The Environmental Manager is responsible for interpreting unsaturated and saturated zone monitoring data and for initiating corrective or mitigation measures in accordance with the provisions of this plan. He will consult with appropriate plant technical and management personnel before initiating these actions.

HH.2 MONITORING PLAN

It is important that background monitoring data be recorded before introduction of any process materials on the demonstration site. Background monitoring data will include analyses of samples taken from saturated and unsaturated zones beneath the site over the longest possible period. Monitoring wells will be placed in locations dictated by site configuration, unit process locations, and aquifer water movement. Lysimeters are placed as near as practical to the location where unsaturated zone contamination may occur.

Table HH.1 shows the monitoring program for the unsaturated zone. Table HH.2 shows the monitoring program for the saturated zone. Some of the preconstruction monitoring wells may be properly located for use in the Groundwater Contingency Monitoring Program, thus reducing the number of new wells required.

**Table HH.1. Groundwater contingency plan monitoring program
for the unsaturated zone**

Lysimeter locations ^a	Lysimeter placement	Sample type and number	Frequency	Parameters
Chromate salt storage and handling area	Shallow, vertical, in local area	One grab sample	Quarterly	Total chromium
Coal storage and handling area	Shallow, vertical, in local area	One grab sample	Quarterly	<i>b</i>
Solid waste storage and handling area	Shallow, vertical, in local area	One grab sample	Quarterly	<i>b</i>
Process areas	Shallow, vertical, in local area	One grab sample	Quarterly	<i>b</i>
Product storage and handling areas	Shallow, vertical, in local area	One grab sample	Quarterly	<i>b</i>
Ash pond and equalization pond	Deep, at angle, around perimeter, under ponds	One grab sample	Quarterly	<i>b</i>
Metal sludge waste landfill and ash landfill	Deep, at angle, around perimeter, under landfills	One grab sample	Quarterly	<i>b</i>

^aSome lysimeter locations may be combined if plant layout precludes differentiating between sources.

^bAppropriate priority (toxic) pollutants from 40 CFR 401.15 and appropriate conventional pollutants from 40 CFR 401.16.

**Table HH.2. Groundwater contingency plan monitoring program
for the saturated zone**

Location	Well placement	Sample type and number	Frequency	Parameters
Equalization pond	<i>a</i>	One grab	Monthly	<i>b</i>
Ash pond	<i>a</i>	One grab	Monthly	<i>b</i>
Metal sludge waste landfill	<i>a</i>	One grab	Monthly	<i>b</i>

^aOne upgradient of groundwater flow and three downgradient in accordance with 40 CFR 265.91.

^bPriority (toxic) pollutants from 40 CFR 401.15 and conventional pollutants from 40 CFR 401.16.

HH.3 GROUNDWATER CONTAMINATION CONTROL

Monitoring well and lysimeter water quality samples will be taken monthly as soon as possible after construction of landfills, holding ponds, and storage and process facilities. Contamination determination and reporting will be in accordance with the provisions of 40 CFR 265.93 and 40 CFR 265.94 respectively. This procedure includes use of the Student's t-test at the 0.01 level of significance to determine variance from background data. If parameters show increases, additional samples will be taken to verify contamination. Reporting procedures include notification of the U.S. Environmental Protection Agency (EPA) Regional Administrator within 7 d after contamination verification, submission of the Groundwater Quality Assessment Program within 15 d, and submission of the report within 30 more d. If contamination is found in any unsaturated or saturated zone being monitored, remedial or mitigation measures should be commenced immediately.

HH.4 REMEDIAL MEASURES

HH.4.1 Process, storage, and handling areas

Contamination of the soils beneath any one of the following areas would be detected by analyses of shallow lysimeter samples located in that area:

1. chromate salt storage and handling area,
2. coal waste storage and handling area,
3. solid waste storage and handling area,
4. process areas, and
5. product storage and handling areas.

The first steps to be taken if contamination is confirmed in any of these areas are to remove all visually identifiable contaminated soil and to dispose of it in an onsite landfill.

Then, shallow borings are taken and retaken from adjacent areas and analyzed for the parameters shown in Table HH.1 until the areal and depth extent of contamination can be determined. Soil from the contaminated area is removed and disposed of in an onsite landfill. Clean soil is placed in the excavated area and compacted to grade.

HH.4.2 Holding pond

The first step to be taken when contamination is found in the saturated or unsaturated zones beneath a holding pond is to construct a new, lined holding pond adjacent to the leaking pond. Then, the old pond is pumped into the new pond.

The old pond can be repaired and reused if the extent of contamination is not too extensive; in this case, the leachate collection system, old lines, and contaminated soil are removed and disposed of in an onsite landfill. A new leachate collection system, liner, lysimeters, and monitoring wells are then installed, and the pond is again ready for use.

If the pond is not to be reused, the old lines, leachate collection system, and contaminated soil are removed and disposed of in an onsite landfill. Then, the old pond is filled and capped with soil removed from the new pond. The cap may consist of either a thick layer of compacted clay or a suitable membrane protected on both sides with layers of soil and sand. The top of the cap is compacted and sloped sufficiently to cause all rainwater to drain off and minimize infiltration. Suitable vegetative cover is then planted to minimize erosion. Isolation from below may be achieved by creating an impermeable barrier in the unsaturated zone below the area of contamination. The technique consists of distributing a liquid into the soil by high-pressure pumping. A common material used for this purpose is sodium silicate catalyzed to produce a water-insoluble reaction product.

If contamination has reached the saturated zone, it may be desirable to determine the extent of the groundwater contamination plume and to institute a special pumping and monitoring program. This is accomplished by boring a series of monitoring indicator wells downgradient from the leaking landfill. After background analyses are obtained, the extent of the contaminated groundwater plume is established by drawing a line on the site plot plan connecting the borings.

Then, pumping and monitoring wells are installed in the contaminated zone between the indicator monitoring wells and the landfill, as close as possible to the landfill. Contaminated water is pumped from the pumping wells, thus drawing in the contaminated groundwater plume. All contaminated water collected is pumped into a process water holding pond for treatment in the industrial wastewater treatment plant. By sampling the groundwater quality in the indicator wells, the location and withdrawal of the contaminated water can be measured.

HH.4.3 Landfills

When unsaturated or saturated zone contamination is determined, the first steps to be taken are to discontinue burial in the disposal trench and to isolate the defective portion of the trench from above and below. Isolation from above is accomplished by concurrent construction of a barrier wall and cap around and over the deposited waste. The barrier wall will consist of compacted clay down to and interlocking with the uppermost trench line. The cover may consist of either a thick layer of compacted clay or a layer of suitable membrane protected on both sides with layers of soil and sand. The top of the cover will be compacted and will have a slope sufficient to permit drainage of all rainwater and minimize infiltration. Suitable vegetative cover is then planted to prevent erosion.

If contamination has reached the saturated zone, the decontamination procedure described in Sect. HH.4.2 may be followed.