

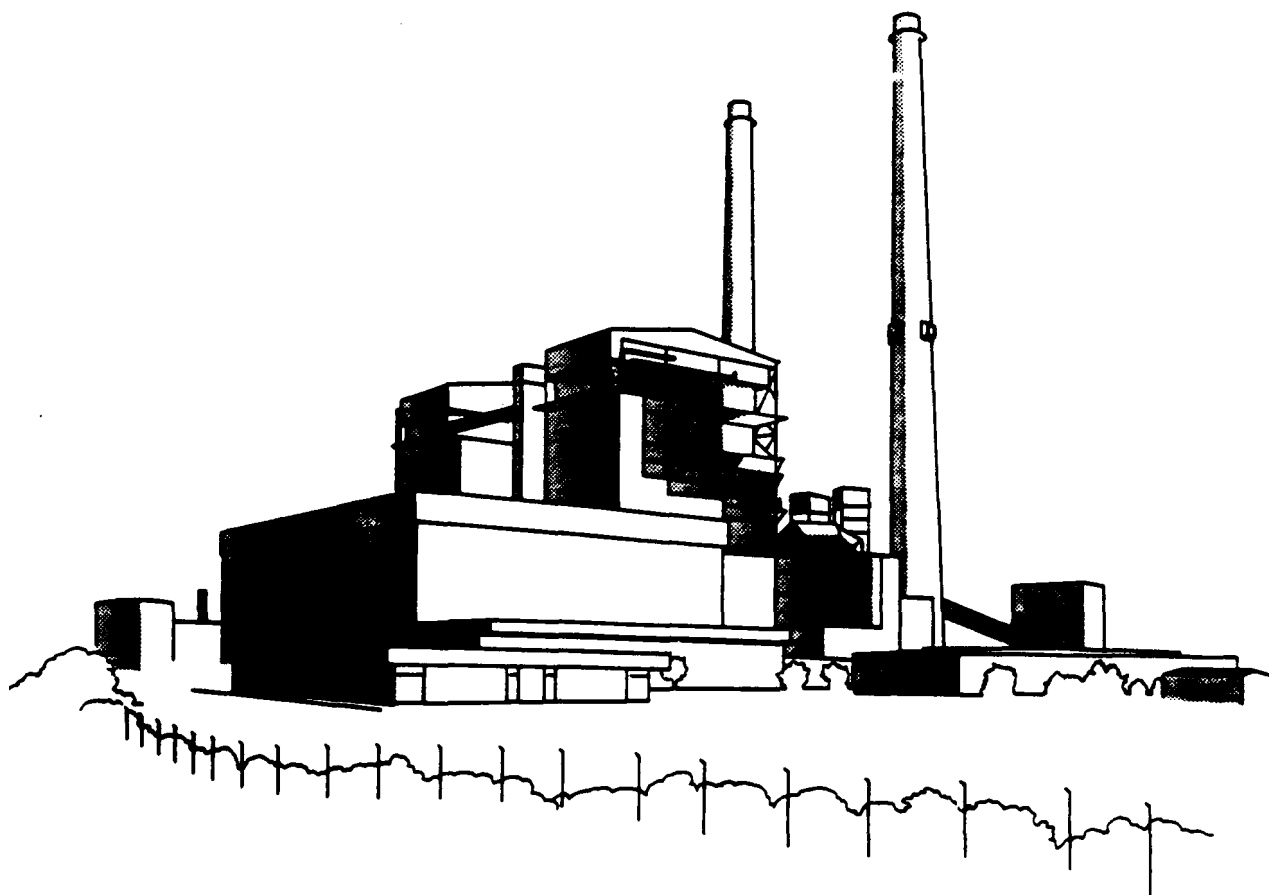
Solid Waste



# Report to Congress

# Appendices

## Wastes from the Combustion of Coal by Electric Utility Power Plants





UNITED STATES ENVIRONMENTAL PROTECTION AGENCY  
WASHINGTON, D C 20460

MAR 8 1988

THE ADMINISTRATOR

Honorable George Bush  
President of the Senate  
Washington, D.C. 20510

Dear Mr. President:

I am pleased to transmit the Report to Congress on Wastes from the Combustion of Coal by Electric Utility Power Plants. The report presents the results of studies carried out pursuant to Section 8002(n) of the Resource Conservation and Recovery Act of 1976 as amended (42 U.S.C. Section 6982(n)).

The report provides a comprehensive assessment of the management of solid wastes generated by the combustion of coal from electric utility power plants. These wastes account for approximately 90 percent of all wastes generated from the combustion of fossil fuels. The principal waste categories covered include fly ash, bottom ash, boiler slag and flue gas emission control waste.

The report and appendices are transmitted in two separate volumes.

Sincerely,

A handwritten signature in dark ink, appearing to read "Lee M. Thomas", written in a cursive style.

Lee M. Thomas

Enclosure



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY  
WASHINGTON, D.C. 20460

MAR 8 1988

THE ADMINISTRATOR

Honorable James C. Wright  
Speaker of the House  
of Representatives  
Washington, D.C. 20515

Dear Mr. Speaker:

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Enclosure

# TABLE OF CONTENTS

	Page
EXECUTIVE SUMMARY . . . . .	ES-1
I. INTRODUCTION . . . . .	1-1
1.1 Legislative History. . . . .	1-1
1.2 Scope and Sources. . . . .	1-7
1.3 Organization . . . . .	1-9
II. OVERVIEW OF THE ELECTRIC UTILITY INDUSTRY . . . . .	2-1
2.1 The Demand for Electricity . . . . .	2-1
2.1.1 Structure of the U.S. Electric Utility Industry . . . . .	2-7
2.1.2 Economic and Environmental Regulation of the Electric Utility Industry . . . . .	2-11
2.2 Importance of Coal to Electric Utilities . . . . .	2-14
2.3 Overview of Coal-Fired Power Plants . . . . .	2-18
2.3.1 Regional Characteristics of Coal-Fired Electric Generating Plants . . . . .	2-18
2.3.2 Electricity Generating Technologies . . . . .	2-21
2.4 Coal Constituents and By-Products . . . . .	2-29
III. WASTES GENERATED FROM COAL-FIRED ELECTRIC UTILITY POWER PLANTS . . . . .	3-1
3.1 Overview of Electric Utility Wastes . . . . .	3-1
3.2 High-Volume Wastes . . . . .	3-3
3.2.1 Ash . . . . .	3-3
3.2.2 FGD Sludge . . . . .	3-21
3.3 Low-Volume Wastes . . . . .	3-41
3.3.1 Boiler Blowdown . . . . .	3-43
3.3.2 Coal Pile Runoff . . . . .	3-45
3.3.3 Cooling Tower Blowdown. . . . .	3-47
3.3.4 Demineralizer Regenerant and Rinses . . . . .	3-50
3.3.5 Metal and Boiler Cleaning Wastes . . . . .	3-52
3.3.6 Pyrites . . . . .	3-57
3.3.7 Sump Effluents . . . . .	3-60
3.4 Summary . . . . .	3-62
IV. COAL COMBUSTION WASTE MANAGEMENT PRACTICES . . . . .	4-1
4.1 State Regulation of Coal Combustion Waste Disposal . . . . .	4-1
4.1.1 State Classification of Coal Combustion Wastes . . . . .	4-2

# TABLE OF CONTENTS (cont'd)

	Page
4.1.2 Requirements for Coal Combustion Waste Disposal . . . . .	4-6
4.1.3 Summary . . . . .	4-9
4.2 Available Waste Management Methods and Current Practices . . . . .	4-10
4.2.1 Land Management of Coal Combustion Wastes . . . . .	4-10
4.2.2 Alternative Waste Management Technologies . . . . .	4-24
4.2.3 Ocean Disposal . . . . .	4-44
4.2.4 Waste Utilization and Recovery of Various Waste By-Products . . . . .	4-45
4.3 Summary . . . . .	4-53
V. POTENTIAL DANGERS TO HUMAN HEALTH AND THE ENVIRONMENT . . . . .	5-1
5.1 RCRA Subtitle C Hazardous Waste Characteristics and Listing Criteria . . . . .	5-2
5.1.1 Corrosivity of Coal Combustion Wastes . . . . .	5-4
5.1.2 Extraction Procedure Toxicity of Coal Combustion Wastes . . . . .	5-5
5.2 Effectiveness of Waste Containment at Utility Disposal Sites . . . . .	5-28
5.2.1 ADL Study of Waste Disposal at Coal-Fired Power Plants . . . . .	5-29
5.2.2 Franklin Associates Survey of State Ground-Water Data . . . . .	5-44
5.2.3 Envirosphere Ground-Water Survey . . . . .	5-48
5.2.4 Summary . . . . .	5-52
5.3 Evidence of Damage . . . . .	5-53
5.3.1 Envirosphere Case Study Analysis . . . . .	5-54
5.3.2 Dames & Moore Study of Environmental Impacts . . . . .	5-56
5.3.3 Case Studies of the Environmental Impact of Coal Combustion By-Product Waste Disposal . . . . .	5-63
5.3.4 Summary . . . . .	5-67
5.4 Factors Affecting Exposure and Risk at Coal Combustion Waste Sites . . . . .	5-68
5.4.1 Environmental Characteristics of Coal Combustion Waste Sites . . . . .	5-69
5.4.2 Population Characteristics of Coal Combustion Waste Disposal Sites . . . . .	5-83
5.4.3 Ecologic Characteristics of Coal Combustion Waste Disposal Sites . . . . .	5-89
5.4.4 Multivariate Analysis . . . . .	5-93
5.5 Summary . . . . .	5-95

**TABLE OF CONTENTS (cont'd)**

	<b>Page</b>
VI. ECONOMIC COSTS AND IMPACTS . . . . .	6-1
6.1 Waste Disposal Costs Associated With Current Disposal Methods . . . . .	6-2
6.1.1 Costs of Waste Placement and Disposal . . . . .	6-5
6.1.2 Costs Associated with Lined Disposal Facilities . . . . .	6-11
6.2 Costs of Alternative Disposal Options . . . . .	6-12
6.2.1 Regulatory Alternatives Under Subtitle C . . . . .	6-13
6.2.2 Cost Estimates for Individual RCRA Subtitle C Disposal Standards . . . . .	6-17
6.2.3 Potential Costs to the Industry of RCRA Subtitle C Waste Management . . . . .	6-30
6.3 Impact of Regulatory Alternatives on Utilization of Coal Combustion Wastes . . . . .	6-33
6.4 Economic Impacts of Alternative Waste Disposal Options . . . . .	6-37
6.5 Summary . . . . .	6-43
VII. CONCLUSIONS AND RECOMMENDATIONS . . . . .	7-1
7.1 Scope of Report . . . . .	7-1
7.2 Summary of Report . . . . .	7-2
7.2.1 Location and Characteristics of Coal- Fired Power Plants . . . . .	7-2
7.2.2 Waste Quantities and Characteristics . . . . .	7-3
7.2.3 Waste Management Practices . . . . .	7-5
7.2.4 Potential Hazardous Characteristics . . . . .	7-6
7.2.5 Evidence of Environmental Transport of Potentially Hazardous Constituents . . . . .	7-7
7.2.6 Evidence of Damage . . . . .	7-9
7.2.7 Potential Costs of Regulation . . . . .	7-9
7.3 Recommendations . . . . .	7-11

**T A B L E O F C O N T E N T S (cont'd)**

	<b>Page</b>
Bibliography	
Glossary	
Appendix A: Letter from Gary N. Dietrich, EPA, to Paul Emler, Jr., USWAG, January 13, 1981 and Memorandum from EPA Headquarters to EPA Regional Directors, February 18, 1981	A-1
Appendix B: Methodology For Estimating Volume of Ash and FGD Sludge Generation	B-1
Appendix C: Regulation of Coal Combustion Waste Disposal In Seventeen High Coal-Burning States	C-1
Appendix D: Waste Fluid Studies	D-1
Appendix E: Arthur D. Little Study of Waste Disposal At Coal-Fired Power Plants	E-1
Appendix F: Data On Sample of Coal-Fired Combustion Waste Disposal Sites	F-1
Appendix G: Methodology For Calculating The Cost of Alternative Waste Management Practices	G-1

## INDEX OF EXHIBITS

### Page

### CHAPTER TWO

2-1	Growth in Electricity Demand - 1975-2000 .....	2-2
2-2	Electricity Sales By Year and Class of Service .....	2-4
2-3	Electricity Demand by EPA Region: 1985 .....	2-5
2-4	EPA Federal Regions .....	2-6
2-5	Generating Capacity in the United States .....	2-8
2-6	Electricity Generation by Primary Energy Source: 1975-2000 .....	2-15
2-7	Electric Utility Dependence on Coal by EPA Region: 1985 .....	2-17
2-8	U.S. Coal Consumption by Sector: 1975-2000 .....	2-19
2-9	Total Number and Average Size of Coal-Fired Plants and Units .....	2-20
2-10	Range of Coal-Fired Power Plant Sizes .....	2-22
2-11	Process For Generating Electricity at Coal-Fired Power Plants .....	2-23
2-12	Diagram of a Pulverized Coal Boiler .....	2-25
2-13	Diagram of a Cyclone Boiler .....	2-27
2-14	Characteristics of Various Types of Stokers .....	2-30
2-15	Diagram of a Spreader Stoker .....	2-31
2-16	Total Coal Boiler Capacity by EPA Region .....	2-32
2-17	Average Coal Boiler Size By Type of Boiler and By EPA Region .....	2-33
2-18	Electric Utility Production of FGD Wastes: 1985 .....	2-36

### CHAPTER THREE

3-1	Representative Ash Contents By Producing Region and Coal Rank: 1985 .....	3-9
3-2	Volume of Ash Generated by Coal-Fired Electric Utility Power Plants -- 1975-2000 .....	3-10
3-3	Average Ash Content of Coal Burned by Electric Utility Power Plants in the U.S. -- 1975-2000 .....	3-12
3-4	Representative Ranges of Values For the Physical Characteristics of Fly Ash, Bottom Ash, and Boiler Slag .....	3-14
3-5	Low and High Concentrations of Major Chemical Constituents Found in Ash Generated by Coal-Fired Power Plants .....	3-16
3-6	Element Concentrations In Ash From Three Geographic Sources .....	3-18
3-7	Effect Of Geographic Coal Source On Ash Element Concentration .....	3-19
3-8	Element Concentrations In Three Types Of Ash .....	3-20
3-9	Major Types of Flue Gas Desulfurization Systems .....	3-23
3-10	Flow Diagram of Wet Flue Gas Desulfurization System .....	3-25



## INDEX OF EXHIBITS

	Page
<b>CHAPTER THREE (Continued)</b>	
3-11 Flow Diagram of Spray-Drying Flue Gas Desulfurization System .....	3-27
3-12 Flow Diagram of Dry Injection Flue Gas Desulfurization System .....	3-28
3-13 Flow Diagrams of Recovery Flue Gas Desulfurization Systems .....	3-30
3-14 FGD Capacity and FGD Sludge Generation -- 1970-2000 .....	3-32
3-15 Representative Ranges of Values for the Physical Characteristics of FGD Sludge .....	3-36
3-16 Concentration of Major Chemical Constituents of Wet FGD Sludge Solids by Scrubber System and Source of Coal .....	3-39
3-17 Concentration of Major Chemical Constituents of Wet FGD Sludge Liquors by Scrubber System and Source of Coal .....	3-40
3-18 Concentration of Trace Elements Found in Wet-FGD Sludges .....	3-42
3-19 Annual Low-Volume Waste Generation At a Representative Coal-Fired Power Plant .....	3-44
3-20 Characteristics of Boiler Blowdown .....	3-46
3-21 Characteristics of Coal Pile Runoff .....	3-48
3-22 Characteristics of Cooling Tower Blowdown .....	3-51
3-23 Characteristics of Spent Demineralizer Regenerants .....	3-53
3-24 Reported Characteristics of Gas-Side Cleaning Wastes .....	3-55
3-25 Characteristics of Spent Water-Side Alkaline Cleaning Wastes .....	3-56
3-26 Characteristics of Spent Water-Side Hydrochloric Acid Cleaning Wastes .....	3-58
3-27 Characteristics of Spent Water-Side Alkaline Passivating Wastes .....	3-59
3-28 Characteristics of Pyrites and Pyrite Transport Water .....	3-61
<b>CHAPTER FOUR</b>	
4-1 State Regulations Governing Coal Combustion Waste Disposal .....	4-3
4-2 Typical Surface Impoundment (Pond) Stages .....	4-12
4-3 Diagrams of Active and Closed Landfills .....	4-15
4-4 Utility Waste Management Facilities By EPA Region .....	4-19
4-5 Location of Utility Waste Management Facilities: On-site versus Off-site .....	4-21
4-6 Installation of Liners For Leachate Control at Utility Waste Management Facilities .....	4-31
4-7 Summary of Current Handling, Treatment and Disposal of Low-Volume Wastes .....	4-39

## INDEX OF EXHIBITS

	Page
<b>CHAPTER FIVE</b>	
5-1 Maximum Concentration of Contaminants For Characteristic of EP Toxicity .....	5-6
5-2 Effect of Geographic Coal Source On Element Concentration In Ash .....	5-10
5-3 Results of Tetra Tech Extraction Tests On Coal Combustion Ash ..	5-12
5-4 Results of Arthur D. Little Testing Showing The Range of Concentration of Metals In EP Extracts .....	5-17
5-5 EP Toxicity Analysis For Untreated and Treated Boiler Chemical Cleaning Wastes .....	5-21
5-6 EP Toxicity Test Results For Liquid Low-Volume Wastes .....	5-23
5-7 Comparison of EP and TCLP Extractions For Low-Volume Sludge Dredged From Wastewater Ponds .....	5-24
5-8 EP Toxicity Test Results of Low-Volume Wastes Before and After Co-Disposal .....	5-26
5-9 Primary And Secondary Drinking Water Standards .....	5-30
5-10 Summary of Arthur D. Little's Ground-Water Quality Data On Primary Drinking Water Exceedances .....	5-35
5-11 Summary of Arthur D. Little's Ground-Water Quality Data on Secondary Drinking Water Exceedances .....	5-37
5-12 Summary of Arthur D. Little's Surface-Water Quality Data On Primary Drinking Water Exceedances .....	5-40
5-13 Summary of PDWS Exceedances in the Franklin Associates Survey .....	5-46
5-14 Summary of SDWS Exceedances in the Franklin Associates Survey .....	5-47
5-15 Summary of PDWS Exceedances in Envirosphere's Ground-water Data .....	5-50
5-16 Summary of SDWS Exceedances in Envirosphere's Ground-water Data .....	5-51
5-17 Distance Of Coal Combustion Waste Sites To Surface Water .....	5-72
5-18 Flow Of Nearest Surface-Water Body .....	5-74
5-19 Depth To Ground Water at Coal Combustion Waste Sites .....	5-77
5-20 Hydraulic Conductivity at Coal Combustion Waste Sites .....	5-78
5-21 Net Recharge at Coal Combustion Waste Sites .....	5-81
5-22 Ground-Water Hardness at Coal Combustion Waste Sites .....	5-82
5-23 Populations Within One Kilometer of Waste Sites .....	5-85
5-24 Populations Within Three Kilometers of Waste Sites .....	5-86
5-25 Populations Within Five Kilometers of Waste Sites .....	5-87
5-26 Populations Served By Public Water Systems Near Waste Sites ....	5-89
5-27 Ecological Status of Waste Sites .....	5-92
<b>CHAPTER SIX</b>	
6-1 Overview of Waste Handling and Disposal Options for Coal Ash .....	6-3

## INDEX OF EXHIBITS

	Page
<b>CHAPTER SIX (Continued)</b>	
6-2 Overview of Waste Handling and Disposal Options for FGD Waste .....	6-4
6-3 Ranges of Average Capital Costs Associated With Coal-Fired Electric Utility Waste Disposal .....	6-6
6-4 Ranges of Average Total Costs For Coal-Fired Electric Utility Waste Disposal .....	6-7
6-5 Summary of Costs to Close Existing Waste Disposal Facilities .....	6-23
6-6 Summary of Costs For Different Types of Lined Waste Management Facilities .....	6-28
6-7 Costs to the Electric Utility Industry For Hypothetical RCRA Compliance Strategies .....	6-29
6-8 Summary of Economic Impacts on By-Product Utilization Under Different RCRA Regulatory Scenarios .....	6-36
6-9 Impact of Current Waste Disposal Costs on Total Electricity Generation Costs .....	6-39
6-10 Impact of Alternative Disposal Options on Electricity Generation Costs .....	6-40



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY  
WASHINGTON, D.C. 20460

JAN 13 1981

OFFICE OF WATER  
AND WASTE MANAGEMENT

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Washington, D.C. 20036

Dear Mr. Emler:

This is a response to your letter of October 10, 1980 to Administrator Costle, regarding the recent Solid Waste Disposal Act Amendments of 1980 and their relation to the electric utility industry. In your letter and its accompanying document, you discussed the specific amendments which address fossil fuel combustion wastes, and suggested interpretive language which EPA should adopt in carrying out the mandate of the amendments. You requested a meeting with our staff to make us more fully aware of the solid waste management practices of the electric utility industry, and to discuss the effect of the amendments on the utility solid waste study which EPA is currently conducting.

I appreciated the opportunity to meet with you, in your capacity as chairman of the Utility Solid Waste Activities Group (USWAG), on November 21 to discuss your concerns. I am taking this occasion to share with you the most recent EPA thinking on the exclusion from our hazardous waste management regulations of waste generated by the combustion of fossil fuels, and to confirm certain agreements which were reached during our meeting. The language contained in this letter should provide you and your constituents with an adequate interpretation of the fossil fuel combustion waste exclusion in Section 261.4(b)(4) of our regulations. This letter is also being circulated to appropriate Agency personnel, such as our Regional Directors of Enforcement, for their information and use. We intend to issue in the Federal Register an official Regulations Interpretation Memorandum reflecting the policies articulated in this letter.

In our May 19, 1980 hazardous waste management regulations, we published an exclusion from Subtitle C regulation for those fossil fuel combustion wastes which were the subject of then pending Congressional amendments. The language of that exclusion in §261.4(b)(4) of our May 19 regulations is identical to pertinent language of Section 7 of the Solid Waste Disposal Act

regulations. We clearly explained in the preamble to Part 261 of our May 19 regulations that we fully intend to eventually regulate the use and recycling of hazardous wastes and, in doing so, would probably, in most cases, develop special requirements that provide adequate protection of human health and the environment without unwarranted discouragement of resource conservation. Consequently, although the burning of hazardous waste as a fuel (a beneficial use assuming that the waste has a positive fuel value) is not now subject to our regulations (except as noted above) it may well be subject to our regulation in the future.

Our second concern with combustion of fuel mixtures is the one at focus in this interpretation. It must first be noted that we do not intend for §261.6 to provide an exemption from regulation for combustion wastes resulting from the burning of hazardous wastes in combination with fossil fuels; it only provides an exemption for the actual burning of hazardous wastes for recovery of fuel value. Thus, if these combustion wastes are exempted from our regulation, such exemption must be found through interpretation of §261.4(b)(4). Secondly, we note that although the pertinent language in Section 7 of the Solid Waste Disposal Act Amendments of 1980 and the related legislative history on this matter speak of allowing the burning of alternative fuel without precisely defining or delineating the types of alternative fuel, the only examples of alternative fuels used in the legislative history are refuse derived fuels. Therefore, a literal reading of the legislative history might enable us to interpret the exclusion to include combustion wastes resulting from the burning of fossil fuels and other fuels, including hazardous wastes. However, since each of these legislative comments was made in the context of refuse derived fuels or other non-hazardous alternate fuels, we do not believe the Congressional intent compels us to make such an interpretation if we have reason to believe that such combustion wastes are hazardous.

Presently, we have little data on whether or to what extent combustion wastes are "contaminated" by the burning of fossil fuel/hazardous waste mixtures. The data we do have (e.g., burning of waste oils) suggests that the hazardous waste could contribute toxic heavy metal contaminants to such combustion wastes. When coal is the primary fuel, the amount of resulting contamination is probably in amounts that are not significantly different than the metals that would be contributed by the fossil fuel component of the fuel mixture. This may not be the case with oil and gas, where huge volumes of waste are not available to provide a dilution effect. We suspect that the other hazardous constituents of the hazardous wastes that typically would be burned as a fuel are either thermally destroyed or are emitted in the flue gas (and therefore are part of our first concern as discussed above). If

these data and this presumption are true, then combustion wastes resulting from the burning of coal/hazardous waste mixtures should not be significantly different in composition than combustion wastes generated by the burning of coal alone. Because the Congress has seen fit to exclude the latter wastes from Subtitle C, pending more study, we feel compelled to provide the same exclusion to the former wastes.

Accordingly, we will interpret the exclusion of §261.4(b)(4) to include fly ash, bottom ash, boiler slag and flue gas emission control wastes generated in the combustion of coal/hazardous waste mixtures provided that coal makes up more than 50 percent of the fuel mixture.

We offer this interpretation with great reluctance and with the clear understanding it is subject to change, if and when data indicate that combustion wastes are significantly contaminated by the burning of hazardous wastes as fuel. We also offer this interpretation with the understanding, as discussed at our meeting of November 21, that the utility industry will work with us over the next several months to improve our data on this matter. We believe it is essential that we make a more informed judgement and possible reconsideration of our interpretation of the exclusion as soon as possible and before completion of our longer-term study of utility waste which is proceeding. Accordingly, we would like you to provide to us all available data on the following questions by August 1, 1981:

1. What types of hazardous wastes are commonly burned as fuels in utility boilers? In what quantity? In what ratio to fossil fuels? How often? What is their BTU content?
2. Does the burning of these wastes contribute hazardous constituents (see Appendix VIII of Part 261 of our regulations) to any of the combustion wastes? If so, what constituents, and in what amounts? How does the composition of combustion wastes change when hazardous wastes are burned?

#### Co-disposal and Co-treatment

The second issue raised in your letter was whether the exclusion extends to wastes produced in conjunction with the burning of fossil fuels which are co-disposed or co-treated with fly ash, bottom ash, boiler slag and flue gas emission control wastes. As examples of such wastes, you specifically mention boiler cleaning solutions, boiler blowdown, demineralizer regenerant, pyrites, cooling tower blowdown, or any "wastes of power plant origin whose co-treatment with fly ash, bottom ash, slag and flue gas emission control sludges is regulated under State-or-EPA-sanctioned management or treatment plans."

The legislative history on this matter clearly indicates that the Congress intended that these other wastes be exempted from Subtitle C regulation provided that they are mixed with and co-disposed or co-treated with the combustion wastes and further provided that "there is no evidence of any substantial environmental danger from these mixtures." (See Congressional Record, February 20, 1980, p. H 1102, remarks of Congressman Bevill; also see remarks of Congressman Rahall, Congressional Record, February 20, 1980, p. H1104.)

We have very little data on the composition, character and quantity of these other associated wastes (those cited above), but the data we do have suggest that they are generated in small quantities relative to combustion wastes, at least when coal is the fuel, and that they primarily contain the same heavy metal contaminants as the combustion wastes, although they may have a significantly different pH than the combustion wastes. These limited data therefore suggest that, when these other wastes are mixed with and co-disposed or co-treated with the much larger quantities of combustion wastes, their composition and character are "masked" by the composition and character of the combustion wastes; that is, they do not significantly alter the hazardous character, if any, of the combustion wastes.

Given this information base and given the absence of definitive information indicating that these other wastes do pose a "substantial danger" to human health or the environment, we believe it is appropriate, in the light of Congressional intent, to interpret the §261.4(b)(4) exclusion to include other wastes that are generated in conjunction with the burning of fossil fuels and mixed with and co-disposed or co-treated with fly ash, bottom ash, boiler slag and flue gas emission control wastes.

We offer this interpretation with some reluctance because it is made in the absence of definitive information about the hazardous properties of these other wastes or their mixtures with combustion wastes. We therefore believe it is imperative that we proceed to collect all available data on this matter within the next several months and reconsider this interpretation when these data are assessed. Toward that end and consistent with the discussion at our meeting of November 21, we are asking that you assist us in collecting these data. Specifically, we ask that you collect and submit by August 1, 1981, any available data on the following questions:

1. What are the "other" wastes which are commonly mixed with and co-disposed or co-treated with fly ash, bottom ash, boiler slag or flue gas emission control wastes? What are their physical (e.g., sludge or liquid) and chemical properties? Are they hazardous wastes in accordance with Part 261?

2. What are the co-disposal or co-treatment methods employed?
3. How often are these wastes generated? In what quantities are they generated? Are they commonly treated in any way before being co-disposed?
4. Does the industry possess any data on the environmental effects of co-disposing of these wastes? Groundwater monitoring data? What are the results?

The interpretation on other associated wastes provided in this letter is limited to wastes that are generated in conjunction with the burning of fossil fuels. We do not intend to exempt hazardous wastes that are generated by activities that are not directly associated with fossil fuel combustion, steam generation or water cooling processes. Thus, for example, the §261.4(b)(4) exclusion does not cover pesticides or herbicide wastes; spent solvents, waste oils or other wastes that might be generated in construction or maintenance activities typically carried out at utility and industrial plants; or any of the commercial chemicals listed in §261.33 which are discarded or intended to be discarded and therefore are hazardous wastes. Further, the exclusion does not cover any of the hazardous wastes listed in §§261.31 or 261.32 of our regulations. None of these listed wastes were mentioned in your letter or our discussions.

The interpretation on other wastes is also limited to wastes that traditionally have been and which actually are mixed with and co-disposed or co-treated with combustion wastes. If any of these other wastes (e.g., boiler cleaning solutions, boiler blowdown, demineralizer regenerant, pyrites and cooling tower blowdown) are segregated and disposed of or treated separately from combustion wastes and they are hazardous wastes, they are not covered by the exclusion. In the same vein, the exclusion does not cover other wastes where there are no combustion wastes (or relatively small amounts of combustion wastes) with which they might be mixed and co-disposed or co-treated--a situation which might prevail where natural gas or oil is the principal fossil fuel being used. Therefore, this interpretation of the exclusion applies only where coal is the primary fuel. We feel this is a legitimate interpretation of Congressional intent, wherein the argument of little potential environmental hazard, primarily due to the dilution factor, is clearly based upon co-disposal or co-treatment with the huge volumes of wastes generated during coal combustion.



EPA Utility Waste Study

The groups of questions raised above bring us to the final subject which you address concerning the study of utility solid waste management which EPA is conducting. We agree that the study, as currently being conducted, does not focus on the matters discussed in this letter. We would, however, like to address these matters and include them in our report to Congress, to the extent possible. To accomplish this, we plan to meet in the very near future with our contractor, Arthur D. Little, Inc., to discuss what studies may need to be carried out in addition to their currently planned activities under the contract. The inputs of your organization could be quite useful in this effort. It may be impossible, however, to modify our present study to include a detailed investigation of all of the issues discussed above.

Notwithstanding, we would like to address the matters discussed in this letter within a shorter time frame--during the next six months. Based on our meeting of November 21, it is my understanding that the utility industry, working closely with EPA, is willing to develop data on the questions put forth above. We agreed that, as a first step, USWAG will prepare a study outline designed to obtain these data. EPA staff and industry representatives designated by your organization will then mutually review the information needs. The data collection effort will then follow. Finally, data and analyses will be presented to EPA for review. This will enable us to reconsider the interpretation provided in this letter and make any changes deemed necessary. Therefore, I would appreciate it if you would designate a technical representative as USWAG's contact person for this coordinated data collection effort.

In the meantime, and pending completion of this effort, EPA will interpret 40 CFR §261.4(b)(4) to mean that the following solid wastes are not hazardous wastes:

- (a) Fly ash, bottom ash, boiler slag and flue gas emission control wastes resulting from (1) the combustion solely of coal, oil, or natural gas, (2) the combustion of any mixture of these fossil fuels, or (3) the combustion of any mixture of coal and other fuels, up to a 50 percent mixture of such other fuels.
- (b) Wastes produced in conjunction with the combustion of fossil fuels, which are necessarily associated with the production of energy, and which traditionally have been, and which actually are, mixed with and co-disposed or co-treated with fly ash, bottom ash, boiler slag, or flue gas emission control wastes from coal combustion.

This provision includes, but is not limited to, the following wastes:

- (1) boiler cleaning solutions,
- (2) boiler blowdown,
- (3) demineralizer regenerant,
- (4) pyrites, and
- (5) cooling tower blowdown.

I am hopeful that our future research activities together will prove fruitful and that these issues can be rapidly resolved. I have designated Ms. Penelope Hansen of my staff as the EPA point of contact for this effort. You may reach her at (202) 755-9206.

Sincerely yours,

Gary N. Dietrich  
Associate Deputy Assistant Administrator  
for Solid Waste



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY  
WASHINGTON, D.C. 20460

DATE:

SUBJECT: EPA Regulation of Utility Waste

FROM: Steffen W. Plehn, Deputy Assistant  
Administrator for Solid Waste (WH-562)

R. Sarah Compton, Deputy Assistant  
Administrator for Water Enforcement (EN-335)

TO: Regional Directors --  
Air and Hazardous Materials Division  
Enforcement Division  
Surveillance and Analysis Division  
Offices of Regional Counsel (see list)  
Director, National Enforcement Investigations Center

Attached is a copy of a letter which provides interpretation of EPA's regulation of solid wastes from fossil fuel combustion. This letter, addressed to Mr. Paul Emler of the Utility Solid Waste Activities Group on January 13, 1981, interprets the language contained in §261.4(b)(4) of the May 19, 1980 regulations for Hazardous Waste Management, implementing Subtitle C of the Resource Conservation and Recovery Act of 1976 (RCRA).

In those regulations, we published an exclusion from Subtitle C regulation for those fossil fuel combustion wastes which were the subject of then pending Congressional amendments. The language of the exclusion in §261.4(b)(4) is identical to pertinent language of Section 7 of the Solid Waste Disposal Act Amendments of 1980 (P.L. 96-482) which was enacted on October 21, 1980 and which mandates that exclusion. Specifically the exclusion language of our regulations provides that the following solid wastes are not hazardous wastes:

"Fly ash waste, bottom ash waste, slag waste,  
and flue gas emission control waste generated  
primarily from the combustion of coal or other  
fossil fuels."

In the January 13 letter, EPA interpreted this exclusion language to mean that the following solid wastes are not hazardous wastes:

- (a) Fly ash, bottom ash, boiler slag and flue gas emission control wastes resulting from (1) the combustion solely of coal, oil, or natural gas, (2) the combustion of any mixture of these fossil fuels, or (3) the combustion of any mixture of coal and other fuels, up to a 50 percent mixture of such other fuels.
- (b) Wastes produced in conjunction with the combustion of fossil fuels, which are necessarily associated with the production of energy, and which traditionally have been, and which actually are, mixed with and co-disposed or co-treated with fly ash, bottom ash, boiler slag, or flue gas emission control wastes from coal combustion.

This provision includes, but is not limited to, the following wastes:

- (1) boiler cleaning solutions,
- (2) boiler blowdown,
- (3) demineralizer regenerant,
- (4) pyrites, and
- (5) cooling tower blowdown.

This exclusion from hazardous waste regulation applies only until such time as EPA studies the environmental effects of disposal of these wastes and makes a determination as to how they should be managed. The utility industry will be assisting EPA in the collection of such information. In the meantime, utility waste is regulated as a solid waste, subject to RCRA Subtitle D criteria.

After receipt of information from the utility industry, our current interpretation of the fossil fuel combustion waste deferral may be revised. In the meantime, however, the guidance provided to Mr. Emler represents EPA's position on this issue. I urge each of you to study carefully the details of and rationale behind the guidance, and make the appropriate persons on your staff aware of it. If you have any questions on this issue or on the letter itself, please contact John Heffelfinger, in the Office of Solid Waste, at (202) 755-9206.

Attachment

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## METHODOLOGY FOR ESTIMATING VOLUME OF ASH AND FGD SLUDGE GENERATION

The estimates of future ash and FGD sludge generation presented in Chapter Three were derived based on assumptions regarding future coal consumption, the amount of coal-fired capacity, the types of boilers in service, and environmental regulations. Estimates were derived for 1985, 1990, 1995, and 2000. This appendix explains the key assumptions and methodology used to develop the estimates of future ash and FGD sludge generation. The major source used to develop these estimates was Analysis of 6 and 8 Million Ton and 30 year/NSPS and 30 Year/1.2 lb Sulfur Dioxide Emission Reduction Cases (prepared by ICF Incorporated for EPA, February 1986).<sup>1</sup>

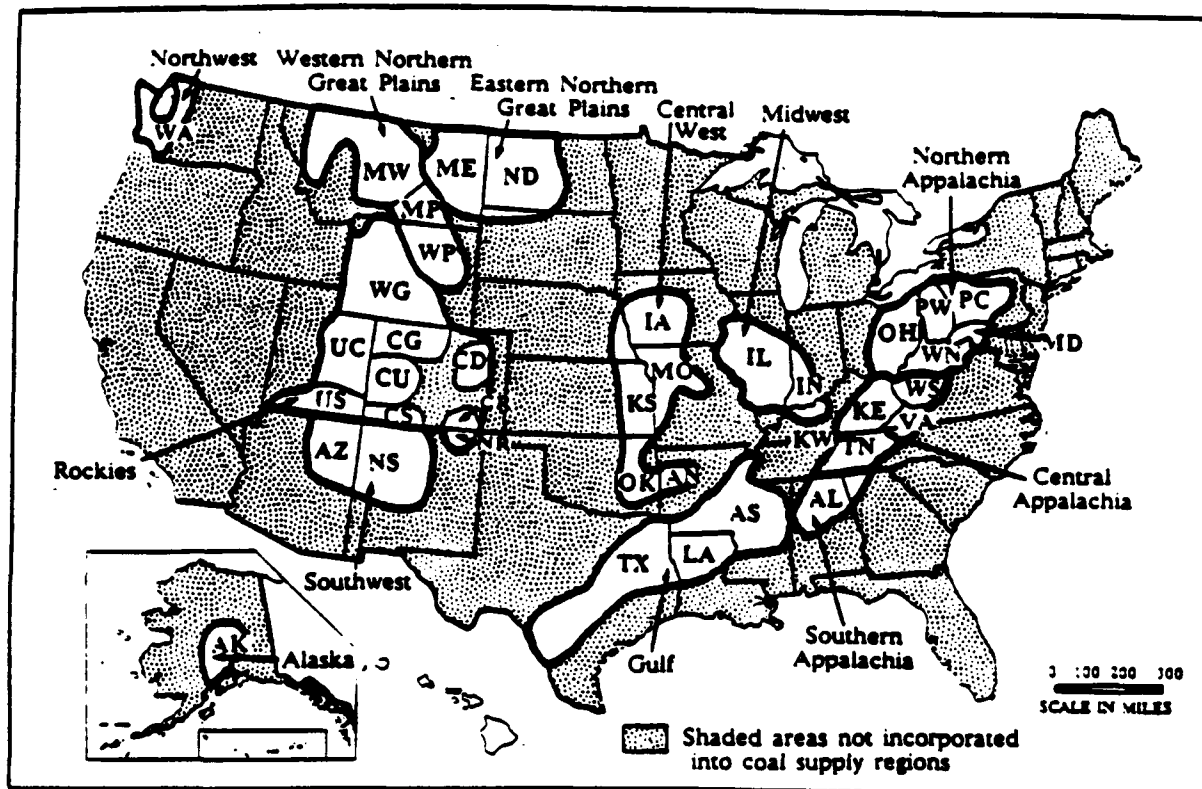
### B.1 ASH

The first step in developing estimates of the volume of ash generated by coal-fired utilities was to determine for each coal-producing region in the U.S. (see Exhibit B-1) an average ash content of coal (on an as-shipped basis), specified by rank, heat content, and volatility level. These average ash contents are shown in Exhibit B-2. Next, these average values were multiplied by the quantity of coal expected to be shipped from each coal-producing region, using the following formula:

$$\begin{aligned} &\text{Ash Content of Coal (\%)} \times \text{Amount of Coal (Million Tons)} \\ &\quad = \text{Amount of Ash (Million Tons)} \end{aligned}$$

## EXHIBIT B-1

## COAL-PRODUCING REGIONS OF THE UNITED STATES

**Northern Appalachia**

Pennsylvania, Central (PC)  
Pennsylvania, West (PW)  
Ohio (OH)  
Maryland (MD)  
West Virginia, North (WN)

**Central Appalachia**

West Virginia, South (WS)  
Virginia (VA)  
Kentucky, East (KE)  
Tennessee (TN)

**Southern Appalachia**

Alabama (AL)

**Midwest**

Illinois (IL)  
Indiana (IN)  
Kentucky, West (KW)

**Central West**

Iowa (IA)  
Missouri (MO)  
Kansas (KS)  
Arkansas, North (AN)  
Oklahoma (OK)

**Gulf**

Texas (TX)  
Louisiana (LA)  
Arkansas South/Mississippi (AS)

**Eastern Northern Great Plains**

North Dakota (ND)  
Montana, East (ME)

**Western Northern Great Plains**

Montana, Powder River (MP)  
Montana, West (MW)  
Wyoming, Powder River (WP)

**Rockies**

Wyoming, Green River (WG)  
Colorado, Green River (CG)  
Colorado, Denver (CD)  
Colorado, Raton (CR)  
Colorado, Uinta (CU)  
Colorado, San Juan (CS)  
Utah, Central (UC)  
Utah, South (US)  
New Mexico, Raton (NR)

**Southwest**

New Mexico, San Juan (NS)  
Arizona (AZ)

**Northwest**

Washington (WA)

**Alaska**

Alaska (AK)

**Imports**

Imports (IM)

## EXHIBIT B-2

AVERAGE ASH CONTENT OF COAL  
(percent)

<u>Coal-Producing Region</u>	<u>Bituminous</u>				<u>Subbituminous</u>	<u>Lignite</u>
	Low and Medium 1/ <u>Volatility</u>	<u>High Volatility 1/</u>				
		10,500- 11,500 <u>Btu/lb</u>	11,500- 14,000 <u>Btu/lb</u>	Over 14,000 <u>Btu/lb</u>		
Central Pennsylvania	12.0	12.0	12.0	12.0		
Western Pennsylvania	7.0		12.0	12.0		
Ohio			12.0	12.0		
Maryland	12.0					
Northern West Virginia	7.0		12.0	12.0		
Southern West Virginia	12.0		12.0	12.0		
Virginia	12.0		12.0	12.0		
Eastern Kentucky			12.0	12.0		
Tennessee			12.0	12.0		
Alabama	12.6		12.6	12.6		
Illinois			10.3	10.3		
Indiana			10.4			
Western Kentucky			12.0			
Iowa		10.0	10.0			
Missouri			12.0	12.0		
Kansas			14.0	12.7		
Northern Arkansas	12.0					
Oklahoma	12.4	12.4	12.4			
Texas						15.3
Louisiana						12.0
Southern Arkansas						14.0
North Dakota						9.1
Eastern Montana					6.9	8.0
Montana, Powder River					6.9	
Western Montana		13.0	13.0			
Wyoming, Powder River					6.0	
Wyoming, Green River		10.0	10.0		10.0	



## EXHIBIT B-2

**AVERAGE ASH CONTENT OF COAL**  
(percent)

<u>Coal-Producing Region</u>	<u>Volatility</u>	<u>Bituminous<sup>▲▲</sup></u>				<u>Subbituminous</u>	<u>Lignite</u>
		<u>High Volatility 1/</u>					
		<u>Low and Medium 1/</u>	<u>10,500-11,500</u>	<u>11,500-14,000</u>			
		<u>Btu/lb</u>	<u>Btu/lb</u>	<u>Btu/lb</u>			
Colorado, Green River		10.0	10.0				
Colorado, Denver					18.0		18.0
Colorado, Raton			10.0	10.0			
Colorado, Uinta	8.0		8.0	8.0			
Colorado, San Juan			10.0	10.0			
Central Utah			8.0	8.0			
Southern Utah		12.0	9.0				
New Mexico, Raton			13.1	13.1			
New Mexico, San Juan		18.3			18.3		
Arizona			10.0				
Washington					16.0		
Alaska					9.0		

1/ Volatility Content, as measured on a dry, mineral-matter-free basis.

Low : 14.0-21.9 percent volatile matter  
Medium : 22.0-30.9 percent volatile matter  
High : Over 31.0 percent volatile matter

Source: See Attachment B-1 for the major assumptions used to develop these average ash contents. These assumptions were used in the analysis summarized in Analysis of 6 and 8 Million Ton and 30 Year/NSPS and 30 Year/1.2 lb. Sulfur Dioxide Emission Reduction Cases, prepared by ICF Incorporated for the Environmental Protection Agency, February 1986.

The results represent the quantities of ash received by electric utility power plants throughout the United States. It was assumed that the total quantity of ash received by utilities would not burn; therefore, the amount of ash generated is equal to the amount received. Exhibit B-3 presents estimates by state of the total amount of ash that will be generated by electric utilities between 1985 and 2000 and the average ash content of the total quantity of coal received by the utilities in each state.

To determine quantities of each type of ash that would be generated, the amount of ash produced by each type of electric utility boiler was calculated. This was determined by apportioning the total quantity of ash generated according to the capacity of each boiler type (as a fraction of total capacity of coal-fired utilities in the U.S.). In Exhibit B-4 total electric utility capacity is described by boiler type. The majority of future coal-fired power plants are expected to use dry-bottom pulverizers, which can burn a greater variety of coals than other boilers. Therefore, it is assumed that the capacity assigned to the "unknown" category in Exhibit B-4 is additional dry-bottom pulverizer capacity.

Once the amount of ash generated by each type of boiler was determined, the quantities of the different types of ash formed could be estimated. Each major boiler type (dry-bottom pulverizers, wet-bottom pulverizers, cyclones, and stokers) produces different proportions of fly ash, bottom ash, or boiler slag, depending on the design of the boiler and operating conditions. The percentage of ash generated as fly ash, bottom ash, and boiler slag by each type of boiler is presented in Exhibit B-5. These percentages were used to determine the amount of each ash type generated by the four types of boilers,

## EXHIBIT B-3

TOTAL AMOUNT OF ASH GENERATED BY ELECTRIC UTILITY POWER PLANTS -- 1985 to 2000 <sup>a/</sup>

State	1985		1990		1995		2000	
	Million Tons	% Ash	Million Tons	% Ash	Million Tons	% Ash	Million Tons	% Ash
Maine/Vermont/New Hampshire	0.2	12.0	0.1	12.0	0.2	12.0	0.4	11.6
Massachusetts/Connecticut/Rhode Island	0.5	12.0	0.9	12.0	0.9	12.0	0.9	12.0
New York	0.8	11.2	0.9	10.5	1.6	11.5	1.5	10.2
Pennsylvania	5.0	12.4	5.1	12.3	5.1	12.4	4.9	12.4
New Jersey	0.4	12.0	0.4	12.0	0.6	12.0	1.0	12.0
Maryland/Delaware/District of Columbia	1.0	9.7	0.9	10.4	1.2	10.3	2.0	10.0
Virginia	0.9	12.0	1.0	12.0	1.2	11.7	2.7	11.8
West Virginia	3.2	11.2	3.8	11.2	3.5	11.3	3.7	11.5
North Carolina/South Carolina	3.9	12.0	3.8	12.0	4.1	12.0	4.8	12.0
Georgia	3.0	11.6	3.4	11.7	3.8	11.8	4.3	11.9
Florida	2.0	11.8	2.5	11.8	3.1	11.8	5.0	11.9
Ohio	6.0	11.8	6.0	11.8	6.3	11.9	7.8	10.9
Michigan	3.2	10.6	3.3	10.2	3.4	10.3	3.4	10.3
Illinois	3.1	9.0	2.8	8.8	3.1	8.9	3.3	8.3
Indiana	4.1	9.8	4.6	9.9	4.8	9.7	4.9	9.7
Wisconsin	1.4	8.2	1.6	7.6	1.7	7.6	1.6	7.8
Kentucky	2.6	12.0	3.9	12.0	4.1	12.0	4.0	12.0
Tennessee	3.4	11.6	3.3	11.4	3.0	11.3	4.6	11.5
Alabama	1.6	12.6	1.9	12.5	2.2	12.4	2.0	12.4
Mississippi	0.5	10.7	0.5	10.7	0.6	10.5	0.6	11.1
Minnesota	0.8	7.0	0.9	7.0	1.1	7.1	1.1	7.1
North Dakota/South Dakota	1.8	9.1	2.1	9.1	2.1	9.1	3.3	8.3
Iowa	1.3	7.4	1.3	7.5	1.3	7.5	1.2	7.5
Missouri	2.7	10.3	2.8	10.4	3.0	9.6	3.6	8.5
Kansas/Nebraska	1.5	7.1	1.6	7.2	1.6	7.2	1.7	7.1
Arkansas	0.8	6.0	0.7	6.0	0.8	6.0	0.8	6.0
Oklahoma	0.9	6.0	1.1	6.0	1.1	6.0	1.8	6.0
Louisiana	0.6	6.0	1.0	7.8	1.0	7.6	2.0	9.1
Texas	8.2	12.5	10.0	12.8	15.7	13.6	23.9	13.3
Montana	0.4	6.9	0.6	6.9	0.6	6.9	0.8	6.9
Wyoming	1.5	7.8	1.5	7.8	1.9	7.3	2.1	7.1
Colorado	1.3	8.3	1.3	8.3	1.4	8.2	1.8	7.7
New Mexico	2.8	18.1	2.6	17.8	2.9	17.0	3.2	16.2
Utah	0.5	8.3	0.9	8.2	1.3	8.1	1.5	8.1
Arizona	1.7	12.6	2.2	14.1	2.1	13.0	2.3	11.9
Nevada	0.8	9.7	0.8	9.7	1.0	9.8	1.0	9.9
Washington/Oregon	0.8	13.9	0.8	14.0	1.0	13.8	1.9	9.5
California	b/	8.0	b/	8.0	0.1	9.0	0.3	9.8
Total U.S.c/	75.0	10.5	83.1	10.5	94.5	10.6	119.1	10.5

a/ For each year, the numbers in the left column indicate the amount of ash generated by coal fired electric utility power plants in the indicated state(s); the numbers in the right column are the average percentages of ash content in the coal received by utilities in the indicated state(s).

b/ Amount of ash is less than 0.1 million tons.

c/ Totals may not add due to independent rounding

Source: See Attachment B-1 for the major assumptions used to develop these estimates. These assumptions were used in the analysis summarized in Analysis of 6 and 8 Million Ton and 30 Year/NSPS and 30 Year/1.2 lb. Sulfur Dioxide Emission Reduction Cases, prepared by ICF Incorporated for the Environmental Protection Agency, February 1986.

## EXHIBIT B-4

**ELECTRIC GENERATING CAPACITY  
OF COAL-FIRED UTILITIES BY BOILER TYPE a/  
(gigawatts)**

	<u>1985</u>	<u>1990</u>	<u>1995</u>	<u>2000</u>
Wet-Bottom Pulverizers	15.2	15.2	15.2	15.0
Dry-Bottom Pulverizers	199.1	198.9	198.7	198.1
Cyclones	23.8	23.8	23.7	23.7
Stokers	1.1	1.1	1.1	1.1
Unknown <u>b/</u>	<u>30.1</u>	<u>54.4</u>	<u>68.4</u>	<u>140.9</u>
TOTAL	269.3	293.4	306.9	378.8

a/ A gigawatt equal 1,000 megawatts.

b/ Plants yet to be constructed are assumed to have primarily dry-bottom pulverizer boilers.

Source: See Attachment B-1 for the major assumptions used to develop these estimates. These assumptions were used in the analysis summarized in Analysis of 6 and 8 Million Ton and 30 Year/NSPS and 30 Year/1.2 lb. Sulfur Dioxide Emission Reduction Cases, prepared by ICF Incorporated for the Environmental Protection Agency, February 1986.

**EXHIBIT B-5****PERCENTAGE OF EACH TYPE OF ASH  
GENERATED BY EACH BOILER TYPE**

	<u>Fly Ash</u>	<u>Bottom Ash</u>	<u>Boiler Slag</u>
Wet-Bottom Pulverizers	50%	--	50%
Dry-Bottom Pulverizers	80%	20%	--
Cyclones	25%	--	75%
Stokers	50%	50%	--

---

Source: Babcock & Wilcox, Steam: Its Generation and Use, New York: The Babcock & Wilcox Company, 1978, pp. 15-7 - 15-8.

and then these amounts were aggregated to determine total ash generation by the electric utility industry in 1985, 1990, 1995, and 2000.

Some minor variances were noted between these estimates and historical trends in ash generation as reported by the American Coal Ash Association. Some adjustments were made in the distribution among ash types (but not the total quantities) so that forecasted quantities were more consistent with historical trends. The ash production forecasts, as well as historical data for 1980 to 1984, are presented in Exhibit B-6.

## **B.2 FGD SLUDGE**

Because the sludge produced by flue gas desulfurization systems can vary a great deal in composition, consistency, and water/solids content, several simplifying assumptions were made to arrive at values for future FGD sludge generation.

- Wet scrubbers were assumed to be of the direct limestone type, producing a waste composed of unreacted reagent (limestone) and reacted reagent (gypsum). Dry scrubbers use lime as a reagent and were assumed to produce a waste composed of 25 percent gypsum and 75 percent  $\text{CaSO}_3 \cdot 1/2(\text{H}_2\text{O})$ .
- The stoichiometry for wet scrubbers is 1.4, while that for dry scrubbers is 1.86.
- The proportion of dry solids in sludge from wet scrubbers is 50 percent<sup>2</sup>; in sludge from dry scrubbers it is 100 percent.
- The purity of the reagents (limestone for wet scrubbers and lime for dry scrubbers) was assumed to be 95 percent.

## EXHIBIT B-6

**ASH GENERATION BY ELECTRIC UTILITY POWER PLANTS**  
**(millions of tons)**

	<u>Fly Ash</u>	<u>Bottom Ash</u>	<u>Boiler Slag</u>	<u>Total</u>
<u>Historical</u>				
1980	48.3	14.5	3.6	66.4
1981	50.2	12.9	5.2	68.3
1982	47.9	13.1	4.4	65.4
1983	47.2	12.7	3.9	63.8
1984	51.3	13.6	4.2	69.1
<u>Estimated</u>				
1985	54.4	15.7	4.9	75.0
1990	60.8	16.9	5.4	83.1
1995	69.4	19.1	6.0	94.5
2000	89.0	22.9	7.2	119.1

---

Source: 1980-1984: American Coal Ash Association

1985-2000: See Attachment B-1 for the major assumptions used to develop these estimates. These assumptions were used in the analysis summarized in Analysis of 6 and 8 Million Ton and 30 Year/NSPS and 30 Year/1.2 lb. Sulfur Dioxide Emission Reduction Cases, prepared by ICF Incorporated for the Environmental Protection Agency, February 1986.

Sludge factors for wet and dry scrubbers, in pounds of sludge generated per pound of sulfur dioxide removed, were derived by applying the assumptions noted in the following equation:

$$\begin{aligned}
 & \left( \frac{\text{lbs. sludge}}{\text{lbs. SO}_2 \text{ removed}} \right) = \frac{\text{Molar Weight of Reacted By-Product and Waste }^3}{\text{Molar Weight of SO}_2^5} + \frac{\text{Molar Weight of Reagent Including Waste }^4}{\text{Percent Dry Solids}} \times (\text{Stoichiometry-1})
 \end{aligned}$$

For wet scrubbers this factor equals 6.90, and for dry scrubbers the factor can be 3.14 or 3.08, depending on the percent of sulfur dioxide that is required to be removed (either 90% or 70% was assumed, depending on which level of sulfur removal was most consistent with the Revised New Source Performance Standard for sulfur dioxide from utility boilers).

Based on the expected sulfur content and total quantity of coal consumed by electric utilities, future federal and state sulfur dioxide regulations, and the amount of scrubber capacity forecasted to be in operation in future years, amounts of sulfur dioxide removed were estimated on a state basis. The sludge factors explained above were then applied to the quantities of sulfur dioxide removed to arrive at total FGD sludge generation. Exhibit B-7 presents historical and future FGD capacity and FGD sludge generation for the U.S.



**EXHIBIT B-7****FGD CAPACITY AND FGD SLUDGE GENERATION**

	FGD Capacity (10 <sup>3</sup> megawatts)	FGD Sludge Production (millions of tons)
<u>Historical</u>		
1970	--	--
1972	0.7	0.2
1975	6.7	2.3
1980	27.4	9.5
<u>Estimated</u>		
1985	45.2	16.0
1990	62.4	24.1
1995	80.7	30.9
2000	179.3	50.3

---

Sources: 1970-1980: Energy Information Administration, Cost and Quality of Fuels for Electric Utility Plants - 1980, DOE/EIA-0191(80), and Arthur D. Little, Inc., Full Scale Field Evaluation of Waste Disposal from Coal-Fired Electric Generating Plants, Volume I, June 1985.

1985-2000: See Attachment B-1 for the major assumptions used to develop these estimates. These assumptions were used in the analysis summarized in Analysis of 6 and 8 Million Ton and 30 Year/NSPS and 30 Year/1.2 lb. Sulfur Dioxide Emission Reduction Cases, prepared by ICF Incorporated for the Environmental Protection Agency, February 1986.

**ATTACHMENT B-1**

**MAJOR ASSUMPTIONS USED IN THE DERIVATION  
OF FUTURE ASH AND FGD SLUDGE GENERATION ESTIMATES** <sup>6</sup>

**MAJOR ASSUMPTIONS USED IN THE DERIVATION OF FUTURE ASH AND FGD SLUDGE GENERATION ESTIMATES**

Critical Parameter	Value		Comments
<u>Global Energy and Economic Conditions</u>			
● GNP (% Per Year Real Growth)	1983-1985	= 5.0	GNP growth is forecasted to be higher during the current recovery and then slow to a 3 percent average per annum growth rate by 1990.
	1986-1990	= 3.5	
	1991-1995	= 3.0	
	1996-2000	= 3.0	
	2001-2010	= 3.0	
● World Oil Prices (mid-1985 \$/bbl)	1985	= 28.10	ICF forecasts assume that oil prices will remain constant in nominal terms through 1985 because of near-term market conditions. Prices are assumed to recover somewhat by 1990, with 2.5-3.0 percent increases per year in real terms thereafter.
	1990	= 29.20	
	1995	= 34.10	
	2000	= 38.90	
	2010	= 49.80	
● Natural Gas Prices and Availability	1985 deregulation is assumed		
<u>Electric Utility Energy Demand</u>			
● Electricity Growth Rate (% Per Year)	1980-1984	= 2.2	
	1984-1985	= 2.4	
	1986-1990	= 2.5	
	1991-1995	= 2.5	
	1996-2000	= 2.5	
	2001-2010	= 2.5	
● Nuclear Capacity (Gw)	1985	= 67	Capacity estimates through 2000 reflect most recent announcements, postponements, and delays of currently planned power plants. Nuclear capacity in 2010 reflects an assumed upturn in nuclear capacity additions after 2000, which more than offset the forecasted retirement of 27 gigawatts of nuclear power plant capacity expected between 2001 and 2010.
	1990	= 105	
	1995	= 108	
	2000	= 109	
	2010	= 120	

**MAJOR ASSUMPTIONS USED IN THE DERIVATION OF FUTURE ASH AND PGD SLUDGE GENERATION ESTIMATES**

Critical Parameter	Value		Comments
● Nuclear Capacity Factors (%)	1985	= 60	Improvement in the availability of nuclear units is expected as recent regulatory and technical problems resulting primarily from the Three-Mile Island experience are resolved.
	1990	= 64	
	1995	= 67	
	2000	= 67	
	2010	= 67	
● Substitution of Coal for Oil and Gas (Gw)	Reconversion capacity (1982-1995)	= 11.3	Reconversions and accelerated replacement are limited by institutional (e.g., state utility commissions) and financial (e.g., bond and equity markets) constraints. Latest estimates reflect expected delays and cancellations. Capital surcharges, which vary by CEUM region, are imposed on accelerated replacements to reflect these constraints.
● Utility Capital Costs (1980 \$/kw)	Coal	= 717- 851	Capital costs include 10 percent real escalation from 1980 to 1985. Nuclear capital cost estimates have been increased about 35 percent above previous EPRI estimates, reflecting (1) significantly longer construction and lead times, (2) more safety requirements for future plants, and (3) additional escalation in materials, equipment and labor costs. Nuclear capital cost estimates correspond to recent DOE estimates. Other power plant cost estimates are based on EPRI figures.
	Nuclear	= 1375-1561	
	Turbine	= 219- 251	
	Scrubbers, Dry	= 79- 91	
	Scrubbers, Wet	= 163- 189	
● Capital Cost Surcharges (1980 \$/kw)	1985-1990:	500-2000 (varies by region)	Capital cost surcharges are imposed on new capacity builds to limit economic replacements. Surcharges reflect regulatory, financial, and institutional constraints to capital investment.
	1995-2000:	500 for WO, CN, CS 750 for all others	
	2010:	0	
● Power plant Lifetime (Years)	Coal Steam	- 60	Power plant units are assumed to retire based on the assumed number of years after their initial date of commercial operation <u>except</u> for announced retirements. Coal power plants are refurbished after 30 years for \$200/kw (early-1985 \$). This is assumed to extend their useful lifetime from 45 to 60 years. Reconversions are assumed to retire 30 years after their reconversion date.
	Oil/Gas Steam	- 45	
	Nuclear	- 35	
	Oil/Gas Turbine	- 20	

# MAJOR ASSUMPTIONS USED IN THE DERIVATION OF FUTURE ASH AND PGD SLUDGE GENERATION ESTIMATES

Critical Parameter	Value		Comments
● Coal Power plant Heat Rates Over Time	0.25% per year increase over current levels, After refurbishment improves heat rates are improved (decreased) by five percent from previous forecasts levels.		Based on empirical studies and engineering assessments of heat rate deterioration over time and the effects of power plant refurbishment.
● Minimum Turndown Rates	Coal - 35% Oil/Gas Steam - 20%		Coal and oil/gas steam units must operate at or above minimum load during the week. Minimum load levels assumed herein are based on various empirical studies of operating practice and constraints.
● Canadian Imports of Electricity (BKWH transmitted)	1985	= 45	Imports reflect current contracts and announced plans.
	1990	= 69	
	1995	= 89.9	
	2000	= 86.8	
	2010	= 96.9	
<b>Financial Parameters</b>			
● Inflation Rate (% Per Year)	1984	= 3.8	Latest forecasts anticipate a small increase in average annual inflation rates.
	1985	= 4.0	
	1986-2010	= 5.0	
● Real Discount Rate (% Per Year)	Coal Mine	= 6.00	
	Utility	= 4.27	
● Real Capital Charge Rates (%)			The retrofit pollution-control capital charge rate is lower than the new pollution-control rate because of the rapid tax write-off provision available to retrofits only. Use of industrial revenue bond financing was not assumed.
Coal/Nuclear/Combined Cycle	9.0		
Pollution-Control--New	9.0		
Pollution-Control--Retrofit	6.5		
Combustion Turbine	10.5		
● Book Life (years)			Longer book life for pollution-control equipment assumed in the previous EPA base is the major reason for lower real capital charge rates for this equipment.
Coal/Nuclear/Combined Cycle	30		
Combustion Turbine	20		
Pollution Control-Retrofit	30		
Pollution Control-New	30		

# MAJOR ASSUMPTIONS USED IN THE DERIVATION OF FUTURE ASH AND FGD SLUDGE GENERATION ESTIMATES

Critical Parameter	Value	Comments												
● Tax Depreciation Life (years) Retrofit Pollution Control Others	5 15	Tax depreciation based on Accelerated Cost Recovery System (ACRS) under Economic Recovery Tax Act of 1981.												
● Input Year Dollars	early 1980													
● Output Year Dollars	early 1985													
● Escalation Input to Output Dollars	1.34													
<u>Real Cost Escalation Parameters</u>														
● Coal Transportation Rates (% Total Real Escalation)	<table><tr><td colspan="2"><u>Rail</u></td></tr><tr><td>1981 - 1985</td><td>= -5.0</td></tr><tr><td>1986 - 2000</td><td>= 0.0</td></tr><tr><td colspan="2"><u>Truck and Barge</u></td></tr><tr><td>1981 - 1985</td><td>= 5.0</td></tr><tr><td>1986 - 2000</td><td>= 0.0</td></tr></table>	<u>Rail</u>		1981 - 1985	= -5.0	1986 - 2000	= 0.0	<u>Truck and Barge</u>		1981 - 1985	= 5.0	1986 - 2000	= 0.0	Growing competition will hold down the marginal rail rates to levels below current average rail rates. Truck and barge rates are assumed to escalate in real terms to account for long-term fuel price increases.
<u>Rail</u>														
1981 - 1985	= -5.0													
1986 - 2000	= 0.0													
<u>Truck and Barge</u>														
1981 - 1985	= 5.0													
1986 - 2000	= 0.0													
<u>Coal Mining Productivity</u>														
● Mining Costs (% Annual Real Escalation)	<table><tr><td>Capital</td><td>= 1.0</td></tr><tr><td>Labor</td><td>= 1.0</td></tr><tr><td></td><td>in 1984;</td></tr><tr><td></td><td>2.0/3 yrs.</td></tr><tr><td></td><td>thereafter</td></tr><tr><td>Materials</td><td>= 0.0</td></tr></table>	Capital	= 1.0	Labor	= 1.0		in 1984;		2.0/3 yrs.		thereafter	Materials	= 0.0	
Capital	= 1.0													
Labor	= 1.0													
	in 1984;													
	2.0/3 yrs.													
	thereafter													
Materials	= 0.0													
● Mining Productivity Base Level (1985) (% of Standard)	<table><tr><td>UMWA</td><td>= 80</td></tr><tr><td>Non-UMWA</td><td>= 95</td></tr><tr><td>Mixed</td><td>= 90</td></tr></table>	UMWA	= 80	Non-UMWA	= 95	Mixed	= 90							
UMWA	= 80													
Non-UMWA	= 95													
Mixed	= 90													
% Annualized Productivity Increase (1985-95)	<table><tr><td>Surface</td><td>= 1.0</td></tr><tr><td>Deep-Continuous</td><td></td></tr><tr><td>Mine</td><td>= 1.0</td></tr><tr><td>Deep-Longwall</td><td>= 2.0</td></tr></table>	Surface	= 1.0	Deep-Continuous		Mine	= 1.0	Deep-Longwall	= 2.0					
Surface	= 1.0													
Deep-Continuous														
Mine	= 1.0													
Deep-Longwall	= 2.0													
● Utility Power plant Capital Costs (% Total Real Escalation)	<table><tr><td>1980-1985</td><td>= 10.0</td></tr><tr><td>1985-2000</td><td>= 0.0</td></tr></table>	1980-1985	= 10.0	1985-2000	= 0.0	Expected real escalation in nuclear plant costs is higher and is incorporated in base nuclear cost estimates.								
1980-1985	= 10.0													
1985-2000	= 0.0													

# MAJOR ASSUMPTIONS USED IN THE DERIVATION OF FUTURE ABE AND PGD SLUDGE GENERATION ESTIMATES

Critical Parameter	Value		Comments
<u>Other Governmental Regulations</u>			
● Federal Leasing Policy	Enough		Federal leasing is assumed to be sufficient to avoid artificially driving up market prices.
● Air Pollution Regulations	Most recent federal and state rules.		Sulfur dioxide emission limits assumed to be tightened in New York and Wisconsin over the next ten years in light of recent state legislation aimed at responding to acid rain and/or ambient air quality concerns. Certain variances are assumed to expire and revisions are assumed to occur. No other changes assumed beyond current emission limitations.
<u>Non-Utility Coal Demand</u>			
● Industrial/Retail Coal Use (10 <sup>6</sup> tons)	1985	= 82	Reflects recent forecasts of industrial boiler coal demand combined with forecast of the kiln and residential/commercial coal markets. Low oil prices and increased reliance on waste products and conservation are expected to dampen near-term coal demand.
	1990	= 109	
	1995	= 135	
	2000	= 170	
	2010	= 220	
● Steam Coal Exports (10 <sup>6</sup> tons)	1985	= 28	Reflects low growth in worldwide electricity demand and less market share going to U.S. producers, particularly in 1985 and 1990. Reduction in longer-term demands concentrated mainly in the Pacific Rim.
	1990	= 25	
	1995	= 48	
	2000	= 69	
	2010	= 120	
● Metallurgical Coal Use (10 <sup>6</sup> tons) -- Export	1985	= 53	Reflects sluggish growth expected in world markets.
	1990	= 49	
	1995	= 53	
	2000	= 61	
	2010	= 65	
-- Domestic	1985	= 54	Continuing trends in steel substitution limit forecasted domestic metallurgical coal use through most of the 1980's. Steel's recovery from the present slump is not yet complete by 1985.
	1990	= 61	
	1995	= 62	
	2000	= 62	
	2010	= 62	

**MAJOR ASSUMPTIONS USED IN THE DERIVATION OF FUTURE ASH AND FGD SLUDGE GENERATION ESTIMATES**

Critical Parameter	Value		Comments
● Synthetics (Coal Input in 10 <sup>6</sup> tons) (Million Tons)	1985	= 4	Outlook for coal-based projects continues to be unfavorable. Some slippage seen in on-line dates of major near-term projects. Great Plains Gasification Project assumed to stay on schedule.
	1990	= 8	
	1995	= 8	
	2000	= 8	
	2010	= 8	



## APPENDIX B

### NOTES

- <sup>1</sup> For more detail regarding assumptions, see Analysis of 6 and 8 Million Ton and 30 Year/NSPS and 30 Year/1.2 lb. Sulfur Dioxide Emission Reduction Cases, February 1986, prepared by ICF Incorporated for the Environmental Protection Agency. The major assumptions concerning future energy demand, economic conditions, and government regulations used to derive the estimates in the ICF study are presented in Attachment B-1 to this Appendix.
- <sup>2</sup> Arthur D. Little, Inc., Full Scale Field Evaluation of Waste Disposal from Coal-Fired Electric Generating Plants, June 1985.
- <sup>3</sup> The reacted by-product generated by wet scrubbers has a molar weight of 179; that generated by dry scrubbers has a molar weight of 146.3.
- <sup>4</sup> The molar weight of limestone (the reagent used in wet scrubbers), including 5 percent waste, is 105.3. The molar weight of lime (the reagent assumed used in dry scrubbers), including 5 percent waste, is 59.
- <sup>5</sup> The molar weight of sulfur dioxide (SO<sub>2</sub>) is 64.064.
- <sup>6</sup> These assumptions were used in the analysis summarized in Analysis of 6 and 8 Million Ton and 30 Year/NSPS and 30 Year/1.2 lb. Sulfur Dioxide Emission Reduction Cases, prepared by ICF Incorporated for the Environmental Protection Agency, February 1986.

## **REGULATION OF COAL COMBUSTION WASTE DISPOSAL IN SEVENTEEN HIGH COAL-BURNING STATES**

This appendix contains a state-by-state description of coal combustion waste disposal regulation. The 17 states whose regulations are described below are the highest coal-burning states in the country -- together they account for over 70 percent of the nation's coal-fired electric capacity. This appendix supplements the description of state regulation found in Chapter 4 and serves as a companion document to the table shown in Exhibit 4-1.

### **Texas**

Coal combustion wastes are regulated under Texas' Industrial Waste Management Regulations. The regulations cover two types of waste, referred to as Class I and Class II wastes, although they do not give any information about how a particular waste stream would be classified. Class I wastes are controlled to a greater extent than are Class II wastes; ground-water monitoring is required at Class I waste facilities. The regulations include no additional design or operating requirements for either type of waste. A permit is required for off-site disposal; on-site disposal requires notification only.

The report conducted for USWAG by Wald, Harkrader, and Ross, Survey of State Laws and Regulations Governing Disposal of Utility Coal-Combustion By-Products, gives information on additional requirements in Texas: "For both on-site and off-site disposal, the Department performs a site-specific technical review based on written guidelines that recommend installation of soil-based liners, ground-water monitoring and vegetative cover. Surface impoundments containing wet fly ash should be scrutinized for excess leachate

head." A follow-up interview with a Texas environmental official gave the same information. According to the interview, a new plant's waste is given temporary Class I classification until the plant proves that the waste is non-hazardous. (The official could not recall any instance of a plant's failing to do so.) Although permits are not required for on-site disposal, plants follow site-specific guidelines issued by the Department when disposing of wastes on-site.

Texas' Industrial Waste Regulations include impoundments in the definition of an industrial waste facility, but do not give separate guidelines. According to the USWAG report and the Texas official, they are subject to the same requirements as are landfills, and regulated by both state water authorities, which govern discharges to surface water, and by state solid waste authorities.

### **Indiana**

Coal combustion wastes are regulated under Indiana's Solid Waste Rules. According to these rules, permits are required for on-site and off-site disposal, and ground-water monitoring may be required. According to the USWAG survey, "both on-site and off-site facilities ... are subject to the sanitary landfill permit requirements, including ground-water monitoring, a periodic cover, and a two-foot final cover." A state environmental official stated during a follow-up interview that ground-water monitoring and other design and operating standards are required on a case-by-case basis, based on the geology of the site and on the results of a chemical testing of the waste.

The USWAG survey does not address Indiana's regulation of impoundments. The regulations only specifically apply to sanitary landfills -- impoundments are not mentioned. An Indiana environmental official states that impoundments are regulated only by the state's NPDES program, which does not specify design or operating requirements.

### **Kentucky**

Under Kentucky's hazardous waste regulations, coal combustion wastes are "special wastes." If a waste fails an EP toxicity test, its disposal will be regulated as a hazardous waste, and be subject to RCRA Subtitle C-type design and operating requirements. Otherwise, the disposal is regulated under Kentucky's solid waste rules. Kentucky's solid waste regulations require leachate control systems; according to the USWAG survey liners are also required. Ground-water monitoring requirements are implemented on a case-by-case basis.

Kentucky's solid waste regulations are for "solid waste disposal facilities," and do not explicitly exclude or include impoundments. According to an interview with a Kentucky solid waste official, if the impoundment is part of a treatment process that discharges to surface water, it must have an NPDES permit. These permits do not specify design or operating requirements. If the impoundment no longer discharges to surface water, solid waste regulations apply.

**Ohio**

Ohio's hazardous waste regulations exempt coal combustion waste from regulation. The solid waste regulations also exclude "non-toxic fly ash." No criteria are given in the regulations for determining toxicity. According to the USWAG survey and a follow-up interview with an Ohio environmental official, the ash is given an EP toxicity test to determine whether it will be subject to Ohio's solid waste regulations. Almost all ash passes the test, and is therefore exempt from all regulation.

Ohio's solid waste regulations specifically exempt "pond or lagoon operations." Such operations are regulated under Ohio's water regulations, which do not specify design or operating requirements.

**Pennsylvania**

Pennsylvania has designed regulations specifically for the disposal of coal combustion waste. These regulations specify that chemical and geologic analysis must be performed at the disposal site; and that ground-water monitoring may be required on a case-by-case basis. However, the lining and leachate collection systems that are required for other solid waste disposal facilities are not required for coal combustion waste disposal sites.

According to the USWAG report, "fly ash ponds are regulated by permit under the Clean Streams Law of Pennsylvania; the permit requires NPDES testing and design standards, which include ground-water monitoring and leachate control."

**Illinois**

Coal combustion wastes are governed by Illinois' solid waste regulations. The regulations state that a permit is required for solid waste disposal facilities. Although the regulations do not distinguish between on-site and off-site disposal, a state environmental official interviewed for this report stated that on-site facilities are exempted from the permit requirement.

Although the regulations do not explicitly require liners, ground-water monitoring, or leachate collection, an Illinois representative indicated that these standards are often required for coal combustion waste disposal on a case-by-case basis.

The solid waste regulations only list regulatory requirements for landfills -- impoundments are not addressed. An agency representative stated that impoundments are regulated by Illinois' NPDES program, which requires ground-water monitoring.

**West Virginia**

Coal combustion wastes are regulated by West Virginia's solid waste regulations, which require permits for disposal. The regulations contain only cover and closure requirements, although the USWAG survey, citing interviews with environmental officials, gives more information: "All disposal sites must meet leachate, waste confinement, and aesthetic standards. There are specific

requirements concerning ground-water monitoring and final cover."

### **Michigan**

Michigan's solid waste regulations call for on-site and off-site landfills to be permitted and to have ground-water monitoring systems. A Michigan official and information in the USWAG survey both confirmed this.

### **North Carolina**

According to North Carolina's solid waste regulations, on-site and off-site landfills must have permits. In order to receive permits, the landfills must have a ground-water monitoring system. This information is confirmed by the USWAG report.

The Solid Waste regulations explicitly exclude impoundments, and leave their regulation to North Carolina's water regulations. The official water regulations regulate only discharge from impoundments, and do not contain any design or operating requirements, such as lining or ground-water monitoring, for surface impoundments.

### **Georgia**

Georgia's solid waste regulations require permits for off-site and on-site disposal. No mandatory design or operating requirements, such as ground-water monitoring, liners, or leachate collection, are listed. According to a Georgia environmental official, design and operating standards are applied on an

case-by-case basis.

Only landfills are addressed in Georgia's solid waste regulations. According to a Georgia environmental official, surface impoundments are regulated by the state water regulations, which cover only discharge to surface water, and do not have requirements for ground-water monitoring or liners.

### **Florida**

Florida's solid waste regulations require that off-site disposal facilities be permitted and have liners, leachate collection, and ground-water monitoring systems. On-site facilities do not need permits. The regulations have been changed significantly since 1983, when the USWAG report was written. The regulations apply only to sanitary landfills -- impoundments are not specifically mentioned.

### **Missouri**

The regulation of coal combustion utility wastes are handled primarily under Missouri's solid waste regulations. According to the regulations, leachate collection systems are required on a case-by-case basis.

The solid waste regulations exempt lagoon operations that have permits from the Clean Water Commission. The Missouri Water Quality Standards do not specify any design or operation requirements for impoundments; the USWAG survey, however, states: "Permits from the Clean Water Commission impose specific requirements on ground-water quality." A follow-up interview with a



Missouri water official confirmed the information derived from the USWAG report.

#### **Alabama**

Alabama's Solid Waste Regulations require permits for off-site and on-site disposal. According to the USWAG survey, off-site disposal requires additional permission from local health authorities. The regulations require ground-water monitoring and an artificial lining on a case-by-case basis.

#### **Tennessee**

Under Tennessee's hazardous waste rules, "fly ash ... [is a] hazardous waste which [is] exempt from certain regulations." The hazardous waste regulations that apply to coal combustion by-products are for the testing of waste. An official from Tennessee indicated that the testing requirement gives the state waste agency information with which to design suitable disposal requirements for coal combustion wastes. Tennessee's solid waste rules govern the design and operation of coal combustion waste disposal facilities. Tennessee's solid waste regulations allow liners and ground-water monitoring to be required on a case-by-case basis.

Like most state solid waste regulations, Tennessee's regulations are unclear about the regulation of on-site facilities. Due to legal challenges, on-site solid waste facilities in Tennessee are not currently being regulated. Tennessee's solid waste regulations only explicitly list requirements for

sanitary landfills. Surface impoundments are not specifically addressed, although according to a Tennessee Valley Authority official, surface impoundments are regulated under NPDES permitting until the pond is full; once the impoundment no longer discharges to surface water, state solid waste regulations apply.

### **Nevada**

Nevada's solid waste regulations pertain only to landfills, and specify only siting restrictions, cover, and layering requirements; ground-water monitoring, lining, and leachate collection are not required. According to the USWAG report, in practice, more stringent requirements are enforced: "The Department now requires a liner or its functional equivalent and groundwater monitoring." Nevada's solid waste regulations require municipalities and districts to devise a waste management system, and local authorities may adopt more stringent regulations than currently mandated by state law.

The solid waste regulations of Nevada appear to address only landfills; impoundments are not explicitly mentioned.

### **South Carolina**

South Carolina regulates the disposal of coal combustion waste under its solid waste regulations. Disposal facilities must have permits, and minimal design and operating standards (cover, grade, siting) are imposed. The regulations require that facilities be designed by state-permitted engineers.

Impoundments are addressed in South Carolina's industrial solid waste disposal regulations: "Disposal of waste sludges and slurries shall be done with special consideration of air and water pollution, and the health and safety of employees ... [and] case-by-case provisions [are made]." No specific requirements are listed.

#### **Wisconsin**

In Wisconsin, coal combustion wastes are regulated under the state's solid waste regulations, which require solid waste disposal facilities to be licensed. Ground-water and leachate monitoring may be required on a case-by-case basis. Impoundments are included in Wisconsin's definition of a solid waste disposal site.

**SOURCES FOR APPENDIX C  
(By State)**

**Texas**

Texas Industrial Waste Management Regulations. Interview with Richard Anderson, Industrial Solid Waste Section, Texas Department of Health, January 2, 1987. Survey of State Laws and Regulations Governing Disposal of Utility Coal-Combustion Byproducts, prepared by Wald, Harkrader & Ross for the Utility Solid Waste Activities Group (USWAG), pp. 62-63.

**Indiana**

Indiana Solid Waste Management Permit Regulations. Interview with George Oliver, Land Pollution Control Division, State Board of Health, January 2, 1987. USWAG Survey, p. 20.

**Kentucky**

Kentucky Waste Management Regulations. Interview with Shelby Jett, Natural Resources and Environmental Protection Cabinet, Department of Environmental Protection, January 6, 1987. USWAG Survey, p. 24.

**Ohio**

Ohio Solid Waste Disposal Regulations. Interview with Tina Redman, Office of Land Pollution Control, Ohio Environmental Protection Agency, January 2, 1987. USWAG Survey, pp. 51-52.

**Pennsylvania**

Pennsylvania Solid Waste Regulations. Interview with Ron Hassinger, Bureau of Solid Waste Management, Department of Environmental Resources, January 2, 1987. USWAG Survey, p. 55.

**Illinois**

Illinois Solid Waste Regulations. Interview with Harry Chapel, Division of Land and Noise Pollution Control, Environmental Protection Agency, January 5, 1987. USWAG Survey, p. 18.

**West Virginia**

West Virginia Solid Waste Regulations. USWAG Survey, p. 69.

**Michigan**

Michigan Solid Waste Management Regulations. Interview with Karen Kligman, Resource Recovery Division, Department of Natural Resources, January 6, 1987. USWAG Survey, p. 32.

**North Carolina**

North Carolina Solid Waste Management Regulations. USWAG Survey, p. 49.

**Georgia**

Georgia solid Waste Management Rules. Interview with Burt Langley, Land Protection Branch, Division of Environmental Protection, Department of Natural Resources, January 2, 1987. USWAG Survey, p. 15.

**Florida**

Florida Resource Recovery and Management Regulations.

**Missouri**

Missouri Solid Waste Rules and Regulations. Missouri Water Quality Standards. Interviews with Suzanne Renard, Missouri Waste Management Program, and with Bob Hengtes, Missouri Clean Water Commission, January 23, 1987. USWAG Survey, p. 36.

**Alabama**

Solid Waste Management Regulations. USWAG Survey, p. 1.

**Tennessee**

Tennessee Hazardous Waste Management Rules. Tennessee Solid Waste Regulations. Interview with Dwight Hinch, Regulations and Legislative Office, December 31, 1986. USWAG Survey, p. 61.

**Nevada**

Nevada Solid Waste Management Regulations. USWAG Survey, p. 41.

**South Carolina**

South Carolina Industrial Solid Waste Disposal Site Regulations, South Carolina Guidelines for Waste Disposal Permits. USWAG Survey, p. 58.

**Wisconsin**

Wisconsin Solid Waste Management Regulations. USWAG Survey, p. 70.

## **WASTE FLUID STUDIES**

This appendix presents the results of studies on the waste fluids in coal combustion waste landfills and impoundments. Waste fluids are not ingested, but the constituents in the waste fluids have the potential to affect the quality of surrounding ground water or surface water. These studies are also useful for illustrating some of the characteristics of coal combustion wastes.

### **Tennessee Valley Authority Power Plants**

A report by R.J. Ruane and others summarized Tennessee Valley Authority (TVA) research on wet ash disposal and wet limestone scrubber-sludge.<sup>1</sup> The study on ash disposal involved 12 TVA coal-fired plants, including a description of the effects of ash disposal at a typical 1000-MW plant, which produces approximately 700 tons of fly and bottom ash per day. The ash is either disposed of in a dry form or sluiced to the ash containment ponds. The wet limestone scrubber-sludge examined in the study was from a 550-MW plant at the Widows Creek Steam Plant.

Several constituents in subsurface leachates from the ash ponds exceeded the primary and secondary drinking water standards. Constituents found in concentrations that exceeded the primary or secondary criteria included cadmium, chromium, iron, manganese, lead, sulfate, pH, and TDS. Some of the ash pond leachates were quite acidic with measured pH values as low as 2.0.

The operation of the wet limestone scrubber and the transfer of scrubber

blowdown to the ash ponds caused statistically significant increases in the concentrations of calcium, magnesium, chloride, sulfate, selenium, TDS and conductivity in the ash pond discharges.

In addition to monitoring ash pond effluents, the TVA also conducted toxicity studies on ash pond effluents from four distinct waste disposal sites. The toxicity studies were performed in the spring and fall. The fall studies showed no significant effects on the tested species (Daphnia pulex and Pimephales promelas) while the spring studies revealed significant effects on the survival and reproduction of Daphnia pulex.

In summary, several of the fly ash leachates had constituent concentrations that exceeded drinking water standards. These constituents included cadmium, chromium, iron, manganese, and lead. Higher concentrations of potential contaminants were associated with extreme pH values. Some of the fly ash leachates had pH values as low as 2.0. Some of the fly ash effluents demonstrated the potential to affect the biological environment.

#### **Turner Study of Arsenic in Coal Ash Leachate**

R.R. Turner (1981) collected ash disposal pond effluents at 12 coal-fired utilities and pond influent samples at three utilities.<sup>2</sup> At one of the sites, two wells were drilled into an older ash basin and used to collect interstitial water from the middle and bottom of the basin. All samples collected, including influents, effluents, and well samples, were analyzed for total dissolved arsenic (TDA) and for arsenic (III).

The effluents from the ponds located at the 11 largest utilities had TDA measurements ranging from 0.5 to 130  $\mu\text{g}/\text{l}$ . The arsenic (III) to TDA ratio was always 0.40 or smaller at these 11 plants. Arsenic concentrations in the pond at the smallest of the 12 plants were between 116 and 460  $\mu\text{g}/\text{l}$  in the pond influent and varied from 118 to 150  $\mu\text{g}/\text{l}$  in the pond effluent. The interstitial fluid drawn from the wells located in the middle and bottom of the older fly ash disposal site had arsenic concentrations that reached 550  $\mu\text{g}/\text{l}$  in the middle well and 1590  $\mu\text{g}/\text{l}$  in the well placed at the bottom of the fly ash. Arsenic (V), the less toxic state of arsenic, was the predominant arsenic species in all of these samples.

There was a wide variability in arsenic concentrations in all of the samples collected from the field as well as in the effluents from column leaching studies that were conducted concurrently with the field studies. This demonstrates the inherent variability of the fly ashes and the environments in which they are located, and thus the difficulty of trying to determine generic conditions for fly ash disposal. Arsenic (V) concentrations appeared to be controlled either by adsorption onto amorphous iron oxyhydroxides in the neutral to slightly acidic pH range or by slightly soluble metal arsenates. Mechanisms controlling arsenic (III) concentrations were not determined by this study.

The study results suggest that the use of iron oxyhydroxides in limiting the migration of trace elements may be beneficial at selected sites.



### **Savannah River Project, Aiken, South Carolina**

In a series of papers, Cherry, Guthrie, and co-workers studied the drainage system for an ash basin serving a coal-fired power plant at the Savannah River Project in Aiken, South Carolina.<sup>3</sup> To provide data for these papers, surface water samples were collected from the influent to and effluent from several large ash basins. Also, samples were taken at several points within the drainage system downstream from the ash disposal ponds. These samples were analyzed to determine the concentrations of constituents.

Plants, invertebrates, and vertebrates were also monitored. These studies took place over a period of more than eight years from mid-1973 to January 1982. During this time, selected water quality parameters were monitored on a monthly, bimonthly, or quarterly basis. By studying the various sinks for the constituents in the effluents from the ash disposal ponds, conclusions were reached as to the dissipation mode of constituents in the surface waters of the drainage system. Differences in constituent concentrations accumulated in the various components of the system were tested by a two-tailed analysis of variance.

The biotic components of the drainage system tended to contain higher concentrations of potentially toxic constituents (titanium, manganese, copper, chromium, zinc, arsenic, selenium, cobalt, cadmium, and mercury) than the surface water components inhabited by the biota. The highest concentrations of constituents occurred in the benthic sediments; the settling of sediments represented the mechanism for the greatest removal of constituents from the

system. Certain constituents, calcium and zinc, were concentrated in invertebrates and fish at a higher level than that found in the sediments. Two constituents, cadmium and selenium, were present in the effluents from the ash ponds in concentrations that exceeded the primary drinking water standards. Though concentrated by invertebrates, the invertebrate concentration of these constituents did not exceed the concentration found in the sediments. At near neutral pH values (pH 6.5), mean concentrations of arsenic, cadmium, chromium, copper, selenium, and zinc in the effluent drainage system were higher than either the maximum and/or 24 hour average allowable for these parameters in the U.S. EPA Water Quality Criteria.<sup>7</sup> The mean elemental concentrations of four of these constituents (cadmium, chromium, copper, and zinc) were from one to two orders of magnitude higher than the allowable 24 hour average.

When the ash disposal system was properly managed, there appeared to be a minimal effect on the aquatic system. However, when an ash pond overflowed into the effluent drainage system without adequate time for settling of the sediments to occur, major impacts upon the effluent drainage system were observed. Heavy sediment concentrations and low pH conditions (the extreme effluent pH observed was 3.5) caused by the overflow resulted in severe reductions of most invertebrate fauna. The invertebrate population densities eventually returned to pre-overflow levels when the problem was corrected. The bioconcentration of potentially toxic constituents will, undoubtedly, have an effect on the biota. It is impossible to ascertain the effect of constituent accumulation from the ash ponds, however, because the constituent concentrations prior to initiation of this study are not known. Several trace

metals have concentrations in ash pond effluents that exceed the primary drinking water standards.

**Bull Run Steam Plant, Oak Ridge, Tennessee**

In cooperation with personnel from the TVA, Coutant and others<sup>4</sup> investigated the chemistry and biological hazard of seepage from an ash pond at the TVA's 900-MW Bull Run Steam Plant near Oak Ridge, Tennessee. Ash from the Bull Run Steam Plant is slurried to three ash ponds connected in a series. The ash stream consists of fly ash, bottom ash and pieces of pyrite that were separated from coal prior to combustion. The three ponds act as settling ponds to allow ash particles to drop out of solution. At the end of the third pond is a weir over which effluent flows into the Clinch River. Monitoring at the discharge weir has been regularly conducted since 1967. During this time, analyses have been performed for a variety of constituents including alkalinity, conductivity, TDS, calcium, magnesium, chloride, sodium, total iron, total manganese, sulfate, and silicon dioxide.

In addition to the flow through the ash ponds and over the weir, there is another flow that was previously uncharacterized. This flow was in a drainage ditch that ran parallel to one of the ash ponds. The drainage ditch ends at a culvert that flows into the Clinch River. The sediments at the bottom of the drainage ditch, the water in the ditch and vegetation that had blown into the ditch were all colored a reddish hue. The objective of this study was both to characterize and understand the mechanism responsible for the reddish hue and to check for biological hazard by exposing fish to the drainage discharge at

its confluence with the Clinch River. Samples were taken so as to follow the flow in the drainage ditch from its uppermost point to its point of discharge at the river.

The reddish precipitate contained over 40 percent iron and was determined, by x-ray diffraction, to be mainly  $\text{FeOOH}$ . The formation of the precipitate was consistent with the chemical data which revealed that iron concentrations in the drainage liquor continuously decreased along the flow path. Total dissolved iron concentration was 927 mg/l at the beginning of the ditch, and fell to 320 mg/l by the time the liquor reached the culvert that discharged into the Clinch River. Concomitant with the drop in total dissolved iron, ferrous iron concentrations fell and ferric iron concentrations rose along the same flow path. Most of the iron leaving the ash ponds went through the drainage ditch and not over the weir at the end of the ash ponds. The liquor in the ditch became more acidic as flow progressed towards the Clinch River. Initial pH values in the flow were 3.2, while the pH fell to 2.9 at the culvert. The total iron discharged from the ditch per unit time was approximately 44 times the iron discharged over the weir, even though the volume of the flow over the weir was roughly 20 times the flow in the ditch.

As might be expected, the discharge from the ditch posed a biological hazard. All fish placed in the ditch at the entrance to the culvert or in the Clinch River at the culvert discharge point died within three days. A control group of fish, placed in an unaffected part of the Clinch River, survived during the time frame of the experiment (2 weeks).

Liquor in the drainage ditch from the ash pond leachate poses a biological threat. This threat is limited because of dilution by the significantly greater flow of the Clinch River. The acidification encountered in this study probably is a result of the oxidation of the pyritic ore that was discharged to the ash ponds. Oxidation of pyrite produces hydronium and sulfate ions. Lower pH values, besides posing a threat to the environment because of the acidity, can mobilize many trace constituents found in the ash. Analyses were not performed for trace constituents in this study.

## APPENDIX D

### NOTES

- 1 Ruane, R.J., J.D. Milligan, R.C. Young, T.Y.J. Chu and H. Olem. "Aquatic Effects of Wet Ash Disposal and Wet Limestone Scrubber Systems." In International Conference on Coal Fired Power Plants and the Aquatic Environment. Supplement to Proceedings. CONF-8208123, Hoersholm, Denmark, Water Quality Institute, pp. 669-673, 1982.
- 2 Turner, R.R. "Oxidation State of Arsenic in Coal Ash Leachate." Environmental Science Technology, Vol. 15, No. 9, pp. 1062-1066, 1981.
- 3 Cherry, D.S., and R.K. Guthrie. "Mode of Elemental Dissipation from Ash Basin Effluent." Water, Air, Soil, Pollution, Vol. 9, pp. 403-412, 1978.  
  
Cherry, D.S., R.K. Guthrie, E.M. Davis and R.S. Harvey. "Coal Ash Basin Effects (Particulates, Metals, Acidic pH) upon Aquatic Biota: An Eight-Year Evaluation." Water Resource Bulletin, Vol. 20, No. 4, pp. 535-544, 1984.
- 4 Coutant, C.C., C.S. Wasserman, M.S. Chung, D.B. Rubin and M. Manning. "Chemistry and Biological Hazard of a Coal Ash Seepage Stream." Journal of Water Pollution Control Federation, Vol. 50, pp. 747-753, 1978.

## **ARTHUR D. LITTLE STUDY OF WASTE DISPOSAL AT COAL-FIRED POWER PLANTS**

Arthur D. Little, Inc. (ADL) conducted a 3-year study for EPA's Office of Research and Development on coal ash and flue gas desulfurization waste disposal practices at coal-fired power plants. The study involved characterizing wastes generated at coal-fired power plants and gathering data to assess the environmental effects and engineering costs associated with the disposal of combustion wastes.

Results of the study were intended to be used: (1) as a technical basis to help EPA determine the degree, if any, to which disposal of these wastes should be managed to protect human health and the environment; and (2) to provide useful information on environmentally sound disposal of coal ash and FGD wastes to utility planners and state and local permitting officials.

To accomplish these goals, in-depth evaluations of six waste disposal sites around the country were undertaken. The study approach is discussed below.

### **E.1 SITE SELECTION PROCESS**

To characterize the different types of waste generated at coal-fired utility power plants, individual assessments of impacts were conducted at specific waste disposal sites. Only six sites were actually investigated, although the original intent of the study was to examine a larger number of utility disposal sites. The process by which these six sites were selected is briefly discussed below.

The 48 contiguous states were divided into 14 physiographic regions,<sup>1</sup> and coal-fired power plants for which data<sup>2</sup> was available were identified in each of these regions.<sup>3</sup> Sites were then screened to identify those for which a reasonable assessment of data obtained from one year of environmental monitoring would be possible. Screening criteria were based on engineering/technology-related, hydrologic, and other site-selection factors (e.g., site age, generating capacity, technological or hydrogeologic complexity, waste types generated, disposal methods, site location, etc.)<sup>4</sup>

As a result of this process about 26 "candidate sites" were chosen. The "candidate sites" were then subjected to further evaluation to assess their suitability. This included:

- contact with the facility to determine its willingness and ability to cooperate in the study.
- a visit to the power plant and disposal sites; and
- review of the available data on the hydrogeologic and environmental setting of the area and site.

On the basis of these evaluations, a final number of six sites were selected. These six sites were the Dave Johnston Plant in Wyoming, the Sherburne County Plant in Minnesota, the Powerton Plant in Illinois, the Elrama Plant in Pennsylvania, the Allen Plant in North Carolina, and the Smith Plant in Florida. Factors that were considered to be important in the selection of each site for of the study are discussed in subsequent sections.



## **E.2 SITE INFORMATION**

Exhibit E-1 shows the general locations of the six sites of the ADL study. Exhibit E-2 provides information from each site, including generating capacity, operating dates, and waste type and disposal method.

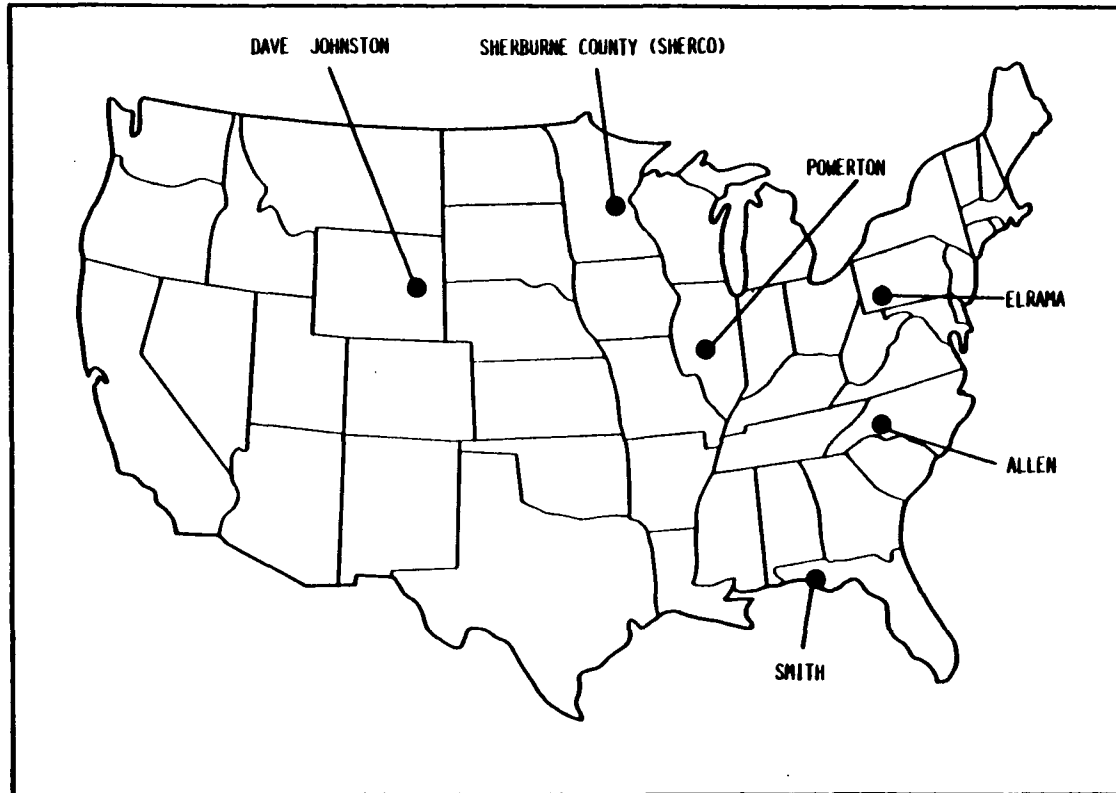
## **E.3 STUDY APPROACH**

Investigations carried out at the six sites included physical and chemical sampling of the wastes, soils, ground water, and surface water at the site, subsurface explorations utilizing boring and wells, soil and rock classification and mapping, and water balance studies. Results were used to make individual environmental assessments of each site (i.e., assessing the effects of waste disposal on ground-water and surface-water quality). Findings from the six sites were also used to try to make generic projections of industry-wide implications of coal ash and FGD Waste Disposal.

The six sites are discussed individually in the following sections, E.4-E.9. A brief description is given of each site's disposal activities, hydrogeology, and reasons for its selection by ADL for study. Also presented are the results of testing done at the site and discussion of these results. An analysis of the testing results at the six sites for QA/QC is presented in Section E.10. A summary of findings at each site and a discussion of conclusions that can be drawn from the ADL study in regard to the environmental impacts that may occur due to waste disposal practices at coal-fired power plants is presented in Chapter 5.

## EXHIBIT E-1

### LOCATIONS OF SITES SELECTED FOR ADL STUDY



Source: Tetra Tech, Incorporated, Groundwater Data Analyses at Utility Waste Disposal Sites. This report evaluated the A.D. Little data for the Electric Power Research Institute.

# EXHIBIT E-2 INFORMATION ON SITES OF ADL STUDY

Plant	Utility	Location		Capacity (MW)		Startup Date		Waste Site Under Study		High Priority Issues Under Study		
		State	County	Nameplate Generating	FGD Unit On	Plant	FGD	Waste Type	Disposal Method	Ground-water Quality	Surface-water Quality	Potentially Mitigative Practice
Allen	Duke Power	NC	Caston	1155	-	-/57	-	Combined fly and bottom Ash	Pond (UL)	x	x	x
Elrama	Duquesne Light	PA	Washington	510	510	6/52	10/75	Stabilized FGD waste Combined fly and bottom ash	Landfill (UL; offsite) Landfill (UL)	x	x	x
Dave Johnston	Pacific Power & Light	WY	Converse	750	-	-/57	-	Fly Ash	Landfill (UL)	x	-	x
Sherburne County	Northern States Power	MN	Sherburne	1458	1458	5/76	5/76	Fly ash/FGD	Pond (AL)	x	-	x
Powerton	Commonwealth Edison	IL	Tazewell	1786	-	-/72	-	Combined fly and bottom ash	landfill (AL)	x	x	x
Smith	Gulf Power	FL	Bay	340	-	6/65	-	Combined fly and bottom ash	Pond (UL)	x	x	x

## Notes:

UL - Unlined  
AL - Artificially Lined

<sup>b</sup> Disposal site operated by Conversion Systems, Inc.

#### **E.4 ALLEN PLANT**

Plant Allen of Duke Power Company is located in Gaston County, North Carolina, four miles southeast of the town of Belmont. The plant began operations in 1957. The plant site is adjacent to the west bank of Lake Wylie, an impoundment that is part of the Catawba River Development. At the time of the study, there were five units at the plant. Electrostatic precipitators were added to all units between 1965 and 1970. The Appalachian bituminous coal used for fuel had about one percent sulfur and 12 to 15 percent ash.

The coal ash disposal site at the Allen Plant consisted of two separate, major units (Exhibit E-3). One unit was the operating or active ash pond, 146 acres in size, which was unlined and dates back to 1973. Combined fly ash and bottom ash were wet-sluiced to the pond (using waters from Lake Wylie). In addition, the pond received two types of low-volume wastes: surface runoff from the power plant (including coal pile runoff) and boiler cleaning wastes. Significant amounts of copper, nickel, and zinc were added to the disposal pond during boiler cleaning events. The liquid supernatant from the pond was discharged untreated into Lake Wylie.<sup>5</sup>

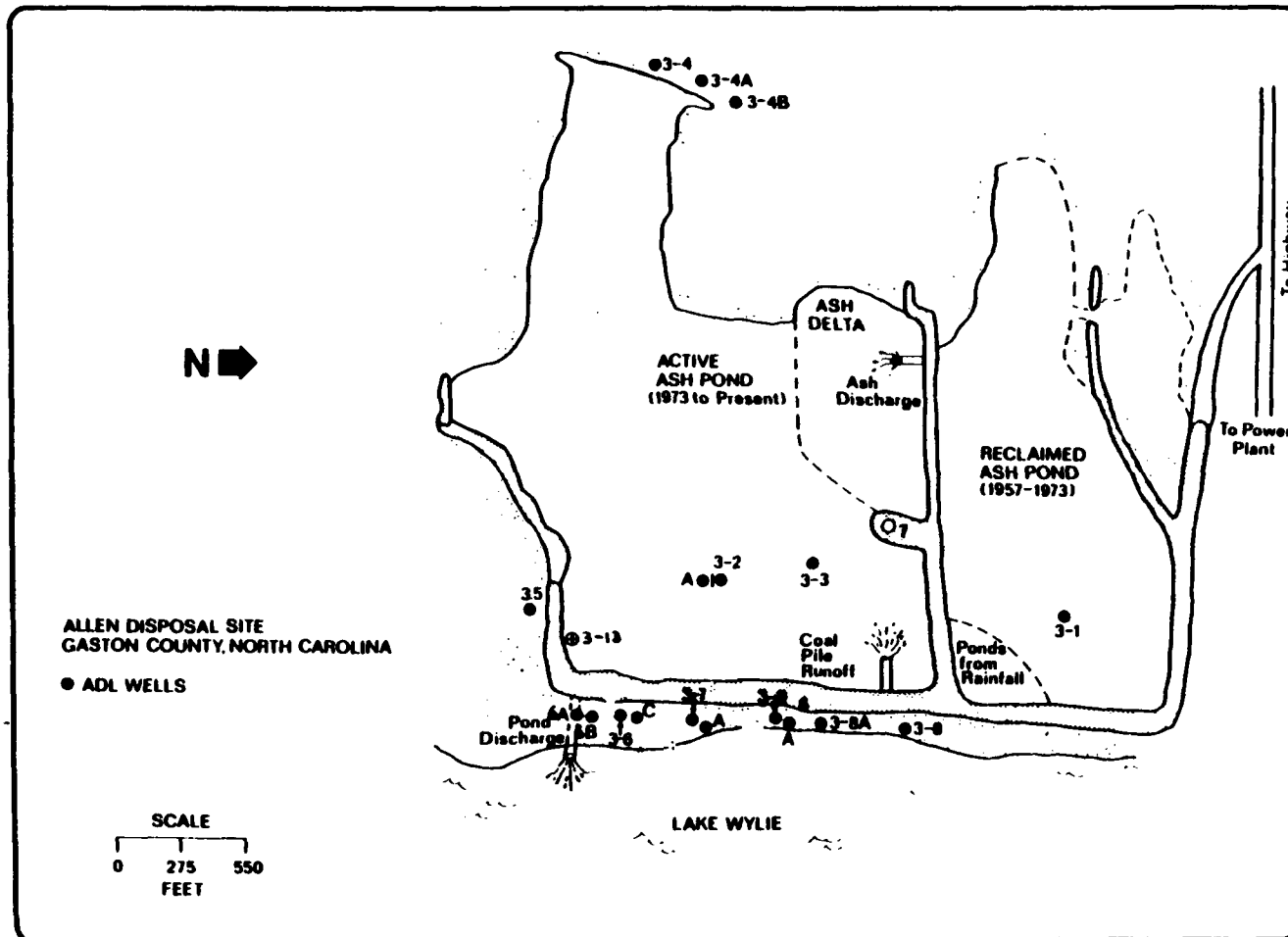
A second retired ash disposal pond was located immediately north of and adjacent to the active pond. This 127 acre facility was used from 1957 to 1973 for disposal of fly ash and bottom ash. Part of this pond had been graded, covered with soil, and seeded.

The igneous bedrock at the site slopes toward the lake and has been intruded with permeable dikes and sills. These dikes and sills tended to create

# EXHIBIT E-3

## DISPOSAL PONDS AND SAMPLING LOCATIONS AT ALLEN SITE

Source: Tetra Tech 1985.



drainage paths. Overlying the bedrock was a thick soil layer formed from the underlying bedrock. This "residual" soil layer ranged from 10 to more than 40 feet in thickness at the site, and was composed chiefly of sand and silt. Beneath some portions of the site, there were alluvial deposits filled with loose and permeable material.

The Allen site received an average of 43 inches of precipitation a year. The net ground-water recharge from precipitation was about 12 inches per year. In addition, a large amount of ash sluice water entered the pond (approximately 30 times as much water as the total direct precipitation on the active pond). There were indications that plant discharges into the disposal ponds had created ground-water mounding in their immediate vicinity and had saturated the vadose zone. The residual soil and alluvium comprised the aquifer in the vicinity of the Allen site. Upgradient from the pond, the water table was approximately 30 feet beneath the land surface. Immediately downgradient, it was continuous with the surface of Lake Wylie. Local surface and ground-water flow was easterly towards Lake Wylie.

Factors that were considered to be important in the selection of the combined fly ash/bottom ash disposal operation at the Allen Plant for study included the following:

- The site was located in the Piedmont Region, which contained significant coal-fired generating capacity;
- The practice of pond disposal of combined fly ash and bottom ash was the most common disposal practice for these wastes in the United States and virtually the only disposal practice in the Piedmont Region;

- The environmental conditions (the amount of precipitation and the mix of residual and alluvial soils) were considered typical of many other locations in the eastern half of the U.S. and are particularly representative of the Piedmont Region; and
- Co-disposal of intermittent, contaminant-rich waste streams (i.e., boiler cleaning wastes and coal pile run-off) in ash ponds occurred at Allen Plant and was also widely practiced at other utility sites.

#### **E.4.1 Sampling Approach**

Samples of wastes and soils were collected for physical and chemical testing. Samples of ground water, waste fluids (or liquors), and ash pond discharge samples were collected for chemical testing. A series of attenuation tests were executed using ash pond liquors and local site soils.

ADL installed 18 monitoring wells at the site, of which four were drilled close together but to different depths. Three wells were intended to be background (upgradient) ground-water wells, however, two (Wells 3-4 and 3-4A) were inundated more than once when the pond elevation rose. Thus only one well yielded representative background ground-water data (Well 3-4B). One downgradient ground-water well (Well 3-5) was drilled on the south side of the active pond dike. The other 10 downgradient ground-water wells were located between the active pond and Lake Wylie. Seven of these downgradient wells were drilled into the residual soils (Wells 3-5, 3-6, 3-6C, 3-7A, 3-8, 3-9, and 3-9A), one was drilled into alluvium (Well 3-6A), and two were drilled into what is identified as "fill" (it is unclear what this material is). Four of the downgradient wells were considered to be "representative" of the site -- Wells 3-6, 3-9, 3-7A, and 3-8.

One monitoring well was located within the retired ash pond (3-1) and appears to have sampled waters in and under the older waste. Three monitoring wells were drilled within the active ash pond. One sampled fluids within the ash solids (pond liquors, Well 3-2A), one sampled water within the alluvium under the ash and within the ash (Well 3-2), and one sampled water in the residual soils under the ash and within the ash (Well 3-3). Fluids from the ash pond that are discharged into Lake Wylie were also examined (Well 3-13).

Locations of site wells are shown on Exhibit E-3. Wells were sampled for contaminant concentrations on three dates. The values of and trends in sampling and analysis results for the site, and comparison of ground-water concentrations with relevant EPA standards for drinking water are discussed below.

#### **E.4.2 Results**

Exhibit E-4 presents the results of chemical sampling at the Allen site. This includes samples from the downgradient and upgradient ground-water wells, samples from wells placed within the wastes to collect interstitial waters or fluids, and water samples obtained from materials beneath the wastes.

Waste Solids. Fly ash and bottom ash wastes in the abandoned pond were found to be segregated due to different discharge locations. The bottom ash was found to have a greater permeability than the finer fly ash. No distinct zones of fly ash and bottom ash were found in the active pond. A range in permeability of  $2 \times 10^{-4}$  cm/sec to  $4 \times 10^{-3}$  cm/sec was found.



# EXHIBIT E-4

## CHEMICAL SAMPLING RESULTS FOR ALLEN SITE

ALLEN SITE  
(no Surface Water data)

Units = ppm		Ground water						Water In and Under Waste						Waste								
PCWS		1/ Total Downgradient (11 wells)			2/ "Representative" Downgrad. (4 wells)			3/ Upgradient (1 well)			4/ Water Under Active Pond (2 wells)			5/ Water Under Retired Pond (1 well)			6/ Pond Liquors (8 stations)					
Contam.	Drinking Water Standard	Total Samples	Exceed. Samples	7/ Max. Exceed.	Total Samples	Exceed. Samples	8/ Max. Exceed.	Total Samples	Exceed. Samples	7/ Max. Exceed.	Total Samples	Exceed. Samples	8/ Max. Exceed.	Total Samples	Exceed. Samples	7/ Max. Exceed.	Total Samples	Exceed. Samples	8/ Max. Exceed.	9/ Detect.	10/ Ave. Conc.	8/ Max. Exceed.
Arsenic (liq.)	0.05	12	0		7	0		2	0		4	0		2	2	1.1		5	0.55		30.5	
Barium	1	31	0		12	0		3	0		6	2	1.3	3	0			7	0.23			
Cadmium 11/	0.01	31	0		12	0		3	0		6	0		3	0			1	0.053		5.3	
Chromium (Cr VI)	0.05	31	0		12	0		3	0		6	0		3	0			4	0.014			
Fluoride	4.0	34	0		14	0		4	0		7	0		3	0			7	0.79			
Lead	0.05	31	0		12	0		3	0		6	0		3	0			0				
Mercury	0.002	0			0			0			0			0				12/ NS				
Nitrate 13/	45	34	0		14	0		4	0		7	0		3	0			8	1.4			
Selenium (liq.)	0.01	5	0		4	0		2	0		2	0		1	0			3	0.0047			
Silver	0.05	31	0		12	0		3	0		6	0		3	0			0				
SDWS																						
Chloride	250	34	0		14	0		4	0		7	0		3	0			8	9			
Copper	1	31	0		12	0		3	0		6	0		3	0			4	0.026			
Iron	0.3	31	7	82	12	3	48	3	0		6	3	89.7	3	0			7	0.02			
Manganese	0.05	31	19	102	12	5	54	3	1	1.4	6	6	280	3	0			7	0.1			
Sulfate	250	34	0		14	0		3	0		7	0		3	0			8	137			
Zinc	5	31	0		12	0		3	0		6	0		3	0			1	0.03			
pH Lab 14/	<=6.5	10	10	4.7	4	4	6.1	1	1	5.9	2	2	6.3	1	0			12/ NS				
	>=8.5	10	0		4	0		1	0		2	0		1	1	10.2		12/ NS				
pH Field 14/	<=6.5	28	21	4.4	10	4	5.9	3	2	6.2	6	2	6.4	3	0			12/ NS				
	>=8.5	28	0		10	0		3	0		6	0		3	3	11.4		12/ NS				

**EXHIBIT E-4 (Continued)**  
**CHEMICAL SAMPLING RESULTS FOR ALLEN SITE**

- 1/ Wells 3-5 (this well is somewhat peripheral to pond), 3-6, 3-6C, 3-7A, 3-8, 3-9, 3-9A, 3-6A, 3-6B, 3-6A, and 3-7.
- 2/ Wells 3-9, 3-7A, 3-6, and 3-8. These wells were chosen by AOL as being representative of the downgradient groundwater.
- 3/ Well 3-4B.
- 4/ Wells 3-2 (all.) and 3-3 (res.). The fluids collected at these wells are from beneath the active ash pond.
- 5/ Well 3-1. The fluids from this well are from beneath the retired ash pond.
- 6/ Stations 3-2 (16-18 ft), 3-2 (20-22 ft), 3-2 (24-26 ft), 3-2 (38-40 ft), 3-2A (24.5-26.4 ft), 3-3 (10-12 ft), 3-3 (22-24 ft), and 3-3 (24-26 ft). These "pond liquors" are fluids collected from within the landfilled wastes.
- 7/ The number of samples with reported concentrations above the drinking water standard.
- 8/ Max. Exceed. is the concentration of the greatest reported exceedance divided by the drinking water standard for that particular contaminant. The only exception is for pH, where Max. Exceed. is the actual measurement.
- 9/ The number of "pond liquor" samples with reported concentrations above the reported detection limits. An entry of "0" indicates that no sample had a detectable contaminant concentration; not that no samples were taken (see footnote 13).
- 10/ Ave. Conc. is the average of the reported concentrations of all "pond liquor" samples taken that showed a contaminant concentration above the detection limit. The reported pH measurements of the "pond liquors" are also averaged.
- 11/ Where the reported detection limit for cadmium was greater than the drinking water standard and the sample contained less contaminant than the reported detection limit, the sample is tabulated as being below the drinking water standard. For some water samples collected from total and "representative" downgradient groundwater, upgradient groundwater, and under the active and retired ash ponds, the reported detection limit of 0.1 was greater than the PDWS for cadmium.
- 12/ The solubility of fluoride in water is markedly affected by temperature. Of the temperature ranges and corresponding maximum allowable contaminant levels reported for fluoride in the NIPWQS, the range shown on this table (26.3-32.5 C) corresponds to the most stringent allowable maximum contaminant concentration.
- 13/ NS = not sampled.
- 14/ As indicated in footnote B, the Max. Exceed. column for reported pH measurements is a tabulation of the actual measurements, not the maximum exceedance divided by the drinking water standard.

Waste Fluids. Results from fluid samples collected from wells implanted within the waste indicate that these fluids or pond liquors, when compared to Primary Drinking Water Standards, exhibit elevated concentrations of arsenic (up to 31 times the PDWS) and chromium (up to 2 times the PDWS). Although waste fluids are not directly ingested, comparison to the drinking water standards are shown to indicate the potential for contamination at the site.

Observed levels of arsenic in the pond liquors were up to 31 times the PDWS. Although interpretations to EP (extraction procedure) test results cannot be readily made, it should be noted that the results of EPA Extraction Procedure (EP) tests on waste samples from this site indicated much lower levels (about two orders of magnitude) of arsenic than the elevated concentrations of arsenic measured in waters from within the ash.

Water samples obtained from in and under the closed ash pond exhibited a slight exceedance of the PDWS for arsenic. The pH of these samples (as high as 11.4) indicated alkalinity. Water samples obtained from in and under the active ash pond exhibited a slight exceedance of the PDWS for barium (1.4 times the PDWS). These samples also exhibited elevated concentrations of iron (up to 90 times the SDWS), elevated concentrations of manganese (up to 280 times the PDWS), and slight acidity (pH as low as 6.3).

Ground water. Estimates were made of seepage velocities at the site. Results from these calculations appeared to indicate that there had been enough time for waste leachate constituents in the eastern (downgradient) portion of the disposal pond to have reached downgradient wells and Lake Wylie.

No exceedances of Primary Drinking Water Standards were found in the ground water of the downgradient wells or the ground water of the upgradient wells. Secondary Drinking Water Standards were found to be exceeded in the downgradient ground water for iron (up to 82 times the SDWS) and manganese (up to 102 times the SDWS). These contaminants were not observed in the pond liquor samples, but were the same as those observed in water samples collected in and under the wastes of the active pond. Downgradient ground water was found to be slightly acidic (pH as low as 4.4). Secondary Drinking Water Standards were also found to be exceeded in the upgradient ground water for manganese (up to 1.4 times the SDWS). The pH also indicated slight acidity (pH as low as 5.9) in the upgradient ground water.

Surface Water. No surface water samples were collected at this site.

Attenuation Tests. The results of attenuation tests with pond liquor solutions and site soils indicated that the local soil attenuation capacity for arsenic was very high (10 micrograms/gram of soil). It appears likely that arsenic was chemically attenuated by iron and/or manganese oxides which were found to be present in high levels in the soils under and around the ash pond. The degree of attenuation was also determined to be high for selenium. The estimated chemical attenuation of strontium and sulfate was found to be moderate.

Ash Pond Discharge. Ash pond discharges are discharged directly into Lake Wylie. Results from sampling are presented in Exhibit E-5. Arsenic was found to exceed the PDWS (up to 1.25 times the PDWS) in the discharge samples and manganese was found to exceed the SDWS (up to 1.8 times the SDWS). These

## EXHIBIT E-5

## ASH POND DISCHARGE RESULTS FOR ALLEN SITE

## ALLEN SITE

(Direct ash pond discharge into Lake Wylie)

Units = ppm		Lake Wylie Discharge		
PDWS		Discharge (1 station)		
Drinking Water Standard		2/ 3/		
Contam.	Water Standard	Total Samples	Exceed. Samples	Max. Exceed.
Arsenic (liq.)	0.05	1	1	1.2
Barium	1	2	0	
Cadmium	0.01	2	0	
Chromium (Cr VI)	0.05	2	0	
Fluoride	4.0	2	0	
Lead	0.05	2	0	
Mercury	0.002	0		
Nitrate 4/	45	2	0	
Selenium (liq.)	0.01	1	0	
Silver	0.05	2	0	
SDWS				
Chloride	250	2	0	
Copper	1	2	0	
Iron	0.3	2	0	
Manganese	0.05	2	1	1.8
Sulfate	250	2	0	
Zinc	5	2	0	
pH Lab 5/	<=6.5	0		
	>=8.5	0		
pH Field 5/	<=6.5	2	0	
	>=8.5	2	1	8.9

1/ Station 3-13.

2/ The number of samples with reported concentrations above the drinking water standard.

3/ Max. Exceed. is the concentration of the greatest reported exceedance divided by the drinking water standard for that particular contaminant. The only exception is for pH, where Max. Exceed. is the actual measurement.

4/ The PDWS for nitrate measured as N is 10 ppm.

5/ As indicated in footnote 3, the Max. Exceed. column for reported pH measurements is a tabulation of the actual measurements, not the maximum exceedance divided by the drinking water standard.

samples were also found to be alkaline and in exceedance of Secondary Drinking Water Standard for pH (pH up to 8.9).

#### **E.4.3. Discussion and Conclusions**

At all ground-water sampling locations at the Plant Allen site, levels of contaminants did not exceed Primary Drinking Water Standards. Some exceedances of Secondary Drinking Water Standards were noted, including iron at downgradient wells and manganese at downgradient and upgradient wells. Samples at both upgradient and downgradient ground-water wells were also found to be slightly to moderately acidic, with a seeming increase in acidity in downgradient well samples. In fluids obtained from the pond wastes (pond liquors), highly elevated concentration levels of arsenic were detected.

It is not clear to what extent migration of waste leachate to downgradient ground water had occurred. Examination of concentrations for ash solutes such as sulfate, boron, chloride, calcium, magnesium, strontium, and sodium in upgradient versus downgradient wells and in pond liquors indicated that these constituents are present in higher concentrations in pond liquors and in ground-water wells downgradient from both active and retired ponds than in upgradient or background ground water. Consequently, this indicates that some leaching and migration of ash wastes had occurred to the extent that solutes have reached the downgradient wells. At the time of the study, no serious degradation of water quality due to ash leaching had occurred. Whether this has changed or may change in future years is discussed below.

The surrounding soils in the immediate vicinity of the ponds appeared to

have been able to attenuate the contaminants arsenic and boron, thereby limiting their downgradient movement. The results of the attenuation tests were evaluated along with the water balance, geological profile, mass balance and physical testing data to estimate the potential for long-term leaching of arsenic from the ash ponds to Lake Wylie. It was estimated that the attenuation capacity of the surrounding soils would be sufficient to prevent passage of arsenic leachate with concentrations in exceedance of drinking water standards into Lake Wylie for longer than the estimated 15 year operating life of the active pond.

As mentioned previously, it was likely that at the time of the study only leachate generated in the downgradient (eastern) portions of the ash ponds had begun to reach downgradient ground-water well locations, and that leachate from the upgradient (western) portions had not yet reached downgradient ground-water wells. This suggests that the downgradient ground water had not yet reached steady state conditions (or concentrations) with respect to the movement and admixing of leachate generated by the ponds, since steady state conditions (i.e., all potential flow paths carrying leachate) would not be achieved until the whole pond contributes leachate to downgradient locations. This means that concentrations of contaminants present in leachate of the waste (pond liquors) could be expected to increase in downgradient ground water over the next several years. While a precise estimate of future ground-water quality at the site cannot be made, steady state concentrations may range between existing concentrations and concentrations typical of ash leachate.

Since Primary Drinking Water Standards contaminants appeared to be either attenuated by soil at the site or were not present at elevated concentrations in

the pond liquors, ground-water degradation by these constituents may not be expected in the future. If arsenic had not been attenuated by soils at the site, future concentrations of arsenic in downgradient ground water could have been as high as 31 times the Primary Drinking Water Standard (the concentration in pond liquors). Additionally, since the Secondary Drinking Water Standard's contaminants were not observed to exceed standards in either the pond liquors or the downgradient wells, significant degradation of the ground-water quality due to future increases in downgradient concentrations (incremental leachate impacts) of these contaminants would not be expected.

It has been suggested that the lack of elevated concentrations observed in the ash pond liquors of elements added to wastes from boiler cleaning wastes (copper, nickel, zinc) was due to their precipitation upon mixing with pond liquors.

In summary, Allen Plant in North Carolina disposed of a mixture of fly ash and bottom ash in two unlined disposal ponds, one retired and one in active use. Intermittent waste streams, such as boiler wastes and coal pile runoff, were also disposed of in the ponds. While comparisons of concentrations of waste-related constituents in upgradient and downgradient ground water and in waste fluids indicated that leachate migration had occurred, exceedances of the Primary Drinking Water Standards were not found to occur in ground-water samples (i.e., no significant degradation of ground-water quality). Elevated concentrations of arsenic (up to 31 times the PDWS) were found in fluids within the active ash pond. Attenuation tests indicated that these concentrations of arsenic were chemically attenuated by iron and manganese in the soils beneath and surrounding the site. Ground-water contamination, particularly from arsenic, could have resulted if these attenuating soils had not been present.



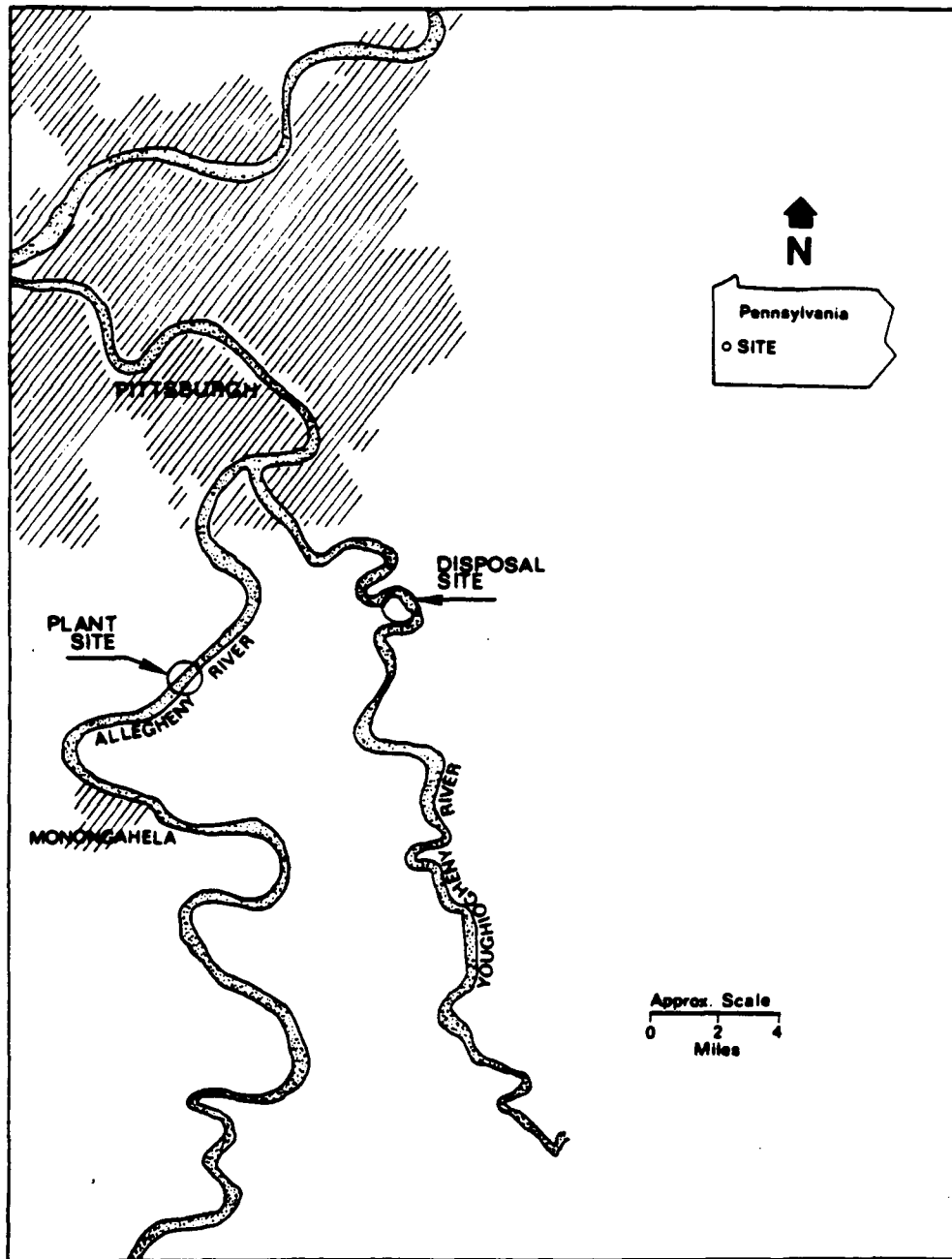
Secondary Drinking Water Standards were found to be exceeded in both the upgradient and downgradient ground water for manganese and in the downgradient ground water for iron. This was attributed to high concentrations of these elements present in the soils of the site. ADL calculations of seepage velocities at the site suggested that it was possible that steady-state conditions had not been achieved. Increases in downgradient ground-water concentrations of non-attenuated waste leachate species may be expected in the future.

#### **E.5 ELRAMA PLANT**

The Elrama Power Plant is located in Washington County, Pennsylvania, approximately 20 miles south of Pittsburgh. At the time of the ADL study, it had four units and burned Appalachian coal having 2-2.5 percent sulfur and 19 percent ash. Waste disposal methods consisted of wet sluicing bottom ash and occasionally fly ash to an on-site interim pond. The dewatered contents of the pond were subsequently excavated and removed to a landfill disposal site. In 1975, limestone scrubbers were added to remove sulfur dioxide from the flue gas. The FGD scrubber sludge was mixed with dry fly ash and lime to form Poz-O-Tec<sup>6</sup> at a processing facility on the power plant site. This fixation step was a proprietary process. The fixated sludge was then trucked approximately 12 miles east to the disposal site, in Elizabeth Township, Allegheny County, where it was placed in a landfill. The plant and disposal site locations are shown in Exhibit E-6. Disposal of scrubbing wastes at the disposal site began in 1979.

**EXHIBIT E-6**

**LOCATION OF THE ELRAMA POWER PLANT AND DISPOSAL SITE**



Source: Tetra Tech

Bottom ash and sludge from a coal pile runoff treatment pond were also disposed at the landfill. At the time of the study, approximately 1500 tons of waste were placed in the facility each day.

The disposal site was on a hillside overlooking the Youghiogheny River in Allegheny County, Pennsylvania. The area of the fill at the time of sampling was 22 acres. The waste was being disposed on top of coal strip-mine spoils, and was implanted in a series of terraced lifts. At completion, the outer part of each Poz-O-Tec lift was covered with about 2 feet of soil and seeded. A vertical profile through the disposal site is shown in Exhibit E-7. Unlined sedimentation ponds at the foot of the landfill collected surface runoff from the waste fill. The westernmost pond had an overflow discharge to the river.

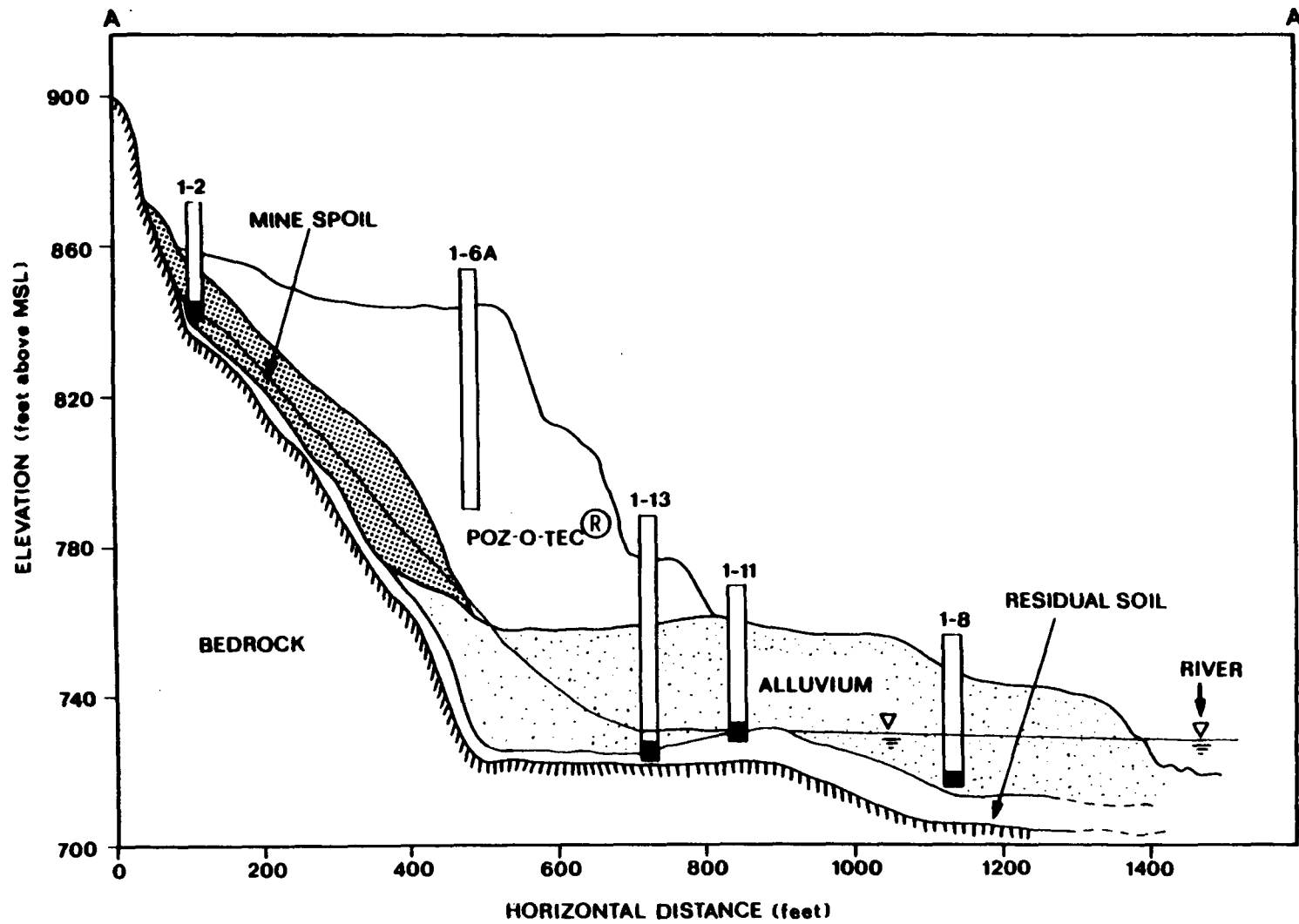
The bench that the landfill was located on was created by mining of the Pittsburgh coal seam. Beneath this bench, the sedimentary bedrock was overlain by floodplain deposits of aluminum (silts and sands) up to 40 feet thick. Under much of the waste, the bedrock was covered by a five to ten feet thick layer of soil and weathered rock ("residual soil"). In the westernmost part of the landfill, mine spoil materials left from previous strip coal mining operations underlay the Poz-O-Tec wastes. The spoil material was an unconsolidated mix of soil, coal wastes, and bedrock fragments. Leachate from the mine spoils was noted by the site operators as being acidic.

The average annual precipitation at the Elrama site was 38 inches. The water table at the Elrama site sloped steeply from southeast to northwest,

EXHIBIT E-7

VERTICAL PROFILE THROUGH LANDFILLED WASTES  
AT ELRAMA DISPOSAL SITE  
(FROM THE SOUTHEAST TO THE NORTHWEST)

Source: Tetra Tech

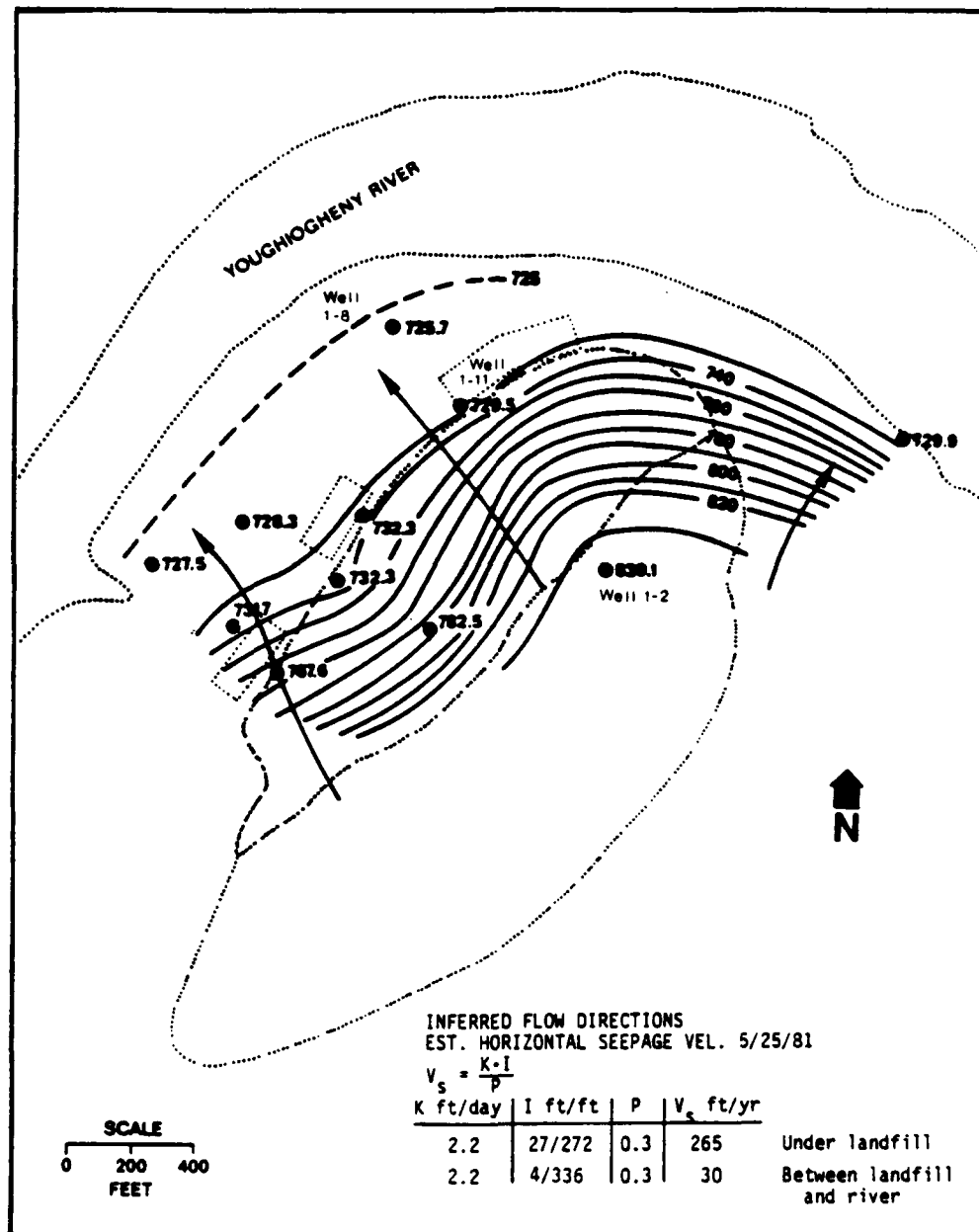


roughly parallel to the ground surface. Most of the mine spoil material was saturated during the period of the ADL study. The saturated zone extended up into the lower portions of the Poz-O-Tec fill. Ground-water levels varied considerably with the site topography, being relatively deep in the bedrock at the higher site elevations and varying from 20 to 30 feet below ground surface in the low lying alluvial deposits. All surface and ground-water flow was northwesterly to the adjacent Youghiogheny River (Exhibit E-8).

Factors that were considered important in the selection for study of the fixated FGD waste landfill operation at the Elrama disposal site included:

- Fixated FGD waste landfiling was available for study at very few sites in 1980; however, this disposal option was planned for many other locations in the United States. The type of fixation practiced at Elrama was based on controlled mixing of FGD combustion waste from a thick slurry to a highly alkaline, soil-like material. This process makes landfill disposal a practical alternative to pond disposal.
- Landfill disposal of FGD wastes in abandoned strip mines was also a growing practice at the time of the study. The Elrama landfill site occupied an abandoned coal mining area that exhibited acid mine drainage. This situation represented an opportunity to fill a significant data gap on highly alkaline waste disposal in a typical acid mine drainage setting.
- Climatic conditions (average rainfall, temperature range and typical frost penetration) was considered representative of the Appalachian Region.
- There was generally good ground-water flow expected in this setting.
- Alluvium underlying the disposal area was anticipated to provide a good monitoring medium.

## EXHIBIT E-8

GROUND-WATER FLOW DIRECTIONS AT KIRAMA  
DISPOSAL SITE

Source: Tetra Tech 1985.

- The landfill was in close proximity to surface water (Youghiogheny River), although it was separated from the river by runoff collection ponds.

#### E.5.1 Sampling Approach

Samples of wastes and soils were collected for physical and chemical testing. Samples of ground water, waste fluids (or liquors), and surface water samples were collected for chemical testing. A series of attenuation tests were performed using local site soils and pond liquor solutions (spiked with trace elements).

Sixteen monitoring wells and three lysimeters were installed at the site. One upgradient ground-water well (Well 1-14) was installed in the alluvial floodplain for background monitoring purposes, and one upgradient ground-water well (Well 1-2) was installed within the mine spoil debris. Following site development and the sampling visit, fixated FGD waste was disposed adjacent to and upgradient of well 1-2. Five downgradient observation wells (1-11, 1-8, 1-10, 1-4, and 1-5) were installed in the alluvial flood plain deposits of the Youghiogheny River. Observation wells (1-6, 1-13, 1-12, 1-15, 1-9, 1-3, 1-6A and 1-15A) and lysimeters (1-6, 1-13A, and 1-12A) were installed in the lower benches of the compacted waste fill to sample waters from beneath and within the wastes. The lysimeters were installed in the unsaturated vadose zone beneath the waste fill deposit to provide interstitial water samples which had not been in contact with any mine spoil leachate. In addition, surface water samples were collected from five sampling stations in Youghiogheny River -- four downgradient (downstream) and one upgradient.

Locations of site wells and surface water sampling locations are shown on Exhibit E-9. Sampling at the site was conducted on three occasions.

#### **E.5.2 Results**

Exhibit E-10 presents the results of chemical sampling at the Elrama site. This includes samples from the downgradient and upgradient ground-water wells, samples from the well and lysimeters implanted within the waste to collect interstitial fluids, water samples obtained from beneath the waste, and surface water samples. Results are discussed below.

Waste solids. Fly ash and bottom ash were found to occur in layers within the waste. Coefficients of permeability ranged from  $7 \times 10^{-6}$  cm/sec to  $1 \times 10^{-3}$  cm/sec.

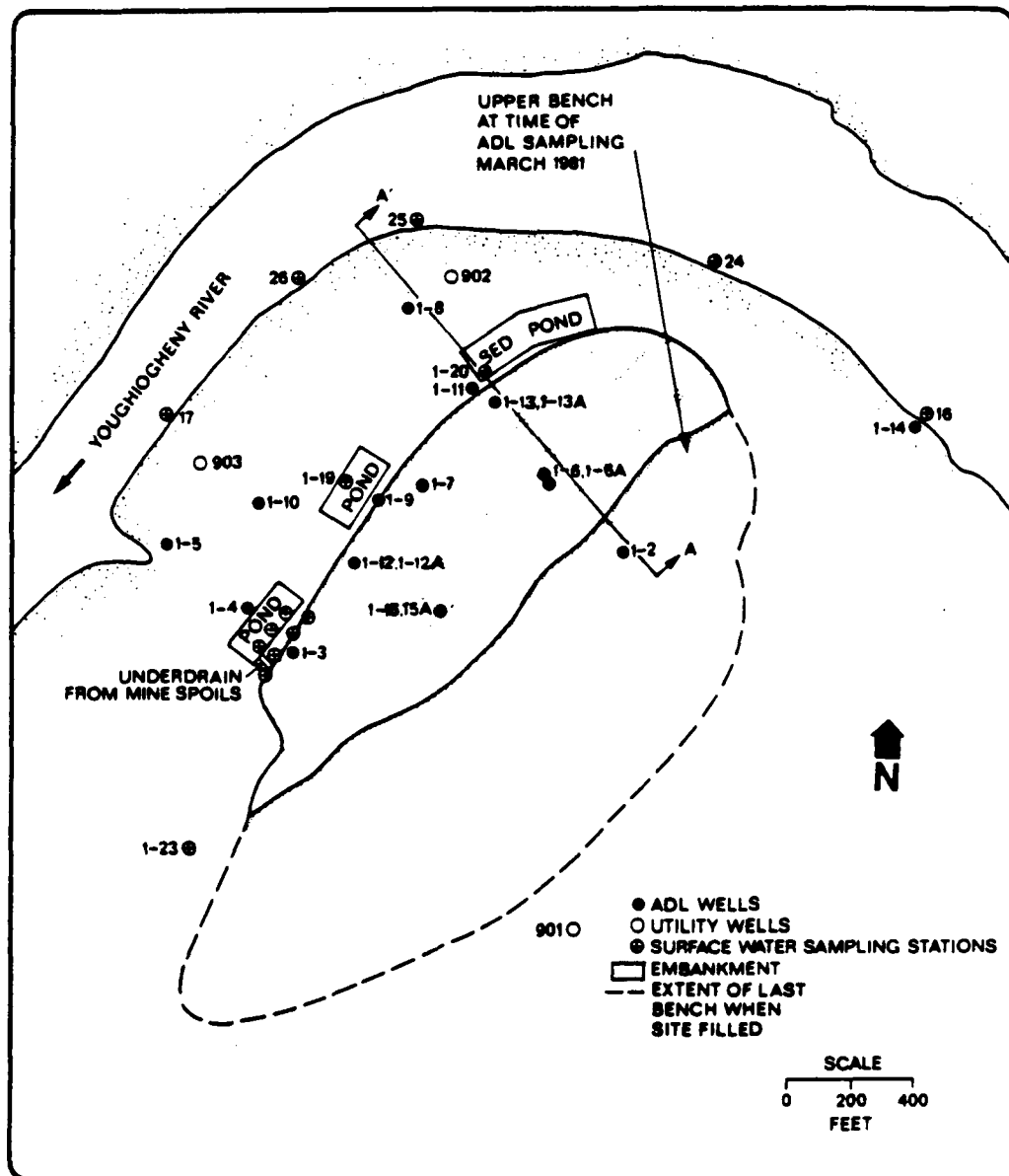
All three wastes disposed at the site, fixated (with lime and fly ash) FGD waste, bottom ash, and mine spoil, were chemically analyzed. Calcium was found to be present at much greater levels in the fixated waste than in the mine spoil. Sulfate and aluminum concentrations were found to be high in the mine spoil and the FGD waste. However, sulfate was noticeably higher in the FGD waste. Arsenic was detected at significantly higher concentrations in the FGD waste than in the other materials. Additionally, the FGD waste was found to be highly alkaline and the mine spoil acidic.

Fluids In and Beneath Waste. Fluid samples collected from the on-site waste may represent leachate from these wastes, so that examination of



## EXHIBIT E-9

## SAMPLING LOCATIONS AT ELRAMA DISPOSAL SITE



Source: Tetra Tech 1985.

# EXHIBIT E-10

## CHEMICAL SAMPLING DATA FOR ELRAMA DISPOSAL SITE

ELRAMA SITE  
(no Pond Liquor data)

Units = ppm		Ground water						In and Under Waste						Surface Water (Youghiogheny River)							
POWS		1/ Downgradient (5 wells)			2/ Upgradient (1 well)			3/ Water in and Under Waste (11 wells)			4/ Water in Mine Spoils (1 well)			5/ Downgradient (4 stations)			6/ Upgradient (1 station)				
Drinking Water Standard		7/ Total Samples		8/ Exceed. Samples		7/ Total Samples		8/ Exceed. Samples		7/ Total Samples		8/ Exceed. Samples		7/ Total Samples		8/ Exceed. Samples		7/ Total Samples		8/ Exceed. Samples	
Contam.																					
Arsenic (liq.)	0.05	1	0		2	0		13	2	5.3	2	0		1	0		1	0			
Barium	1	19	0		4	0		33	0		4	0		7	0		3	0			
Cadmium 9/	0.01	19	3	20	4	0		33	9	20	4	2	20	7	0		3	0			
Chromium (Cr VI)	0.05	19	1	1.2	4	0		33	0		4	1	1.6	7	0		3	0			
Fluoride	4.0	21	0		4	0		32	0		4	0		7	0		3	0			
Lead	0.05	19	0		4	0		33	0		4	0		7	0		3	0			
Mercury	0.002	0			0			0			0			0			0				
Nitrate 10/	45	20	0		4	0		32	0		3	0		7	0		3	0			
Selenium (liq.)	0.01	1	0		2	0		13	0		2	0		1	0		1	0			
Silver	0.05	19	0		4	0		33	0		4	0		7	0		3	0			
SDWS																					
Chloride	250	21	0		4	0		31	11	2.3	4	0		7	0		3	0			
Copper	1	19	0		4	0		33	0		4	0		7	0		3	0			
Iron	0.3	19	0		4	1	1.8	33	7	221	4	3	570	7	0		3	0			
Manganese	0.05	19	19	456	4	4	197	33	22	466	4	4	680	7	7	7.4	3	3	4.2		
Sulfate	250	19	9	4.7	4	3	1.5	33	33	8.1	4	4	9.3	7	0		3	0			
Zinc	5	19	0		4	0		33	0		4	0		7	0		3	0			
pH Lab 11/	<=6.5	0			0			0			0			0			0				
	>=8.5	0			0			0			0			0			0				
pH Field 11/	<=6.5	14	9	5.2	2	2	4.5	17	10	5.9	3	2	5.1	7	4	6.1	3	2	6		
	>=8.5	14	0		2	0		17	3	9.9	3	0		7	0		3	0			

## EXHIBIT E-10 (Continued)

### CHEMICAL SAMPLING DATA FOR ELRAMA DISPOSAL SITE

1/ Wells 1-11, 1-8 (29 ft), 1-8 (40 ft), 1-10 (36 ft), 1-10 (37 ft), 1-4 (8 ft), 1-4 (28 ft), 1-4 (41 ft), and 1-5.

2/ Well 1-14.

3/ Wells 1-3, 1-15A, 1-13A, 1-12A, 1-7, 1-6 (50 ft), 1-6 (52 ft), 1-6 (55 ft), 1-13, 1-12, 1-15, 1-9, 1-6A (52 ft), and 1-6A (50-55 ft). Lysimeters were used at wells 1-13A, 1-7, and 1-12A for sample collection.

4/ Well 1-2.

5/ Stations 1-17, 1-24, 1-25, 1-26.

6/ Station 1-16.

7/ The number of samples with reported concentrations above the drinking water standard.

8/ Max. Exceed. is the concentration of the greatest reported exceedance divided by the drinking water standard for that particular contaminant. The only exception is for pH, where Max. Exceed. is the actual measurement.

9/ Where the reported detection limit for cadmium was greater than the drinking water standard and the sample contained less contaminant than the reported detection limit, the sample is tabulated as being below the drinking water standard. For some water samples collected from downgradient and upgradient groundwater, the reported detection limit of 0.1 was greater than the PDWS for cadmium.

10/ The solubility of fluoride in water is markedly affected by temperature. Of the temperature ranges and corresponding maximum allowable contaminant levels reported for fluoride in the NIPDWS, the range shown on this table (26.3-32.5 C) corresponds to the most stringent allowable maximum contaminant concentration.

11/ As indicated in footnote 7, the Max. Exceed. column for reported pH measurements is a tabulation of the actual measurements, not the maximum exceedance divided by the drinking water standard.

results from chemical analysis of these samples can yield information on the potential for ground-water contamination.

Waters collected from materials beneath and within the wastes (utilizing monitoring wells and lysimeters) exhibited an exceedance of the Primary Drinking Water Standards for arsenic (up to 5 times the PDWS), cadmium (up to 20 times the PDWS). Exceedances of Secondary Drinking Water Standards were noted for chloride (up to 2 times the SDWS), iron (up to 221 times the SDWS), manganese (up to 466 times the SDWS), and sulfate (up to 8 times the SDWS). Exceedances were also noted for pH (as low as 5.9 and as high as 9.9).

Waters collected from within mine spoil debris beneath the waste exhibited exceedances of the Primary Drinking Water Standards for cadmium (up to 20 times the PDWS) and chromium (up to 2 times the PDWS). These samples exhibited exceedances of the Secondary Drinking Water Standards for iron (up to 570 times the SDWS), manganese (up to 680 times the SDWS), and sulfate (up to 9 times the SDWS). Values for pH indicated acidity (as low as 5.1).

The fluids collected from within and beneath the waste are not ingested; comparison to drinking water standards were done to indicate the potential for contamination at the site.

Ground water. Because of runoff transport, contaminants were expected to migrate from the wastes to the downgradient alluvium and eventually to the river relatively quickly by the runoff and seepage directed to the ponds and subsequent recharge to the alluvium. Ground-water travel times from the landfill to downgradient well locations were uncertain, but appeared to range

from one to five years for near downgradient locations and from five to ten years for far downgradient locations. Travel time from the runoff collection ponds to far downgradient locations were in the one to five year range. Thus it would appear that there had been enough time for constituents in waste leachate to have reached downgradient wells and the Youghiogheny River. However, there had also probably been ample time and opportunity for acid drainage from earlier mining operations to have infiltrated the site's ground water. Because the fixated waste had been at the site for only about 2 years at the time of sampling, solutes in leachate from the waste may not have reached wells furthest downgradient.

Primary Drinking Water Standards were found to be exceeded in the ground water of the downgradient wells for cadmium (up to 20 times the PDWS) and for chromium (up to 1.2 times the PDWS). There were no upgradient exceedances in ground water of the Primary Drinking Water Standards.

Secondary Drinking Water Standards were found to be exceeded in the downgradient ground-water wells for manganese (up to 456 times the SDWS) and sulfate (up to 5 times the SDWS). Exceedances for these contaminants were also found in upgradient ground water -- manganese at up to 197 times the SDWS and sulfate at up to 1.5 times the SDWS. Additionally, iron was found to exceed the Secondary Drinking Water Standards (1.8 times the SDWS) in the upgradient well. Both the upgradient and downgradient ground-water wells were found to exhibit pH's below the lower limit (6.5) for Secondary Drinking Water Standards. The pH of the upgradient samples were found to be as low as 4.5, and those of the downgradient samples as low as 5.2.

Surface Water. Primary Drinking Water Standards were not found to be exceeded for any contaminants in both the upgradient and downgradient surface water (river) samples. Secondary Drinking Water Standards were found to be exceeded for manganese in both the downgradient (7 times the SDWS) and upgradient (4 times the SDWS) surface water samples. Both the downgradient and upgradient surface water samples exhibited pH values below the lower limit of Secondary Drinking Water Standards (as low as 6.0).

Attenuation Tests. Attenuation tests using various pond liquor solutions and the soils obtained from the Elrama site indicated that these soils generally had moderate capacities to attenuate trace metals.

#### **E.5.3 Discussion and Conclusions**

Cadmium (up to 20 times) and chromium (up to 1.2 times) were found to exceed the Primary Drinking Water Standards in downgradient ground water. Manganese and sulfate were observed to exceed Secondary Drinking Water Standards in downgradient and upgradient ground water. Exceedances for iron were also observed in upgradient ground water. Elevated concentrations of arsenic, cadmium, chromium, and fluoride were observed in waters obtained from within and beneath the landfilled FGD wastes. Chloride, iron, manganese, and sulfate were observed at elevated concentrations in waters in and under the waste.

These results and their implications to FGD waste disposal and ground water quality at the Elrama disposal site are difficult to interpret due to the coal mining activities that had taken place -- and subsequent acid mine drainage

that was occurring -- at the site. Interpretations of the results that can be made are discussed below.

Based on sampling results, differences in concentrations between background or upgradient ground water, mine spoil leachate and FGD waste leachate, were observed to occur. Background waters were typically neutral or acidic or alkaline (alkalinity up to 5 meq/l), and had low to moderate levels of iron and manganese and low levels of total salts. Mine spoil leachate was neutral to acidic and had high levels of iron and manganese relative to background concentrations. Samples taken from fluids within the Poz-O-Tec FGD waste were found to be different from both of these two types of samples. It was neutral to alkaline, high in dissolved solids (or solutes), but low in iron and manganese, and arsenic and selenium were found to be concentrated in interstitial waters. Boron mean levels were higher in both types of waste interstitial waters than in the background samples.

All wells at the site, except the lysimeters screened in the FGD wastes, were potentially affected by both leachate from the FGD wastes and from the mine spoil. Both water quality and the water table configuration indicated that the upgradient background well (1-14) was influenced by mine spoil leachate or coal seam seepage. High pH (7.9 to 9.9) characterized ground water samples directly associated with the alkaline fixated FGD waste. As mentioned previously, neutral to low pH (4.5) characterized the background ground-water samples. Low pH was also found to characterize some of the downgradient ground-water samples. For both the background (upgradient) and downgradient samples this was very likely the result of acid mine drainage in the area. The western portion of the site exhibited the highest downgradient solute

concentrations. This observation was consistent with the higher permeabilities measured in the area, plus the fact that the disposal area of FGD wastes and mine spoils was closer to the downgradient wells here than in areas to the north.

The high levels of arsenic observed within the interstitial water or leachate of the FGD waste were not observed in downgradient ground water. Thus, it appeared that arsenic was being attenuated by the surrounding soils. High levels of arsenic were not evident in waters attributable to mine spoil leachate.

Iron and manganese concentrations were elevated at many locations. The iron concentration was especially high in ground-water samples affected by FGD-related wastes, while manganese levels seemed highest in samples more affected by mine drainage. Nonetheless, even the least contaminated ground-water samples showed levels of these constituents that exceeded the Secondary Drinking Water Standards. This may suggest that the concentrations of these constituents were characteristically high in ground water in the area, and both mining and FGD wastes are likely contributing to incremental elevations.

Concentrations of some major FGD waste constituents (e.g., sulfates) appeared generally elevated at this site, prior to its use for utility waste disposal, as a result of acid mine drainage. This is illustrated by the similar concentrations evident in lysimeters and wells downgradient of the landfill and within ground water downgradient of mine drainage.

The data did not indicate a measurable effect of the landfill on the water



quality of the Youghiogheny River. Surface water results indicated that the river was diluting migrating leachate.

The trends in contaminant concentrations over the sampling period indicated that ground water at several downgradient locations had not yet reached steady-state concentration and was only beginning to be affected by the landfill. The effects can be expected to increase over time. Even in the future, there may be little basis for qualitative distinction between the ground water affected by the fixated FGD waste and acid mine drainage at the site, and the influence of projected steady-state ground-water concentrations for many contaminants may be small in magnitude in an already contaminated situation. However, results from sampling at the Elrama site indicated that the FGD wastes had been, and may have continued to be, a source of contamination for some constituents at the site. This may be especially true for the observed cadmium contamination, since the source for this trace metal was probably less likely to be the mine spoils (overburden) than the utility wastes.

In summary, the Elrama Plant in Western Pennsylvania disposed of fixated FGD sludge-fly ash mixture (known as Poz-O-Tec) along with small volumes of bottom ash and sludge from coal pile runoff treatment ponds, in an abandoned coal-mining area twelve miles from the plant. Part of the landfill was underlain by acid-producing spoils from the strip mining of coal. Cadmium was found to exceed the Primary Drinking Water Standards in downgradient ground water by as much as 20 times, especially in the well closest to the landfill. Steady-state conditions did not appear to have been achieved at the site, so that effects of leachate from the landfill may have increased with time.

Certain Secondary Drinking Water Standards (for pH, manganese, sulfate, and iron) were found to be exceeded in both upgradient and downgradient ground water at the site. These exceedances probably occurred because of characteristics of the disposal area and because ground water was already contaminated from acid mine drainage. Results did not indicate a measurable effect by the landfill on the water quality of the Youghiogheny River.

Among the trace metal species, arsenic, in water collected from the waste deposit, was often detected at levels three to five times the Primary Drinking Water Standards, but appeared to be attenuated by site soils. Arsenic could be of concern if it were not attenuated by surrounding soils or diluted before reaching drinking water.

Results from sampling at the Elrama disposal site indicated that the fixated FGD wastes had been a contamination source at the site. Due to the contamination of the water by acid mine drainage, the FGD leachate may have had a small incremental impact on water quality.

## **E.6 DAVE JOHNSTON PLANT**

The Dave Johnston Power Plant of Pacific Power and Light Company is located approximately 30 miles east of Casper, Wyoming. The plant and its ash disposal facility are located on the north bank of the North Platte River. The plant has been in operation since 1959. At the time of the study, the subbituminous coal burned was from the Powder River Basin of Wyoming and had about 0.45 percent sulfur and 9 to 11 percent ash. Three of the generating units were equipped with electrostatic precipitators, and fly ash from these units was transported

in dry form to several landfills. The fourth unit had a wet ash scrubber, and fly ash from it was disposed in ponds north of the power plant.

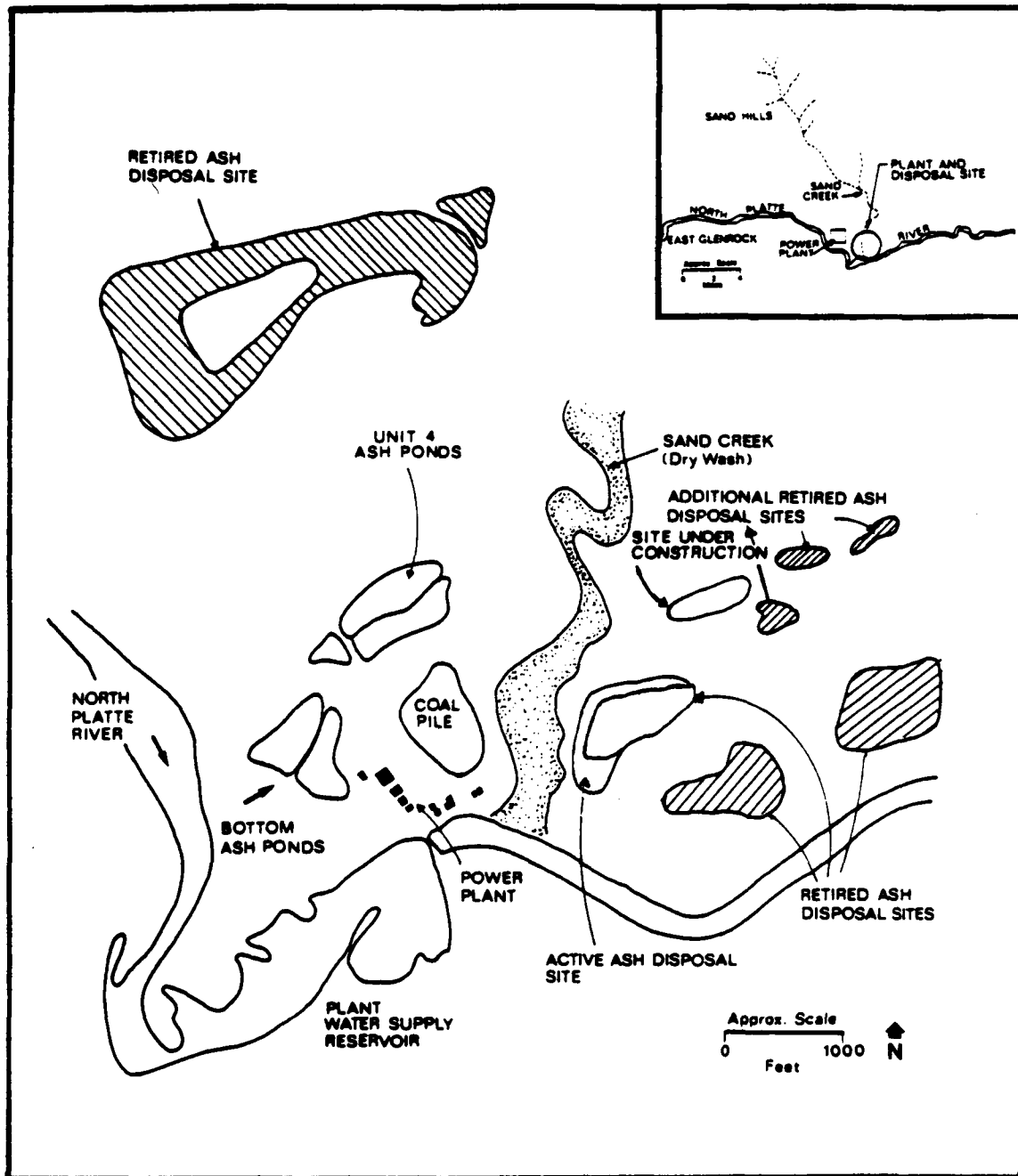
There were a number of disposal areas at this site (Exhibit E-11). The ADL study only investigated a site east of Sand Creek. Two major ash disposal areas, reflecting different times and methods of placement, were assessed. One was the existing and operational dry fly ash disposal site and municipal landfill. The other, to the southeast, was an unlined, abandoned, and reclaimed ash disposal site. The operational fly ash disposal area was excavated into the natural sand deposits. No liner was placed in the excavation which was in close proximity to the ground-water table. There were several other closed ash landfills at this site, which were estimated to be 10 to 20 years old.

The Dave Johnston Plant was selected for study primarily because it provided the opportunity to evaluate landfill disposal of dry fly ash. Other factors that were considered to be in the selection and evaluation of the landfilling operations at the Dave Johnston Plant included the following:

- The environmental setting combined significant net evaporation with a flood-plain location that would be expected to illustrate contaminant migration in identifiable patterns, while exemplifying arid western conditions.
- Active and inactive landfills were available for study in the selected portion of the site. These landfills have been developed over about a 20-year period.

## EXHIBIT E-11

## LOCATION OF DISPOSAL AREAS AT DAVE JOHNSTON SITE



Source: Tetra Tech 1985.

- The disposal operation was considered to be representative of existing and future operations at many western locations. At the active landfill studied, dry fly ash was disposed of along with small amounts of miscellaneous plant trash, a practice characteristic of western plants.

The environmental assessment carried out at this plant focused on the effect of fly ash landfill disposal on downgradient ground-water quality in an arid floodplain environment.

The Dave Johnston site was located in an arid area. The mean annual precipitation in the site vicinity was only 12 inches. The majority of the precipitation was lost through evaporation. Nearly all recharge to the ground-water system occurred during spring runoff. The area was underlain by bedrock of shales with interbedded sandstones and thin coal units. The bedrock was overlain by sand and gravel river terrace deposits and alluvial sediments. Sand dunes were common throughout the site area. Ground water was found within the site area in two different and separate hydrogeological environments -- in a deeper bedrock aquifer and in the near-surface unconsolidated fluvial deposits. The ground water flowed generally southeast across the active disposal site and south under the retired landfill (see Exhibit E-12) towards the adjacent North Platte River. At the closed landfill, located to the southeast of the active landfill, the distance between the base of the ash and the water table was about 10 feet. The active landfill was excavated to within a foot or less of the water table.

### E.6.1 Sampling Approach

Samples of wastes and soils were collected for physical and chemical testing. Samples of ground water and fluids from within the waste (pond liquors) and beneath the waste were collected for chemical testing.

Twelve monitoring wells were installed at the site. Their locations are shown in Exhibit E-13. Two were installed to sample upgradient ground water (7-5 and 7-11), three were installed to sample ground water peripheral to the disposal areas, three were installed to sample downgradient ground water (7-4, 7-6, and 7-9), and one was installed to sample ground water between the active and inactive ash landfills (7-12). One monitoring well was emplaced in each of the ash landfills to sample water from beneath these wastes (7-2 and 7-3) and one was emplaced within the active ash landfill to sample interstitial waste fluids (pond liquors -- 7-2A).

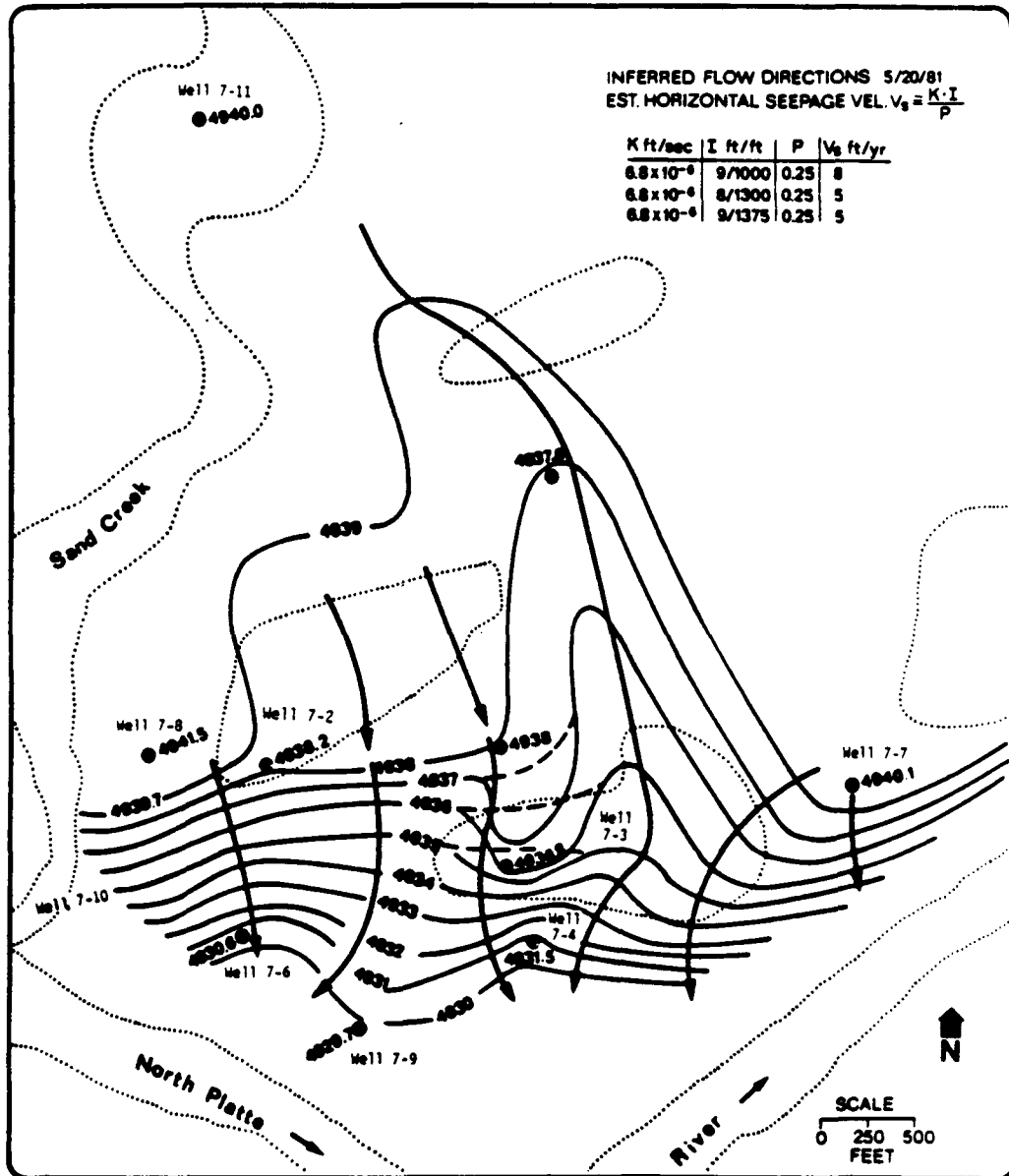
### E.6.2 Results

Exhibit E-14 presents the results of chemical sampling at the Dave Johnston site. This includes samples from the downgradient and upgradient ground-water wells, fluids samples from within the wastes, and water samples obtained from beneath the waste. Results are discussed below.

Waste Solids. Fly ash was found to be layered with bottom ash in the active ash landfill. Permeability of the waste was found to range between  $2 \times 10^{-7}$  to  $6 \times 10^{-5}$  cm/sec.

## EXHIBIT E-12

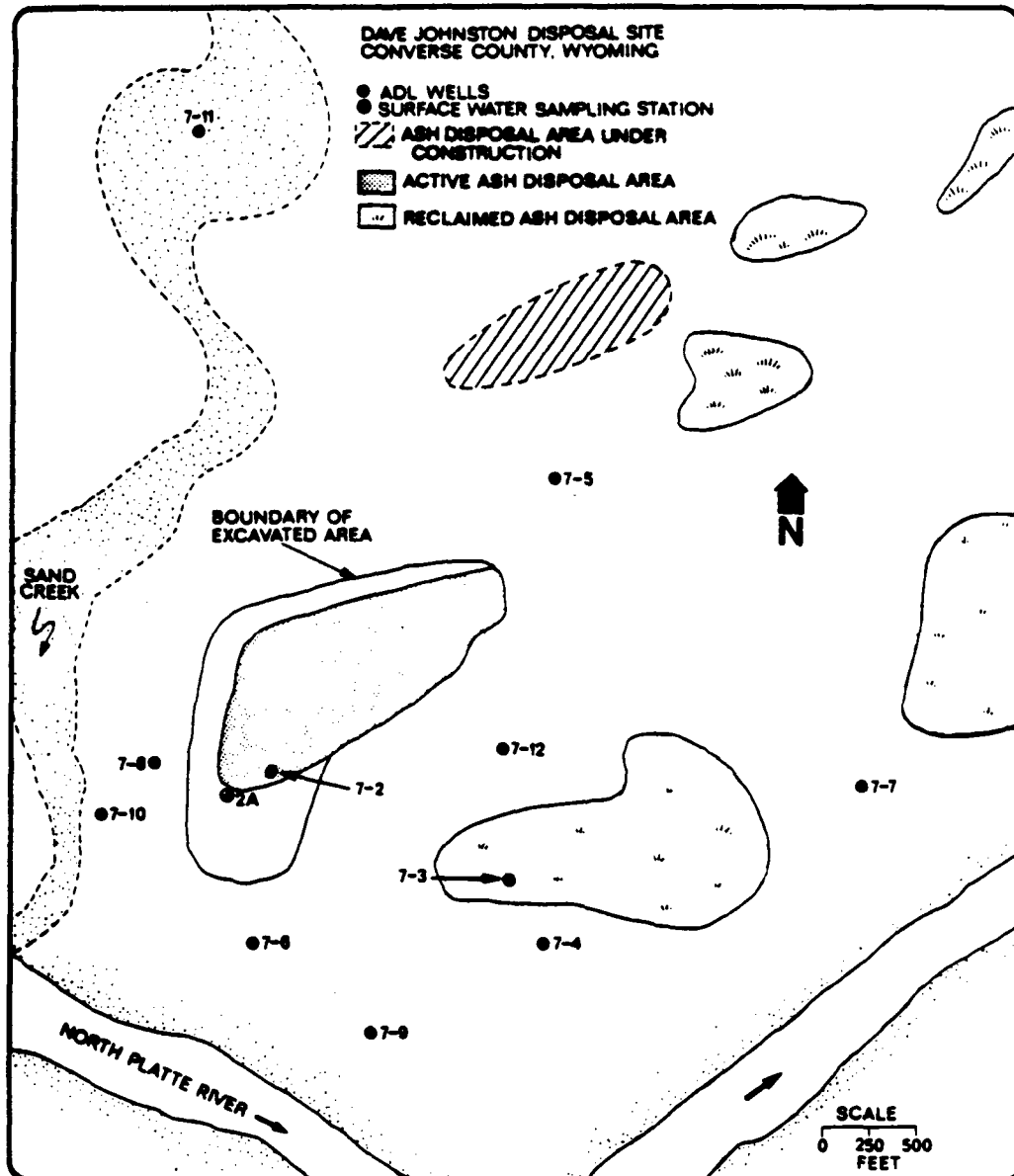
## GROUND WATER FLOW DIRECTIONS AT DAVE JOHNSTON SITE



Source: Tetra Tech 1985.

## EXHIBIT E-13

## DISPOSAL AREAS AND SAMPLING LOCATIONS AT DAVE JOHNSTON SITE



Source: Tetra Tech 1985.



# EXHIBIT E-14

## CHEMICAL SAMPLING RESULTS FOR DAVE JOHNSTON SITE

DAVE JOHNSTON SITE

(no Surface Water data)

Units = ppm		Ground water						Under Waste						Waste							
POWS		1/				2/				3/				4/				5/			
		Downgradient (3 wells)				Upgradient (2 wells)				Btw. Active/Inactive Area (1 well)				Water Under Waste (2 wells)				Pond Liquors (2 stations)			
Drinking Water Standard		Total Samples	Exceed. Samples	b/ Max. Exceed.	7/	Total Samples	Exceed. Samples	b/ Max. Exceed.	7/	Total Samples	Exceed. Samples	b/ Max. Exceed.	7/	Total Samples	Exceed. Samples	b/ Max. Exceed.	7/	8/ (Samples Detect.	9/ Ave. Conc.	Max. Exceed.	
Arsenic (liq.)	0.05	2	0			3	0			0				4	0			NS	11/		
Barium	1	9	0			6	0			3	0			6	0			1	0		
Cadmium	0.01	9	6	3		6	3	3		3	2	3		6	4	3		2	2	5	
Chromium (Cr VI)	0.05	9	0			6	0			3	0			6	0			0			
Fluoride	4.0	12	0			8	0			4	0			8	0			1	1		
Lead	0.05	9	0			6	0			3	0			6	0			0			
Mercury	0.002	0				0				0				0				10/ NS			
Nitrate 11/	45	12	0			8	0			4	0			8	0			0			
Selenium (liq.)	0.01	2	0			3	0			0				4	0			10/ NS			
Silver	0.05	9	0			9	0			3	0			6	0			0			
SDWS																					
Chloride	250	12	0			8	0			4	0			8	0			2	0		
Copper	1	9	0			6	0			3	0			6	0			1	0		
Iron	0.3	9	0			6	0			3	0			6	0			2	0		
Manganese	0.05	9	1	3.2		6	1	4.6		3	0			6	3	8.4		2	1	1	
Sulfate	250	12	12	5.8		8	4	5.1		4	4	5.1		8	8	6.2		2	2	9.8	
Zinc	5	9	0			6	0			3	0			6	0			2	0		
pH Lab 12/	<=6.5	0				0				0				0				10/ NS			
	>=8.5	0				0				0				0				10/ NS			
pH Field 12/	<=6.5	9	0			6	0			3	0			6	0			10/ NS			
	>=8.5	9	0			6	0			3	0			6	0			10/ NS			

**EXHIBIT E-14 (Continued)**  
**CHEMICAL SAMPLING RESULTS FOR DAVE JOHNSTON SITE**

- 1/ Wells 7-4, 7-6, and 7-9.
- 2/ Wells 7-5 and 7-11.
- 3/ Well 7-12. This well is located between the active and inactive ash landfills.
- 4/ Wells 7-2 and 7-3, but not 7-2A. The fluids collected from these wells are groundwater from beneath the waste.
- 5/ These "pond liquors" are fluids collected from within and on top of the landfilled wastes at station 7-2A.
- 6/ The number of samples with reported concentrations above the drinking water standard.
- 7/ Max. Exceed. is the concentration of the greatest reported exceedance divided by the drinking water standard for that particular contaminant. The only exception is for pH, where Max. Exceed. is the actual measurement.
- 8/ The number of "pond liquor" samples with reported concentrations above the reported detection limits. An entry of "0" indicates that no sample had a detectable contaminant concentration, not that no samples were taken (see footnote 10).
- 9/ Ave. Conc. is the average of the reported concentrations of all "pond liquor" samples taken that showed a contaminant concentration above the detection limit. The reported pH measurements of the "pond liquors" are also averaged.
- 10/ NS = not sampled.
- 11/ The solubility of fluoride in water is markedly affected by temperature. Of the temperature ranges and corresponding maximum allowable contaminant levels reported for fluoride in the NIPDWS, the range shown on this table (26.3-32.5 C) corresponds to the most stringent allowable maximum contaminant concentration.
- 12/ As indicated in footnote 6, the Max. Exceed. column for reported pH measurements is a tabulation of the actual measurements, not the maximum exceedance divided by the drinking water standard.

Waste From In and Under Wastes. Results from fluid samples collected from wells emplaced within the waste indicated that these fluids or "pond liquors," when compared to Primary Drinking Water Standards, exhibited elevated concentrations of cadmium (up to 5 times the PDWS). Comparison of pond liquors to Secondary Drinking Water Standards showed elevated levels of manganese (up to 1 times the SWDS), and sulfate (up to 10 times the SWDS). No analyses were conducted for arsenic.

Water samples obtained from under the waste showed exceedances of the Primary Drinking Water Standards for cadmium (up to 3 times the PDWS). These samples also exhibited elevated concentrations of manganese (up to 8 times the SDWS), and sulfate (up to 6 times the SDWS).

Ground Water. Seepage velocities at the site were estimated to be only five to eight feet per year, due to the arid climate. This suggests that because the landfills had been in operation for less than 10 years, there may not have been enough time for waste leachate to have reached the downgradient wells. However, the active landfill was constructed in an excavation that may have intersected the underlying water table. This may have allowed contaminant migration via direct contact between the bottom of the fill and the ground water.

Primary Drinking Water Standards were found to be exceeded in the ground water of the downgradient wells for cadmium (up to 3 times the PDWS). Cadmium was also found to exceed the PDWS in the waste fluids and in waters from beneath the waste. Upgradient exceedances of the Primary Drinking Water Standards in ground-water samples were also found for cadmium (up to 3 times the PDWS).

Secondary Drinking Water Standards were found to be exceeded in downgradient ground water for manganese (up to 3 times the SDWS) and sulfate (up to 6 times the SDWS). These are the same contaminants observed at concentrations greater than Secondary Drinking Water Standards in the pond liquors and waters from beneath the waste. Upgradient exceedances of the Secondary Drinking Water Standards in ground-water samples were also observed for manganese (up to 4.6 times the SDWS) and sulfate (up to 5 times the SDWS). The ground-water well installed between the active and inactive waste landfills was observed to exhibit exceedances of drinking water standards for the same constituents observed in upgradient and downgradient ground water wells and at similar concentrations -- cadmium (up to 3 times the PDWS), and sulfate (5 times the SDWS) -- with the exception that no exceedance was observed of manganese.

Surface Water. No surface water samples were collected at the site.

Attenuation Tests. Attenuation tests conducted using background soils at the site showed the soil to have low attenuative capacities for a variety of trace metals, especially arsenic.

### **E.6.3 Discussion and Conclusion**

All ground-water sampling conducted at the Dave Johnston site (both upgradient and downgradient) indicated levels of cadmium in exceedance of Primary Drinking Water Standards. Cadmium was also observed at elevated concentrations within and beneath the wastes. Secondary Drinking Water Standards were exceeded for manganese and sulfate in both upgradient and

downgradient ground water, and in fluids obtained from within and beneath the wastes of the disposal areas.

These results did not indicate whether migration of waste leachate to downgradient ground water had occurred, or whether the observed contamination was caused by a source other than the ash wastes. Other site information that can aid in interpretation of results at site are discussed below.

The estimation that leachate from the active waste area may not have reached downgradient wells by the time of sampling would suggest that there may have been other contamination sources besides the active disposal area. However, it may be possible that wastes had been in direct contact with the ground water, allowing for a considerable increase in the velocity of contaminant migration.

Outside of exceedances of drinking water standards, there did appear to be a general increase downgradient in ground-water concentrations of major ash constituents (e.g., chlorine, magnesium, sodium, silicon, and sulfate). These increases may be attributable to natural mineral weathering (as discussed below), or may be due to the effects of ash disposal.

Weathering of the mineralized soils at the site, in conjunction with the low ground-water velocities in this area, may have allowed natural solute pickup as ground water moved across the site toward the North Platte River. This pickup added to the difficulty of distinguishing the effects of waste leachate from the natural increases in downgradient solute concentrations. However, in wells screened below the disposal areas, it appeared that waste leachate had caused increases in solute concentrations (e.g., chlorine, sulfate, etc.). In wells

further downgradient from the disposal areas the effect of waste leachate were difficult to distinguish.

Interpretation of results from the Dave Johnston site was difficult due to its complex hydrogeologic regime and the many waste disposal locations of varying ages at the disposal site, including the two disposal areas studied. The actual location of the closed ash disposal sites was uncertain. These old disposal areas were probably located upgradient from the retired ash pond and may have also been upgradient of the active ash pond. Thus, leachate from past disposal activities, instead of weathering of soils, may have been the cause of upgradient contamination of ground water.

Leachate from the wastes may have eventually reached downgradient ground water and the North Platte River. If the ground-water contamination observed at the site was attributable to waste disposal, this contamination can be expected to increase as leachate reaches steady-state concentrations. It is also probable that, at least for the observed contamination by cadmium, the ground-water contamination may have been due to the ash wastes areas, active or closed, present at the site.

It should be noted that arsenic, which was found in elevated concentrations within waste fluids from the other ADL sites, was not tested for at this site. This information on arsenic would have been useful to contrast its concentration in the waste fluids with the low chemical attenuation observed for the soils of this site.

In summary, the Dave Johnston plant in Wyoming was located in an arid region

with little ground-water recharge. The plant was relatively old and burned low sulfur western coal. There were a number of disposal areas at the site. The ADL study investigated two landfills southeast of the site, an active one and a closed one. These landfills were unlined and used for fly ash disposal. Exceedances of the Primary Drinking Water Standards were found in ground water upgradient and downgradient of the site for cadmium (up to 5 times the PDWS). These were the same contaminants found at elevated concentrations in waters within and beneath the wastes. Exceedances of Secondary Drinking Water Standards were observed in downgradient and upgradient ground water for manganese and sulfate. Both of these contaminants, along with boron, were found in elevated concentrations in waters beneath and within the waste. No samples were analyzed for arsenic in the waste fluids. Chemical attenuation by soils of the site were found to be low for trace metals such as arsenic.

Interpretations of the sampling results were difficult to make due to the occurrence of other potential contamination sources, in the form of older waste disposal areas at the site (the location and ages of which are uncertain); potential pickup of major ash constituents from mineralized soil solutes; and uncertainties in whether, and to what degree, leachate from the two landfills had reached the downgradient wells. Contamination from the two landfills could have increased until steady-state concentrations were reached. It appeared that at least some of the contamination observed, especially for contaminants such as cadmium, was due to leaching from the many ash deposits at the site.

**E.7 SHERBURNE COUNTY PLANT**

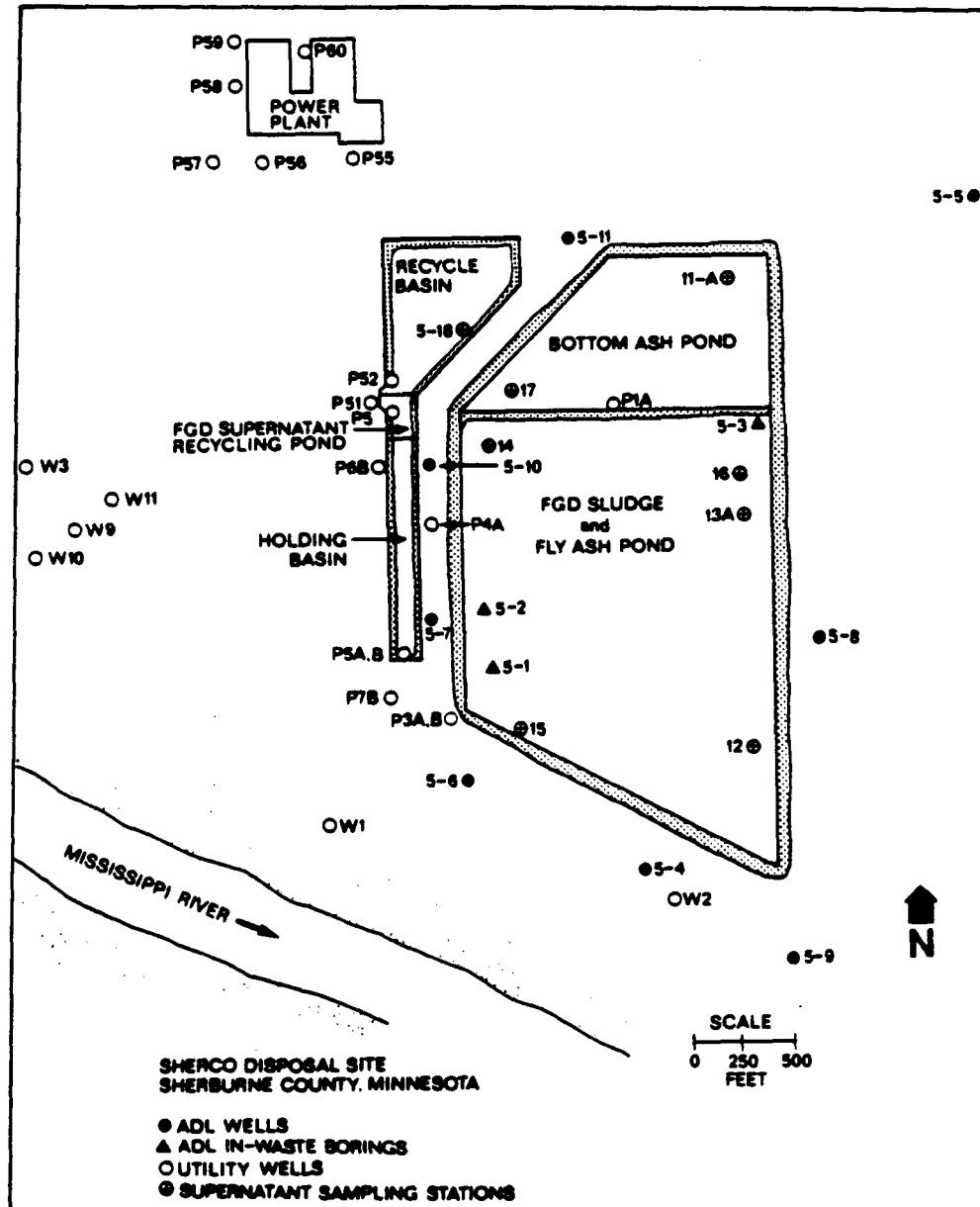
The Sherburne County Plant in Minnesota was located approximately 30 miles northwest of Minneapolis. The plant site was adjacent to the northeast bank of the Mississippi River, and consisted of two units, each equipped with fly ash alkali FGD scrubbers that used limestone. The plant used subbituminous coal from Montana and Wyoming with a sulfur content of 0.8 percent and an ash content of about nine percent.

Combined fly ash/FGD waste effluent was thickened and disposed of in a clay-lined pond which covered 62 acres and lay just southeast of the power plant (Exhibit E-15). Bottom ash was disposed of in a separate, adjacent, 18-acre clay-lined pond immediately north of the FGD sludge/fly ash pond. Overflow from these disposal ponds was directed into a clay-lined basin to the west of the bottom ash pond, effluents from which were recycled as a scrubber medium or for waste sluicing. The disposal ponds had been in use since 1976.

The Sherburne Plant was underlain by granite at a depth varying from 50 to 150 feet. Soils throughout the site area consisted of glacial drift (sands and gravels). Discontinuous lenses and layers of glacial till (dense mixtures of silt, sand, and clay) also occurred within the drift deposits. Ground water was in the unconsolidated glacial outwash (drift) sands and gravels. The water table was approximately 30 to 40 feet below the land surface. Ground-water flow was generally southwesterly towards the Mississippi River (Exhibit E-16). In general, there was no surface runoff in the site area with all precipitation infiltrating rapidly through the soils to the ground-water table. Annual precipitation was about 28 inches.



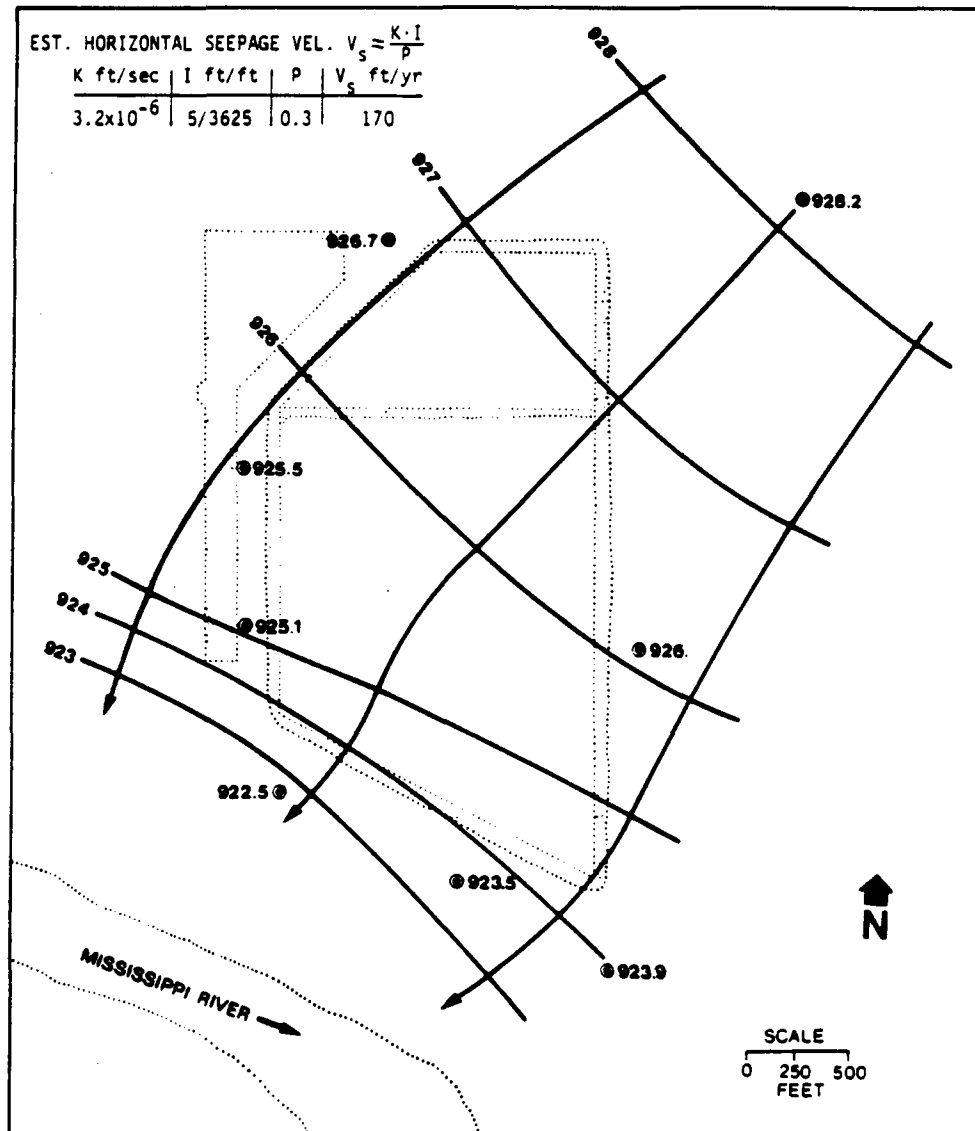
## EXHIBIT E-15

DISPOSAL PONDS AND SAMPLING LOCATIONS AT  
SHERBURNE COUNTY SITE

Source: Tetra Tech 1985.

## EXHIBIT E-16

## GROUND-WATER FLOW DIRECTIONS AT SHERBURNE COUNTY SITE



Source: Tetra Tech 1985.

Factors that were considered to be important in the selection of this site's ponding operations for study included:

- Fly ash and sulfur oxides from the plant were removed simultaneously using external forced oxidation. This produced a waste that was sulfate-rich and easy to dewater and handle. Few other plants practice forced oxidation, but it had been identified as a potentially mitigative measure for FGD waste management and its use was expected to grow in the future.
- Pond lining and recycling operations were in use at very few other plants and were considered to be potentially mitigative features at future sites. The site afforded an opportunity to study linear performance in the ponding of wastes.
- Western coal was employed at the Sherburne County Plant. Generating capacity using western coal with FGD systems was expected to grow.
- The high-quality ground water and modest precipitation at this site and its isolation from other sources of potential contamination was expected to facilitate the identification of any waste-related ground-water contamination.

#### **E.7.1 Sampling Approach**

Two upgradient and six downgradient ground-water monitoring wells were installed and sampled to determine the presence of any leachate in the ground water. Samples were also taken of wastes from the two ponds, liner materials, soils, waste "liquors" (waters) from the ponds (including FGD waste interstitial water and FGD pond supernatants), liquids from within the clay liner of the fly ash/FGD pond, and liquids from soils beneath the liner.

Locations of the waste ponds, recycling pond, monitoring wells, and other sampling locations are shown in Exhibit E-15. Wells were sampled for

contaminant concentrations on three dates. Soil attenuation tests and a site water balance were also conducted. Earlier results from ground-water monitoring conducted at the site since 1977 were also available for review. The value of and trends in sampling and analysis results for the site, and comparison of ground-water concentrations with relevant EPA standards, are discussed below.

### **E.7.2 Results**

Exhibit E-17 presents the results of chemical sampling at the Sherburne County (Sherco) site. This includes samples from the downgradient and upgradient ground-water wells, and fluid samples collected from within (interstitial water) and beneath the wastes. Results are discussed below.

Waste and Liner Solids. No significant stratification of the FGD waste was observed and, therefore, the permeability of the waste was observed to be fairly uniform throughout the deposit, ranging from  $7 \times 10^{-5}$  to  $5 \times 10^{-6}$  cm/sec (indicating low permeability). The earthfill pond liner was tested for permeability and was found to range from  $5 \times 10^{-7}$  to  $1 \times 10^{-7}$  cm/sec.

Waste Fluids. Results from fluid samples collected from wells placed within the FGD sludge/fly ash waste and from pond supernatant indicated that these fluids or "pond liquors," when compared to Primary Drinking Water Standards, exhibited elevated concentrations of cadmium (up to 30 times the PDWS), chromium (up to 16 times the PDWS), fluoride (up to 4.5 times the PDWS), lead (up to 28 times the SDWS), nitrate (up to 7 times the PDWS), and selenium (up to 25 times the PDWS). Comparison of pond liquors to Secondary Drinking Water Standards showed elevated levels of chloride (up to 2 times the SDWS), iron (up to 6 times

# EXHIBIT E-17

## CHEMICAL SAMPLING RESULTS FOR SHERBURNE COUNTY SITE

SHERBURNE COUNTY SITE  
(no Surface Water data)

Units = ppm		Ground water						Under Waste			Waste		
PDMS		1/ Downgradient (3 wells)			2/ Upgradient (2 wells)			3/ Waters Under Liner (3 wells)			4/ Pond Liquors (13 stations)		
Drinking Water Standard		Total Samples	Exceed. Samples	Max. Exceed.	Total Samples	Exceed. Samples	Max. Exceed.	Total Samples	Exceed. Samples	Max. Exceed.	14/ Samples Detect.	8/ Ave. Conc.	6/ Max. Exceed.
Arsenic 9/ (liq.)	0.05	3	0		3	0		4	1	1.8	6	0.028	
Barium	1	12	0		8	0		8	0		5	0.063	
Cadmium 10/	0.01	12	2	2	8	2	2	8	4	132	14	0.073	30
Chromium 11/ (Cr VI)	0.05	12	1	1.2	8	0		8	3	7.6	3	0.35	16
Fluoride 12/	4.0	12	0		8	0		8	2	2	9	9.5	4.5
Lead 13/	0.05	12	0		8	0		8	2	103	1	1.4	28
Mercury	0.002	0			0			0			NS		
Nitrate 15/	45	12	2	1.1	8	2	27	4	4	9.6	9	108	6.8
Selenium 16/ (liq.)	0.01	3	0		3	0		4	0		7	0.06	25
Silver	0.05	12	0		8	0		1	0		0		
SDMS													
Chloride	250	12	0		8	0		8	1	2.7	12	183	1.9
Copper	1	12	0		8	0		8	5	24	13	0.054	
Iron	0.3	12	0		8	1	1.9	8	8	86	13	0.46	6.1
Manganese 17/	0.05	12	2	22	8	1	1.4	8	1	788	11	5.8	316
Sulfate	250	12	0		8	0		8	7	116	12	4880	42
Zinc	5	12	0		8	0		8	3	17	7	0.31	
pH Lab 18/	<=6.5	0			0			0			NS		
	>=8.5	0			0			0			NS		
pH Field 18/	<=6.5	8	0		6	0		NR			0		
	>=8.5	8	0		6	0		NR			0		

## EXHIBIT E-17 (Continued)

### CHEMICAL SAMPLING RESULTS FOR SHERBURNE COUNTY SITE

1/ Wells 5-4, 5-6, and 5-9.

2/ Wells 5-5 and 5-11.

3/ Wells 5-1, 5-2, and 5-3. The fluids collected at these wells are groundwater from beneath the waste.

4/ Stations 5-1 S3, 5-1 S4, 5-1 U3, 5-2 U1, 5-2 S2, 5-3 (20 ft), 5-3 S9, 5-3 U4, 5-12, 5-13A, 5-14, 5-15, and 5-16. These "pond liquors" are fluids collected from within and on top of the landfilled wastes.

5/ The number of samples with reported concentrations above the drinking water standard.

6/ Max. Exceed. is the concentration of the greatest reported exceedance divided by the drinking water standard for that particular contaminant. The only exception is for pH, where Max. Exceed. is the actual measurement.

7/ The number of "pond liquor" samples with reported concentrations above the reported detection limits. An entry of "0" indicates that no sample had a detectable contaminant concentration; not that no samples were taken (see footnote 14).

8/ Ave. Conc. is the average of the reported concentrations of all "pond liquor" samples taken that showed a contaminant concentration above the detection limit. The reported pH measurements of the "pond liquors" are also averaged.

[Comment on footnotes 9-15:

Where the reported detection limit for a contaminant was greater than the drinking water standard and the sample contained less contaminant than the reported detection limit, the sample is tabulated as being below the drinking water standard.]

9/ For some water samples collected from water under the waste, the reported detection limit of 0.074 was greater than the PDWS for arsenic.

10/ For some water samples collected from water under the waste, the reported detection limit of 1.5 was greater than the PDWS for cadmium.

11/ For some water samples collected from water under the waste, the reported detection limit of 1.5 was greater than the PDWS for chromium.

12/ For some water samples collected from water under the waste, the reported detection limit of 24.6 was greater than the PDWS for fluoride. The solubility of fluoride in water is markedly affected by temperature. Of the temperature ranges and corresponding maximum allowable contaminant levels reported for fluoride in the NIPDS, the range shown on this table (26.3-32.5 C) corresponds to the most stringent allowable maximum contaminant concentration.

13/ For some water samples collected from water under the waste, the reported detection limit of 7.5 was greater than the PDWS for lead.

14/ NS = not sampled.

15/ For some water samples collected from water under the waste, the reported detection limit of 0.123 was greater than the PDWS for selenium.

16/ For some water samples collected from water under the waste, the reported detection limit of 1.5 was greater than the PDWS for manganese.

17/ As indicated in footnote 6, the Max. Exceed column for reported pH measurements is a tabulation of the actual measurements; not the maximum exceedance divided by the drinking water standard.

18/ NR = not reported.

the SDWS), manganese (up to 316 times the SDWS), and sulfate (up to 42 times the SDWS). Concentrations measured in the pond supernatant were generally higher than those measured in the interstitial waters of the wastes (e.g., 10,000 ppm sulfate in pond surface liquids and 2000 ppm in waste fluids). Pond liquors obtained from the smaller bottom ash pond also exhibited elevated concentrations of cadmium (up to 50 times the PDWS), and manganese (up to 9 times the SDWS). Because these fluids are not ingested, comparison to the drinking water standards is shown only to indicate the potential for contamination at the site.

Misc. Fluids. Results obtained from chemical analyses of the clay liner pore water showed concentrations of cadmium, chromium, iron, sulfate, and manganese that were above drinking water standards. Fluid samples obtained from under the liner showed elevated concentrations for most of the contaminants tested for, including arsenic, cadmium, chromium, fluoride, lead, selenium, nitrate, boron, sulfate, chloride, copper, iron, zinc, and manganese. It is unclear as to what these samples represented, and the method used to collect the liquid samples from the unsaturated soils beneath the clay liner may have resulted in these observed to be above drinking water standards values being greater than the trace below-liner concentrations. Concentrations of cadmium, boron, and manganese were observed in fluids obtained from the recycling basin.

Ground Water. Estimates were made of seepage velocities at the site. Results from these calculations indicated that enough time had elapsed for some constituents in the waste leachate to have reached the nearer downgradient wells (Wells 5-4 and 5-6). However, steady-state conditions had probably not been reached at the site (i.e., chemical equilibrium between the waste, leachate, and downgradient ground water had not occurred).

Primary Drinking Water Standards were found to be exceeded in the ground water of the downgradient wells for cadmium (up to 2 times the PDWS) chromium (up to 1.2 times the PDWS), and nitrate (up to 1.1 times the PDWS). Upgradient exceedances of the Primary Drinking Water Standards in ground-water samples were also found for cadmium (up to 2 times the PDWS) and nitrate (up to 27 times the PDWS). Secondary Drinking Water Standards were found to be exceeded in downgradient ground water for manganese (up to 22 times the SDWS). Upgradient exceedances of the Secondary Drinking Water Standards in ground-water samples were observed for iron (up to 1.9 times the SDWS) and manganese (up to 1.4 times the SDWS). It should be noted that concentration measurements for arsenic and selenium in the ground water were sparse.

Surface Water. No surface water samples were collected at the Sherburne County site.

Attenuation tests. Attenuation tests conducted with site soils and pond liquor solutions (spiked with trace elements) from the Sherburne County and Allen sites indicated that the sandy soils that prevailed over much of the site had a relatively low capacity to chemically attenuate trace metals. Tests of the clay liner soil indicated these materials had a somewhat better attenuative capacity.

### **E.7.3 Discussion and Conclusions**

Exceedances of the Primary Drinking Water Standards for cadmium (up to 2 times the PDWS) and nitrate (up to 27 times the PDWS upgradient and up to 1.1



times the PDWS downgradient) were observed in both the upgradient and downgradient ground water at the Sherburne County disposal site. There were manganese exceedances in both upgradient wells (up to 1.4 times the SDWS) and downgradient wells (up to 22 times the SDWS).

Wastes fluids from the FGD sludge/fly ash pond exhibited high concentrations of several constituents; cadmium (up to 30 times the PDWS), chromium (up to 16 times the PDWS), fluoride (up to 4.5 times the PDWS), nitrate (up to 7 times the PDWS), lead (up to 28 times the PDWS), and selenium (up to 25 times the PDWS). Elevated concentrations were also observed for chloride (up to 2 times the SDWS), iron (up to 6 times the PDWS), manganese (up to 316 times the SDWS), and sulfate (up to 42 times the PDWS).

Although the wastes and fluids exhibited high concentrations of contaminants, leachate from these wastes did not appear to have migrated into or mixed with the ground water to any great extent. There were indications that some waste-related solutes had migrated to downgradient wells from the FGD sludge/fly ash pond. Concentrations profiles of sulfate were greater downgradient than upgradient in the closer well, 5-4. Higher than background concentrations of solutes at downgradient well 5-6 may not have been associated with the disposal ponds, but may have reflected leakage that was reported to have occurred from holding ponds at the site. Possible explanations of results and future expectations are discussed below.

Nitrate exceedances of the Primary Drinking Water Standards were widespread at various locations at the site (including background), but seemed to be unrelated to disposal operations.

Observed solute concentrations (e.g., sulfate, boron) suggested that the clay liner had reduced the rate of release of leachate from the disposal pond. However, concentrations of waste-related contaminants in downgradient ground water may eventually increase, since leachate was not currently leaking out of the landfill at a maximum, or steady-state, concentration, and only a portion may have reached the downgradient wells at the time of sampling. In other words, only a small quantity of leachate had, at the time of sampling, mixed with the larger amounts of uncontaminated ground water. If the landfill had not contained a liner, estimates of leachate movement indicated that steady-state concentrations of leachate would have reached downgradient wells several years prior to the study.

Two other factors that could contribute to the observed lack of contamination in downgradient ground water include:

- Leachate that originally permeated the liner may have been less contaminated than the leachate currently found in the FGD wastes (leachate may not have yet been in equilibrium with the wastes, and early plant operations did not involve recycling plant water); and
- Most of ADL's wells were screened over a depth interval of 20 feet or greater, thereby yielding composite ground-water samples that may have exhibited lower contaminant concentrations than if the wells were screened only at a level and length commensurate with the expected migration of leachate.

The waste-related contaminant selenium may be of concern at this site since the surrounding soils may not chemically attenuate selenium, and its concentration in ground water could be higher than indicated once steady-state concentrations were achieved.

In summary, the Sherburne County Plant in Central Minnesota disposed of combined fly ash and FGD waste in one clay-lined pond and bottom ash in an adjacent clay-lined pond. Exceedances of the Primary Drinking Water Standards were observed in both upgradient and downgradient ground water for cadmium (up to 2 times the PDWS for both) and for nitrate (up to 27 times the PDWS upgradient and up to 1.1 times the PDWS downgradient), and in downgradient ground water for chromium (up to 1.2 times the PDWS). Waters from the pond wastes were found to exhibit high concentrations (relative to Drinking Water Standards) of several constituents including cadmium (up to 30 times the PDWS), chromium (up to 16 times the PDWS), fluoride (up to 4.5 times the PDWS at 26-33 °C), nitrate (up to 7 times the PDWS), lead (up to 28 times the PDWS), and selenium (up to 25 times the PDWS).

While the waste fluids exhibited high concentrations of contaminants, leachate from these wastes did not appear to have migrated into and mixed with ground water to a great extent. Ground-water samples collected at the site do seem to indicate that a few waste-related species (sulfate and boron) have migrated from the wastes. The clay liner appeared to have significantly reduced the rate of release of leachate from the disposal ponds, precluding the development of elevated trace metal contaminant concentrations at downgradient wells. Over time, downgradient wells may increase the level of contamination, since steady-state conditions have not been achieved between leachate from the landfill and the ground water. Without the clay liner, the leachate seepage rate would have been much greater, leading to greater contamination of ground water. Since the surrounding soils may not chemically attenuate it, the waste-related contaminant selenium may be of concern at this site once

steady-state concentrations in ground water are reached.

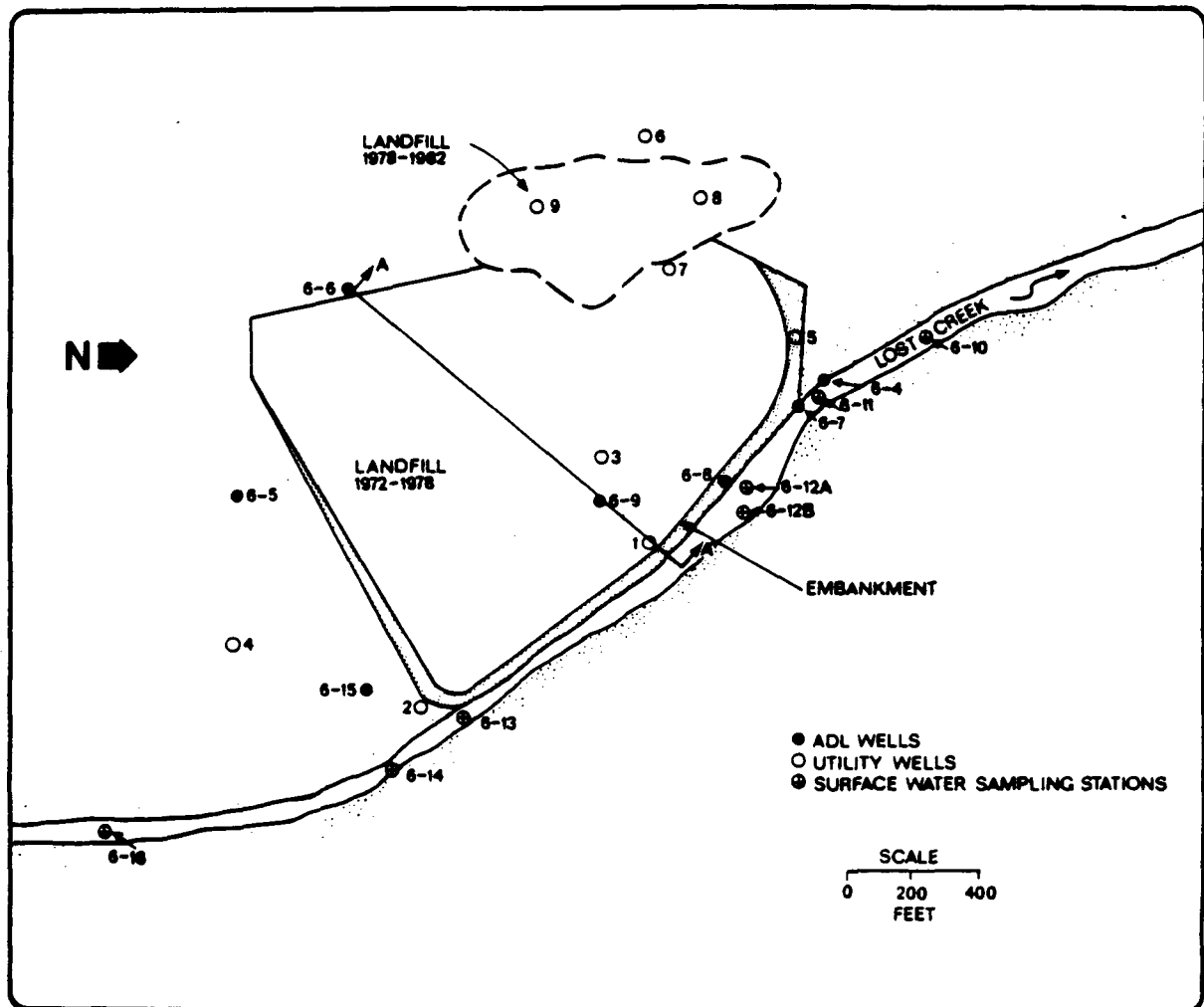
### **E.8 POWERTON PLANT**

The Powerton Power Plant is located in Tazewell County, Illinois, approximately 10 miles south of Peoria. The site is located one mile south of the Illinois River, and the disposal area is another mile south of the plant. The existing facility began operation in 1972, although a smaller plant had previously operated at the site. Originally, bituminous coal with four percent sulfur was burned. In 1976, the plant began burning Montana subbituminous coal with 0.6 percent sulfur and six percent ash. At the time of the study, the Powerton wastes consisted of boiler slag that was dewatered and trucked to the disposal area, and fly ash which was collected from an electrostatic precipitator, stored, and then transported dry to the disposal area.

The disposal area consisted of two adjacent landfill areas which border Lost Creek (Exhibit E-18). The large portion of the disposal area was used from 1972 until 1978, and had since been reclaimed. The smaller area west of this section was operated from 1978 until 1982. The newer portion of the landfill occupies an abandoned borrow pit in which fly ash and slag were intermixed. In the older portion of the landfill, there were distinct layers of slag and fly ash. The newer landfill, and part of the older one, were underlain by a liner of Poz-O-Pac,<sup>7</sup> which consisted of a chemically stabilized mixture of fly ash, lime, and bottom ash. The liner was reported to be five feet thick beneath the newer part of the landfill and only eight inches thick

## EXHIBIT E-18

## LANDFILL AREAS AND SAMPLING LOCATIONS AT THE POWERTON SITE



Source: Tetra Tech 1985.

beneath the older area. The surface area of the entire landfill was approximately 438 acres.

The following factors were considered to be important for selecting the Powerton landfill operation for study:

- The collection, handling, and landfill disposal of ash as practiced at Powerton was one of the prevalent practices nationwide in the utility industry.
- The interior climatic and hydrogeologic setting (relatively permeable soils and moderate, regular precipitation) were considered to be typical and allowed effects of landfill disposal of coal ash generated from western coal to be studied.
- While artificial lining of managed coal ash landfills was not a prevalent practice nationwide at the time of the study, this site was considered a useful opportunity to study a potentially mitigative practice.
- The retired landfill was bordered by a small stream (Lost Creek). Because there were no major point source discharges to Lost Creek, this was considered a good opportunity to study potential impacts of coal ash disposal on a small surface water body.

In the Powerton area, the bedrock consisted of limestone, sandstones, and shales. These were overlain by thick deposits of glacial outwash (sands and gravels). The older portion of the landfill was underlain by sand and silt deposits, within which are a number of clay lenses. The site receives an average of 36 inches of precipitation per year. The glacial outwash deposits made up the principal aquifer (water-bearing units) underlying the landfill. This aquifer discharged to Lost Creek. At the upgradient edge of the landfill (the western edge), the water table was approximately 35 feet below the fill. Along the downgradient edge (that bordering Lost Creek), the water table was within a few feet of the ash and occasionally intercepted the ash fill. All surface and ground-water flow was northeasterly towards Lost Creek, which

subsequently flowed to the Illinois River (Exhibit E-19).

#### **E.8.1 Sampling Approach**

At the Powerton landfill, three upgradient (one background, two peripheral) ground-water monitoring wells and three downgradient ground-water monitoring wells were installed (Exhibit E-18). Additionally, one well was drilled through the ash and slag wastes of the older landfill to sample waters directly beneath the fill. These wells were installed to determine (via chemical testing) the presence and vertical extent of any leachate. Additionally, chemical analyses were performed on surface water samples at the site. Samples were collected from six surface water stations in Lost Creek. Three of these stations were located upstream (6-13, 6-14 and 6-16), two were located in the middle of the site, and one was located downstream (6-10). No samples were collected of interstitial waters or liquors from within the wastes.

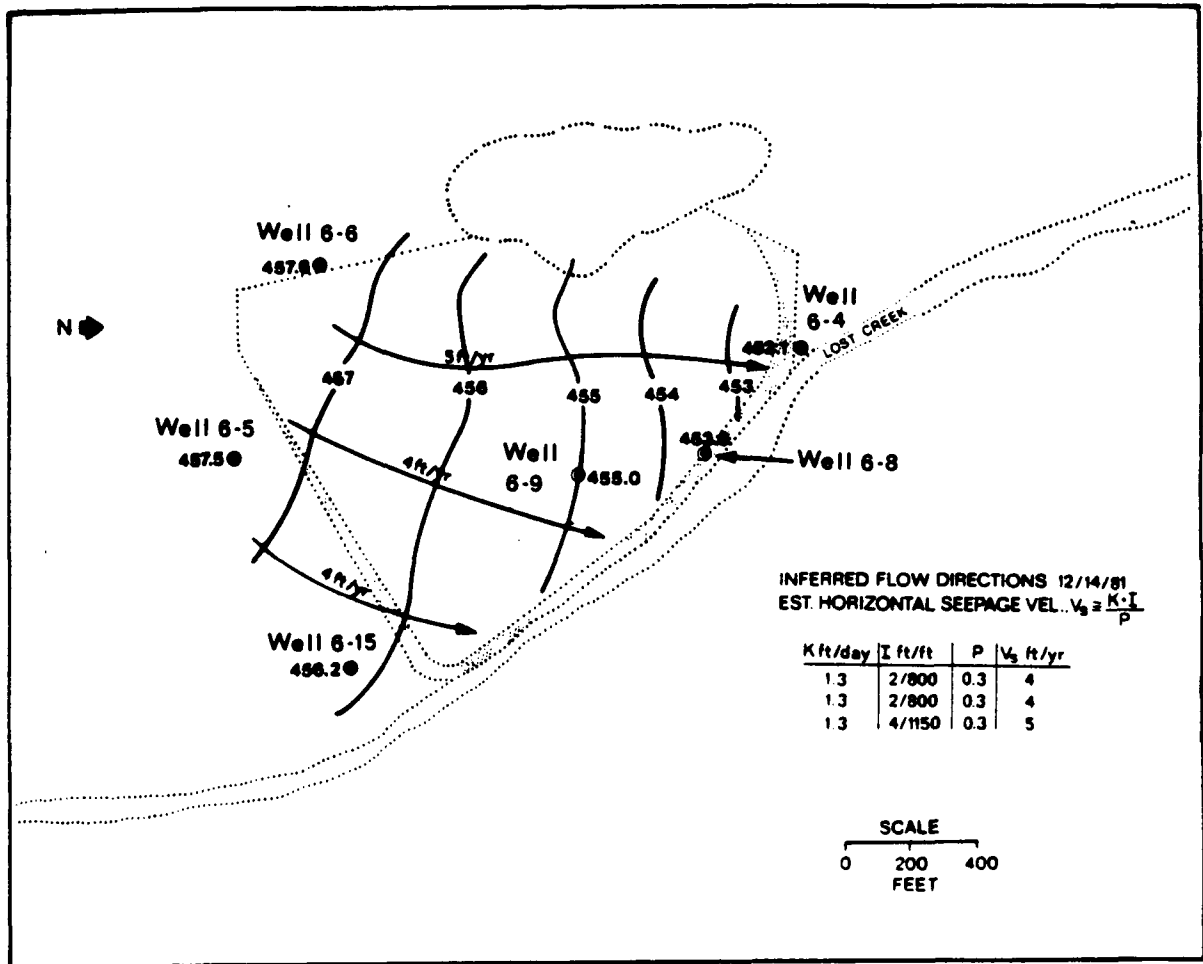
#### **E.8.2 Results**

Exhibit E-20 presents the results of chemical sampling at the Powerton site. This includes samples from the downgradient and upgradient ground-water wells, samples from the surface water stations, and water samples obtained from materials beneath the wastes. Results are discussed below.

Waste Solids. Permeability of the landfilled wastes ranged from a high of  $3 \times 10^{-2}$  cm/sec for the slag to a low of  $1 \times 10^{-4}$  cm/sec for the fly ash. In the

## EXHIBIT E-19

## GROUND-WATER FLOW DIRECTIONS AT THE POWERTON SITE



Source: Tetra Tech 1985.



## EXHIBIT E-20

## CHEMICAL SAMPLING RESULTS FOR POWERTON SITE

POWERTON STATION SITE  
(no Pond Liquor data)

Units = ppm		Ground water				Under Waste				Surface Water (Lost Creek)							
		1/				2/				3/				4/			
POWS		Downgradient (3 wells)				Upgradient (1 well)				Water Under Waste (1 well)				Downgradient (1 station)			
		6/				7/				6/				7/			
Drinking																	
Contam.	Water Standard	Total Samples	Exceed. Samples	Max. Exceed.	Total Samples	Exceed. Samples	Max. Exceed.	Total Samples	Exceed. Samples	Max. Exceed.	Total Samples	Exceed. Samples	Max. Exceed.	Total Samples	Exceed. Samples	Max. Exceed.	Total Samples
Arsenic (liq.)	0.05	8	0		2	0		3	0		1	0		2	0		
Barium	1	9	0		4	0		3	0		3	0		8	0		
Cadmium	0.01	9	8	3	4	2	1	3	3	2	3	2	2	8	5	2	
Chromium (Cr VI)	0.05	9	0		4	0		3	0		3	0		8	0		
Fluoride	4.0	9	0		4	0		3	0		3	0		8	0		
Lead	0.05	9	1	4	4	0		3	0		3	0		8	0		
Mercury	0.002	0			0			0			0			0			
Nitrate 8/	45	9	0		4	2	1.1	3	1	1.7	3	1	1.1	7	3	1.2	
Selenium (liq.)	0.01	8	0		2	0		3	0		1	0		2	0		
Silver	0.05	9	0		4	0		3	0		3	0		8	0		
SDWS																	
Chloride	250	9	0		4	0		3	0		3	0		8	0		
Copper	1	9	0		4	0		3	0		3	0		8	0		
Iron	0.3	9	4	42	4	0		3	0		3	0		8	0		
Manganese	0.05	9	9	194	4	2	11	3	3	6	3	2	2.2	8	2	1	
Sulfate	250	9	6	2.7	4	0		3	3	3.6	3	0		8	0		
Zinc	5	9	0		4	0		3	0		3	0		8	0		
pH Lab 9/	<=6.5	0			0			0			0			0			
	>=8.5	0			0			0			0			0			
pH Field 9/	<=6.5	9	1	6	3	0		2	0		3	0		8	0		
	>=8.5	9	0		3	0		2	0		3	1	8.5	8	2	8.5	

**EXHIBIT E-20 (Continued)**  
**CHEMICAL SAMPLING RESULTS FOR POWERTON SITE**

1/ Wells 6-4, 6-7, and 6-8.

2/ Well 6-6.

3/ Well 6-9. The fluids collected at this well are groundwater from beneath the waste.

4/ Station 6-10.

5/ Stations 6-13, 6-14, and 6-16.

6/ The number of samples with reported concentrations above the drinking water standard.

7/ Max. Exceed. is the concentration of the greatest reported exceedance divided by the drinking water standard for that particular contaminant. The only exception is for pH, where Max. Exceed. is the actual measurement.

8/ The solubility of fluoride in water is markedly affected by temperature. Of the temperature ranges and corresponding maximum allowable contaminant levels reported for fluoride in the NIPQS, the range shown on this table (26.3-32.5 C) corresponds to the most stringent allowable maximum contaminant concentration.

9/ As indicated in footnote 7, the Max. Exceed. column for the reported pH measurements is a tabulation of the actual measurements, not the maximum exceedance divided by the drinking water standard.

more recent section of the ash landfill, where slag and fly ash were mixed, the permeability of the waste was approximately  $5 \times 10^{-4}$  cm/sec.

Waste Fluids. No samples were collected of waters from within the landfilled wastes (waste liquors). Results from water samples collected from beneath the waste indicated that these waters, when compared to Primary Drinking Water Standards, exhibited elevated concentrations of cadmium (up to 2 times the PDWS), and nitrate (up to 1.8 times the PDWS). Comparison of these samples to Secondary Drinking Water Standards indicated elevated levels of manganese (up to 6 times the SDWS), and sulfate (up to 3.6 times the SDWS).

Ground-Water. Estimates of seepage velocities at the site indicated that waste leachate constituents could have reached downgradient ground-water wells and possibly Lost Creek by the time of ADL's sampling.

Primary Drinking Water Standards were found to be exceeded in the ground water of the downgradient wells for cadmium (up to 3 times the PDWS) and lead (up to 4 times the PDWS). Slight exceedances in upgradient ground water of the Primary Drinking Water Standards were found for cadmium (up to 1 times the PDWS). Note that the one upgradient well (6-6) bordered the landfilled wastes. Occasional exceedances of the Primary Drinking Water Standard for cadmium were observed in the two ground water wells peripherally located to the wastes.

Surface Water. The Primary Drinking Water Standard for cadmium was found to be exceeded occasionally at all surface water stations at the site. Cadmium was observed at up to 2 times the Primary Drinking Water Standard at the upgradient (upstream) stations and at the downgradient stations. Nitrate exceeded the

Primary Drinking Water Standards in both upgradient (up to 12.3 times the PDWS) and downgradient (up to 11.6 times the PDWS) surface water locations. Secondary Drinking Water Standards were found to be exceeded in both upgradient (1 times the SDWS) and downgradient (up to 2.2 times the SDWS) surface water locations for manganese.

Attenuation Tests. Attenuation tests conducted using pond liquor solutions (spiked with trace elements) from the Allen and Sherburne County sites and soils obtained from the Powerton site indicated that these soils generally had intermediate capacities to attenuate trace metals such as arsenic.

### **E.8.3 Discussion and Conclusions**

The assessment of sampling results from the site focused on the effects of ash landfill leachate on downgradient ground-water quality, and the effects of ash landfill leachate on Lost Creek surface-water quality. Emphasis on analyzing the effectiveness of the Poz-O-Pac liner under the landfill was discontinued after a general absence of the liner under the older, larger, disposal area was discovered.

Cadmium was observed to exceed the Primary Drinking Water Standard in the downgradient ground-water wells (up to 3 times the PDWS). Cadmium was also observed at the Primary Drinking Water Standard on one occasion in the upgradient ground-water well. Since the upgradient well is located very close to the landfill border, the slightly elevated concentration of cadmium observed in this well's samples may have been from the leaching of cadmium. However, it must be noted that cadmium exceedances in surface water were observed upstream

as well as downstream (up to 2 times the PDWS), potentially indicating that the utility waste was not the source.

One exceedance of the Primary Drinking Water Standard for lead was observed at a downgradient ground-water well (up to 4 times the PDWS). However, the usefulness of this information was limited since lead was only reported to be detectable on one occasion and, in other samples, lead was not detectable at all. Elevated nitrate concentrations observed in ground water from various sampling locations could possibly be attributed to local agriculture activities. Trace elements such as arsenic and selenium were found to be similar to background concentrations and were below drinking water standards. These trace elements may not have leached from the landfill, or may have been chemically attenuated by the soil.

Chemical sampling results at the Powerton site indicated that leaching and migration of ash wastes had occurred since solutes had reached the downgradient wells. Major ash constituents that are observed to exceed Secondary Drinking Water Standards in the downgradient ground water at the site were sulfate (up to 3 times the PDWS), iron (up to 4 times the PDWS), and manganese (up to 194 times the PDWS). Of these contaminants, the elevated levels of sulfate might have been due to leaching from the waste. Only manganese was observed to exceed Secondary Drinking Water Standards at the upgradient well (up to 11 times the PDWS).

The ground-water concentrations of the major waste constituents indicated that leachate migration from the landfill might have reached approximately steady-state conditions with respect to the concentrations of these species in

the waste and downgradient wells. If this had occurred, further increases in the concentrations of such species would not be expected. Additionally, levels of trace metals in the ground water suggested that a combination of dilution and chemical attenuation was preventing the buildup of significant concentrations of these constituents at downgradient locations. Given these ground-water results, the Powerton site might have had some effect on ground-water quality, but increased degradation should not be expected.

The consistently elevated concentrations of boron observed in downstream surface water of Lost Creek would seem to indicate some leaching of this waste constituent since it is being detected in the surface waters of Lost Creek. This body of water may be substantially diluting the waste constituents; however, the small number of sampling stations do not allow further data analysis.

In summary, the Powerton Plant disposed of fly ash, bottom ash, and slag in an older landfill approximately one mile south of the site. More recent disposal operations consisted of disposing of intermixed fly ash and slag in a newer portion of the landfill. The newer landfill and part of the older one were underlain by a liner consisting of ash and lime (Poz-O-Pac). The downgradient ground-water wells exhibited levels of cadmium up to three times the Primary Drinking Water Standard and levels of lead at up to four times the Primary Drinking Water Standard. An upgradient well, located on the border of the landfill wastes, also exhibited an elevated concentration of cadmium at the level of the Primary Drinking Water Standard. Secondary Drinking Water Standards were exceeded in downgradient wells for iron, manganese, and sulfate, and in the upgradient well for manganese (but at a lower level of exceedance

compared to the downgradient measurement).

Results indicate that leaching and migration of ash wastes had occurred at the site, but it is difficult to determine how significant an impact the leachate has had, or will have, on ground-water quality. Dilution and chemical attenuation may have prevented the development of significant concentrations of trace metals such as arsenic and selenium at downgradient locations. The degree to which Lost Creek was diluting the waste constituents that may reach it may have been significant, but could not be determined from the available information.

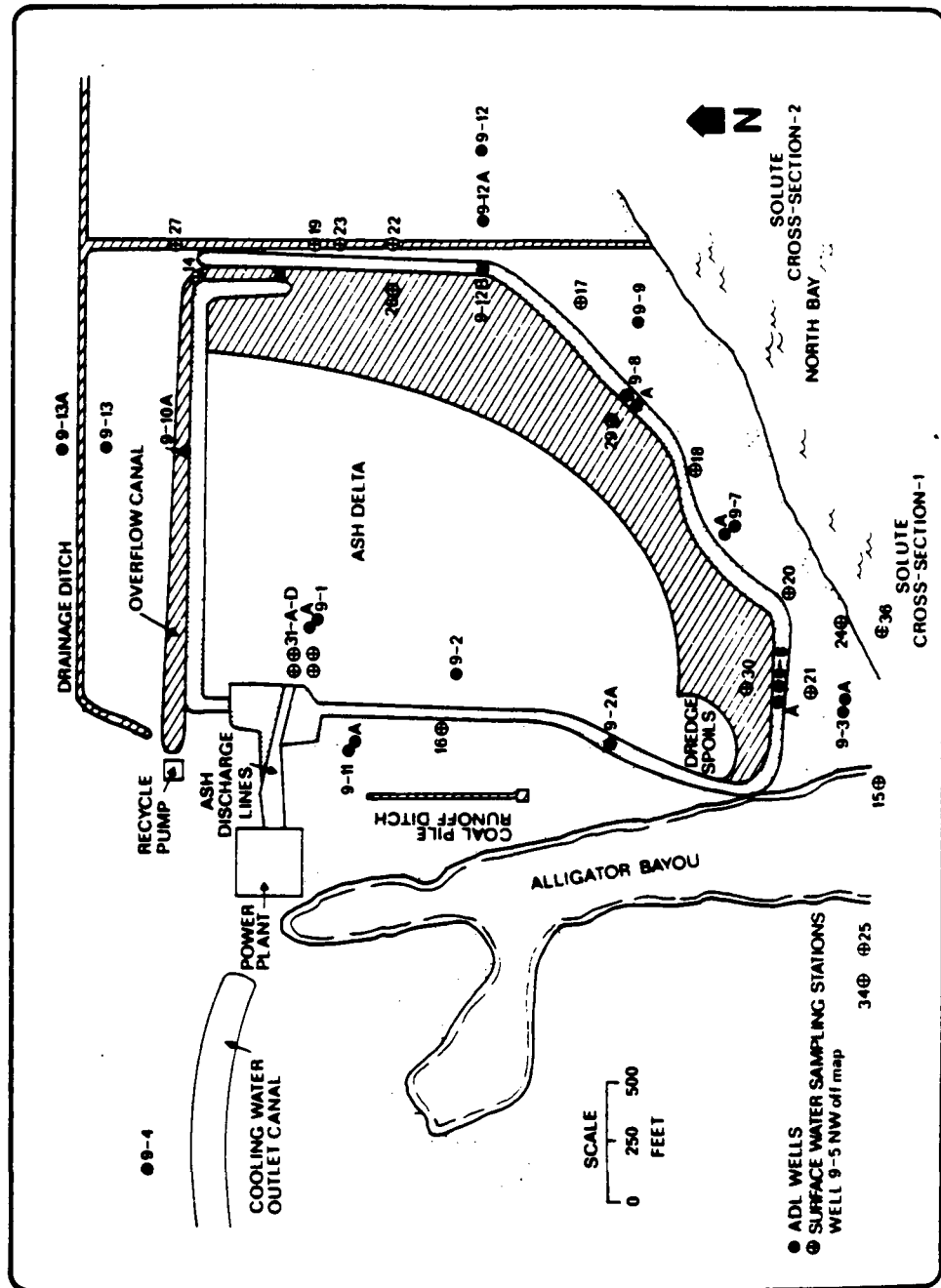
#### **E.9 LANSING SMITH PLANT**

The Lansing Smith power plant is located on a coastal plain approximately eight miles north of Panama City, Florida. The power plant lies approximately one-half mile inland from the shore of North Bay (within the St. Andrews Bay System) at the tip of Alligator Bayou. At the time of the ADL study, the two units at the site were equipped with electrostatic precipitators. The coal used was primarily low sulfur bituminous coal.

Fly ash, bottom ash, mill rejects, and coal pile runoff were sluiced to an unlined ash disposal pond which covers approximately 200 acres and lies generally between the power plant and the shore of North Bay (Exhibit E-21). The disposal pond has been in continuous use since 1965. The landfill was contained by dikes through the exterior slopes of which seepage had been

EXHIBIT E-21

DISPOSAL POND AND SAMPLING LOCATIONS AT  
LANSING SMITH SITE



Source: Tetra Tech 1985.



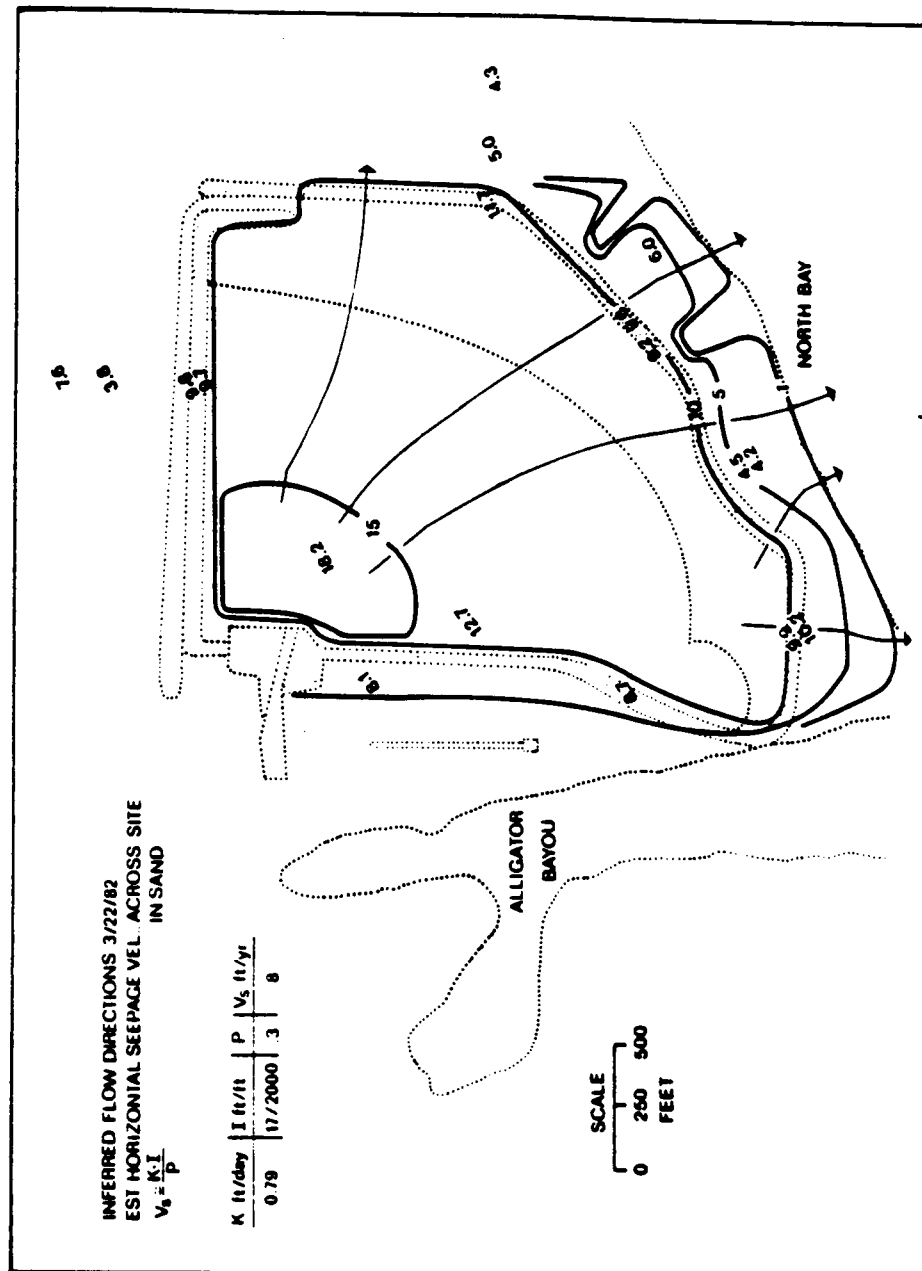
visually observed. Standing water in the disposal pond was channelled through a recycling canal and pumped back to the plant for reuse as sluicing water.

The plant was located on low-lying, almost level, marine terraces, which are drained by bayous and small creeks. The site experienced heavy precipitation (approximately 58 inches/year) and the low elevations of the site area had experienced flooding from both the river basin and coastal storms. Part of the land underlying the ash pond was once a swamp.

Surface deposits at the site consisted of thin topsoil and shallow organic deposits. Limestone of the confined Floridan Aquifer lay at a depth of approximately 90 feet, and was the principal water supply aquifer of the county. A thick layer of unconsolidated permeable silts and sands was between the Floridan Aquifer and the surface deposits. Due to saltwater intrusion, ground water in these deposits was not considered potable (and was not used as a drinking water supply at the time of the study). The water table at the site was close to the ground surface, resulting in swampy conditions. Ground water was in contact with the disposed ash materials. Regional ground-water flow was southeasterly towards North Bay (Exhibit E-22), however, flow patterns were multi-directional in the plant vicinity.

Surface water in the plant vicinity consisted of the ash disposal pond, the sluice water recycle canal, various drainage ditches and tidal creeks around the ash disposal pond, Alligator Bayou, and a cooling-water outlet canal, some of which contained seawater.

**EXHIBIT E-22**  
**GROUND WATER FLOW DIRECTIONS AT LANSING SMITH SITE**



Source: Tetra Tech 1985.

Factors for including the Lansing Smith Plant in the ADL study were:

- The disposal method employed at the plant -- that of combined disposal of fly ash and bottom ash in an unlined pond -- was the most prevalent utility waste disposal practice in the nation.
- The disposal operation had been in existence for more than 15 years, allowing sufficient time for measurable leachate to reach the surrounding environment.
- The site was a coastal area and would allow the study of a situation where ash pond leachate and seawater would mix.
- The site experienced heavy precipitation in a setting of permeable soils and was expected to illustrate a maximal extent of leachate formation and transport in a pond disposal setting.
- Increases were anticipated in coal conversion of coastal oil-fired power plants, and there was a paucity of data and previous studies of coastal disposal operations.

#### E.9.1 Sampling Approach

Samples of wastes and soils were collected for physical and chemical testing. Samples of ground water, waste fluids (or pond liquors), and surface water samples were collected for chemical testing. A series of attenuation tests were performed using local site soils and pond liquor solutions (spiked with trace elements) obtained from the Allen and Sherburne County sites.

Twenty-four monitoring wells were installed throughout the site area (Exhibit E-21). There were three upgradient ground-water wells (9-4, 9-5, and 9-13A) and five true downgradient ground-water wells (9-3, 9-3A, 9-7, 9-7A, and 9-9). Eleven monitoring wells were drilled within the ash pond or through the dike (9-1, 9-1A, 9-2, 9-2A, 9-6, 9-6A, 9-8, 9-8A, 9-10, 9-10A, and 9-12B). Two

of these wells were used to sample water from under the waste. An additional five wells were located along the perimeter of the dike. In addition, 18 surface water sampling stations were established. Locations of site wells and surface water sampling locations were shown in Exhibit E-21.

#### E.9.2 Results

Exhibit E-23 presents the results of chemical sampling at the Lansing Smith site. This includes samples from the downgradient and upgradient ground-water wells, samples from wells emplaced within the waste to collect interstitial water or fluids (includes supernatant fluids), water samples obtained from beneath the waste, and surface water samples. Results are discussed below.

Waste Solids. The waste was generally found to be segregated into lenses of coarser and finer grained ash. A permeability of  $9 \times 10^{-4}$  cm/sec was measured for the coarser ash, and  $3 \times 10^{-5}$  cm/sec for the finer fly ash.

Waste Fluids. Results from fluid samples collected from wells emplaced within the waste indicate that these fluids or "pond liquors", when compared to Primary Drinking Water Standards, exhibit elevated concentrations of cadmium (up to 6 times the PDWS), chromium (up to 21 times the PDWS), and fluoride (up to 10 times the PDWS). Comparison of pond liquors to Secondary Drinking Water Standards showed elevated levels chloride (up to 61 times the SDWS), manganese (up to 7 times the SWDS), and sulfate (up to 6 times the SDWS). These fluids were also fairly alkaline (up to a pH of 11). Since these fluids are not ingested, comparison to the drinking water standards is shown to demonstrate the potential for contamination at the site.

EXHIBIT E-23

CHEMICAL SAMPLING RESULTS FOR LANSING SMITH SITE

LANSING SMITH STEAM PLANT

Units = ppm		Ground water						Under Waste						Surface Water (Alligator Bayou, North Bay, and a stream on the east side)									Waste					
PDWS		1/			2/			3/			4/			5/			6/			7/								
		Downgradient (5 wells)			Upgradient (3 wells)			Water Under Waste (2 wells)			Downgradient (6 stations)			Peripheral (3 stations)			Downgradient - Saline (2 stations)			Pond Liquors (9 stations)								
Drinking Water Standard		Total Samples	Exceed. Samples	8/ Max. Exceed.	9/ Samples	8/ Exceed. Samples	9/ Max. Exceed.	Total Samples	Exceed. Samples	8/ Max. Exceed.	9/ Samples	8/ Exceed. Samples	9/ Max. Exceed.	Total Samples	Exceed. Samples	8/ Max. Exceed.	9/ Samples	8/ Exceed. Samples	9/ Max. Exceed.	Total Samples	Exceed. Samples	8/ Max. Exceed.	9/ Samples	10/ Detect.	11/ Ave. Conc.	9/ Max. Exceed.		
Arsenic (liq.)	0.05	5	0		4	0		3	0		2	0		1	0		3	0		8	0.0055							
Barium	1	14	0		6	0		4	0		13	0		8	0		5	0		18	0.26							
Cadmium	0.01	14	10	5	6	2	2	4	4	4	13	10	5	8	4	4	5	5	4	16	0.029			6				
Chromium (Cr VI)	0.05	14	1	4	6	0		4	1	2	13	0		8	0		5	1	1.2	8	0.16			21.4				
Fluoride 12/	4.01	14	5	13.5	6	0		3	1	2.2	13	5	6.5	8	2	2	5	2	20	3	20			10				
Lead 13/	0.05	14	0		6	0		4	0		13	0		8	0		5	0		0								
Mercury	0.002	0			0			0			0			0			0			14/ NS								
Nitrate 15/	45	0			0			0			0			0			0			14/ NS								
Selenium (liq.)	0.01	5	0		4	0		3	0		2	0		1	0		3	0		8	0.0014							
Silver	0.05	14	0		6	0		4	0		13	0		8	0		5	0		0								
SDMS																												
Chloride	250	14	14	22.4	6	0		4	4	49	13	13	11.9	8	5	10	5	5	57.8	18	3790			61				
Copper	1	14	0		6	0		4	0		13	0		8	0		5	0		10	0.11							
Iron	0.3	14	14	118	6	6	37	4	0		13	11	370	8	6	34	5	0		12	0.12							
Manganese	0.05	14	13	17.2	6	2	1.4	4	1	5.2	13	11	64	8	6	4.8	5	0		8	0.17			7.4				
Sulfate	250	14	8	8.4	6	0		4	4	9.8	13	12	7.5	8	4	3.4	5	5	9.9	18	866			6.4				
Zinc	5	14	0		6	0		4	0		13	0		8	0		5	0		9	0.12							
pH Lab 16/	<=6.5	6	4	4.4	2	1	6.5	1	0		6	5	3.3	3	2	3.8	1	0		6	9.3							
	>=8.5	6	0		2	0		1	1	9.5	6	0		3	0		1	0		6	9.3			11				
pH Field 16/	<=6.5	13	10	2.9	6	4	6	3	0		10	5	4.1	7	4	3.4	5	0		12	9.1			6				
	>=8.5	13	0		6	0		3	3	9.5	10	0		7	0		5	0		12	9.1			11				

## EXHIBIT E-23 (Continued)

### CHEMICAL SAMPLING RESULTS FOR LANSING SMITH SITE

- 1/ Wells 9-3 (deep, south), 9-3 (low tide), 9-3A (shallow, south) 9-3A (low tide), 9-7A, 9-7, and 9-9.
  - 2/ Wells 9-4, 9-5, and 9-13A.
  - 3/ Wells 9-2 and 9-1. The fluids collected at these wells are waters from beneath the waste.
  - 4/ Stations 9-18, 9-20, 9-21, 9-24, 9-34, 9-25, but not station 9-34 (dissolved solids).
  - 5/ Stations 9-27, 9-23, and 9-22.
  - 6/ Stations 9-15, 9-36.
  - 7/ Stations 9-1A, 9-1 (screen at interface), 9-1 (6-8 ft), 9-2 (0-2 ft), 9-2 (4-6 ft), 9-14, 9-30, 9-29, and 9-26. These "pond liquors" are fluids collected from within and on top of the landfilled wastes.
  - 8/ The number of samples with reported concentrations above the drinking water standard.
  - 9/ Max. Exceed. is the concentration of the greatest reported exceedance divided by the drinking water standard for that particular contaminant. The only exception is for pH, where Max. Exceed. is the actual measurement.
  - 10/ The number of "pond liquor" samples with reported concentrations above the reported detection limits. An entry of "0" indicates that no sample had a detectable contaminant concentration, not that no samples were taken (see footnote 14).
  - 11/ Ave. Conc. is the average of the reported concentrations of all "pond liquor" samples taken that showed a contaminant concentration above the detection limit. The reported pH measurements of the "pond liquors" are also averaged.
- [Comment on footnotes 12-13:  
Where the reported detection limit for a contaminant was greater than the drinking water standard and the sample contained less contaminant than the reported detection limit, the sample is tabulated in this table as being below the drinking water standard.]
- 12/ For some water samples collected from downgradient groundwater, downgradient surface water, and "pond liquors," the reported detection limit of 25 was greater than the PDWS of fluoride. For some water samples collected from downgradient saline surface water and water under the waste, the reported detection limit of 50 was also greater than the PDWS for fluoride. Finally, for some water samples collected from peripheral surface water, the reported detection limit of 5 was greater than the PDWS for fluoride.  
The solubility of fluoride in water is markedly affected by temperature. Of the temperature ranges and corresponding maximum allowable contaminant levels reported for fluoride in the NIPDWS, the range shown on this table (26.3-32.5 C) corresponds to the most stringent allowable maximum contaminant concentration.
  - 13/ For some water samples collected from downgradient groundwater, water under the waste, downgradient surface water, peripheral surface water, downgradient saline surface water, and "pond liquors," the reported detection limit of 0.1 was greater than the PDWS for lead.
  - 14/ NS = not sampled.
  - 15/ As indicated in footnote 9, the Max. Exceed. column for the reported pH measurements is a tabulation of the actual measurements, not the maximum exceedance divided by the drinking water standard.

Water samples obtained from under the waste showed exceedances of the Primary Drinking Water Standards for the same constituents with high concentration levels in the waste fluids; cadmium (up to 4 times the PDWS), chromium (up to 2 times the PDWS), and fluoride (up to 2.2 times the PDWS). These samples also exhibited elevated concentrations of boron (up to 8 times the SDWS), chloride (up to 49 times the SDWS), manganese (up to 5 times the SDWS), and sulfate (up to 10 times the SDWS). The pH of these samples (up to 9.5) also indicated alkalinity.

Ground Water. Estimates were made of seepage velocities at the site. Results from these calculations appeared to indicate that there has been enough time for constituents in waste leachate to have reached downgradient wells and North Bay.

Primary Drinking Water Standards were found to be exceeded in the ground water of the downgradient wells for cadmium (up to 5 times the PDWS), chromium (up to 4 times the PDWS), and fluoride (up to 13.5 times the PDWS). These were the same contaminants found to exceed the standards in the waste fluids. Upgradient exceedances of the PDWS in ground-water samples were also found for cadmium (up to 2 times the PDWS). However, this exceedance was less common and at lower levels than the downgradient samples. Arsenic and selenium were found to be below the Primary Drinking Water Standards in the ground-water (and waste fluid) samples at this site.

Secondary Drinking Water Standards were found to be exceeded in downgradient ground water for chloride (up to 22 times the SDWS), iron (up to 118 times the SDWS), manganese (up to 17 times the SDWS), and sulfate (up to 8 times the

SDWS). Except for iron, these were the same contaminants observed at concentrations greater than Secondary Drinking Water Standards in the pond liquors. Samples were found to be acidic (maximum low pH of 2.9). This differed from the alkalinity exhibited by the pond liquors.

Upgradient exceedances of the Secondary Drinking Water Standards in ground-water samples were observed for iron (up to 37 times the SDWS) and manganese (up to 1.4 times the SDWS). The Secondary Drinking Water Standards contaminants found at elevated concentrations in the pond liquors and in the downgradient ground water wells were not found to be elevated in upgradient ground water.

Surface Water. Primary Drinking Water Standards were exceeded in downgradient surface water samples for cadmium (up to 5 times the PDWS) and fluoride (up to 6.5 times the PDWS). In downgradient saline surface water samples, exceedances were observed for cadmium (up to 4 times the PDWS), chromium (up to 1.2 times the PDWS), and fluoride (up to 20 times the PDWS). In surface water samples collected peripheral to the ash disposal pond (east side), exceedances were found for cadmium (up to 4 times the PDWS) and fluoride (up to 2 times the PDWS).

Secondary Drinking Water Standards were exceeded in downgradient surface water samples for chloride (up to 12 times the SDWS), iron (up to 370 times the SDWS), manganese (up to 64 times the SDWS). These were the same contaminants found to exceed the Secondary Drinking Water Standards in peripheral surface water samples, although the levels of exceedance were lower. Both the downgradient and peripheral surface water samples were below the Secondary



Drinking Water Standards for pH (as low as 3.4). Saline surface water samples collected downgradient were found to exceed Secondary Drinking Water Standards for chloride (58 times the SDWS), and sulfate (10 times the SDWS). No true upgradient surface water samples were collected.

### E.9.3 Discussion and Conclusions

Cadmium, chromium, and fluoride were observed to exceed the Primary Drinking Water Standards in downgradient ground water in a greater proportion of samples and at higher levels than upgradient ground water. Elevated concentrations of these same contaminants were observed in the interstitial waters of the wastes (pond liquors) and in waters from under the waste. Sulfate, chloride, iron, and manganese were observed to exceed Secondary Drinking Water Standards in downgradient ground water. These same contaminants, with the exception of iron and manganese<sup>8</sup>, were not observed at elevated concentrations at upgradient ground water wells. Sulfate, chloride, and manganese were observed at elevated concentrations in waters in and under the waste. These results, in conjunction with the fact that leachate migration from the waste was predicted to have reached downgradient wells, strongly suggest that degradation of the ground-water quality in excess of the drinking water standards at the site had occurred due to leaching of some contaminant from the ash wastes. At this site, the ground water was not used as a drinking water source. Sampling of the deep underlying aquifer showed no evidence of contamination by ash pond leachate (or by seawater).

Constituent concentrations observed at the site indicated that leachate migration from the ponded wastes had probably reached steady-state conditions

with respect to the concentrations of these species in the waste and downgradient wells. In this case, further increases in the concentrations of waste species in the downgradient ground water would not be expected.

Findings at the site are somewhat difficult to interpret due to the site's estuarine setting and consequent intrusion and infiltration of seawater. Difficulties in interpretations also arise from the use of saline bay waters for ash-sludge make-up water. This is discussed below.

While the exceedance of Primary Drinking Water Standards for the trace metals chromium and cadmium in the downgradient ground water appeared to be directly related to the leaching of constituents in the ash, this may not have been the case for ash-related constituents that were found to naturally occur in seawater. For example, the use of bay water as sludge make-up and its presence in adjacent downgradient areas may have masked the potential for significant impact from the ash constituents sulfate, and chloride (which are observed in elevated concentrations in downgradient ground water).<sup>9</sup> These constituents were found at similarly elevated concentrations in the bay waters, indicating that concentrations of these constituents were probably influenced by seawater. These seawater-related species were of concern only as Secondary Drinking Water Standards.

The use of bay waters as ash sludge make-up water may have diluted and reduced the availability of trace metals that might have otherwise been readily leachable from the surface layers of the ash. This could have resulted in lower concentrations of trace metals observed in downgradient ground (and surface) water than if seawater were not used.

A scrap metal disposal area located on the west side of the ash disposal pond at the Lansing Smith site may have been a contributor to the large exceedances of the Secondary Drinking Water Standards observed in the ground and surface waters. Attenuation studies conducted at the site indicated that chemical attenuation may be occurring in soils surrounding the disposal pond for arsenic, strontium, and calcium.

Since no upgradient surface water samples were collected at the site, few interpretations could be made of the available surface water data. On-site flooding and pond seepage which had occurred at the site may have contributed to the transport of leachate away from the disposal pond and into the surface water. As with ground-water samples, seawater would influence concentrations of seawater-related species in surface water samples. The elevated concentrations of fluoride observed in the saline, downgradient, surface-water samples -- and not in non-saline downgradient surface-water samples -- indicated that the concentrations of fluoride observed in the downgradient ground water at the site may have been influenced by, or even the result of, the use of seawater in site operations and its intrusion (by flooding) downgradient of the wastes.

In summary, the Lansing Smith plant in southern Florida disposed of a mixture of fly ash and bottom ash in an unlined disposal pond located in a coastal area. Concentrations greater than the Primary Drinking Water Standards were observed for cadmium (up to five times the PDWS), chromium (up to four times the PDWS), and fluoride (up to 13.5 times the PDWS) in the downgradient ground water at the site and, with the possible exception of fluoride, appear to be due largely to these contaminants leaching from the ponded ash wastes.

Exceedances of Secondary Drinking Water Standards for several species (sulfate, chloride, manganese, and iron) were also observed in downgradient ground water. However, most of these species were seawater-related and their reported concentrations appeared to be influenced by the use in plant operations and infiltration of estuarine (saline) water at the site. Generated leachate migrates to a shallow, unused, tidal aquifer.

Ash disposal from utility operations at this site has had a measurable impact on ground-water quality. However, human health risks at this particular site were probably minimal since the ground and surface water were not used for drinking purposes.

#### **E.10 QA/QC OF ADL TESTING DATA**

As part of its study approach, ADL collected QA/QC samples at the six study sites. These included field replicates, laboratory splits, and field blanks. Standard solution and spiked solutions were also measured in the laboratory. Analysis of data produced by this QA/QC program included that:

- The variability introduced by the sampling and analytical procedures utilized in the study was less than the field variability. Thus the analytical methods used should have been capable of detecting concentration differences attributable to the field conditions.
- Analytical precision, as measured by the relative standard deviation, varied among constituents. For major ions (e.g., Mg, Cl, and SO<sub>4</sub>), precision was high (RSD less than 10 percent); for the trace metals above detection, plus NO<sub>3</sub> and F<sub>3</sub>, precision was lower (RSD greater than 20 percent).

Examination of the ADL field data indicates that:

- Most concentrations of Ag, Ba, Be, Br, Cu, Cr, Pb, PO<sub>4</sub>, Sr, Th, Ti, and Zn were below detection limits.
- Reported detection limits for constituents were variable upon occasion, spanning two orders of magnitude for some constituents. Occasionally, the reported detection limits were above the drinking water standards.
- Overall, approximately 1.5 percent of the ADL chemical data may be outliers.

In general, QA/QC results do not indicate large shortcomings in the chemical data. However, caution must be used in interpreting the data using rigorous deterministic methods. Some of the constituents (e.g., cadmium) for which variations in detection limits were observed are of possible concern in regard to human health and coal combustion waste disposal practices. However, it is unclear from the available analysis information how significant these variations might be in regard to assessing the environmental impact of coal combustion wastes. It is possible that some of the constituents for which detection limits were reported to be in excess of drinking water standards, may be of greater concern than the data indicate.

## NOTES

<sup>1</sup> Each physiographic region has a distinctive climate, particular vegetative types, characteristic soils, a particular water regime, and differences in principal natural resources.

<sup>2</sup> Data sources included precursor U.S. EPA study -- Versar, Inc., Selection of A Representative Coal Ash and Coal Ash/FGD Waste Disposal Sites for Future Evaluations, 1979 (Research Triangle Park, North Carolina. EPA-IERL, 2771, 1979) and a data base resulting from work by EPA, EPRI, TVA, DOE, and others.

<sup>3</sup> At the time of the ADL study there were more than 350 steam-electric plants in the U.S. Of this number 340 had greater than 25 megawatts capacity and utilized coal for more than 80 percent of their power production. Approximately 55 percent of these plants were located in the physiographic regions that cover the Appalachian and Midwest areas of the country.

<sup>4</sup> Sites with a generating capacity of less than 200 megawatts, very complex sites (both technological or hydrogeological), plants which sell greater than 50 percent of their ash output, and plants with disposal sites less than two years old, sites were eliminated from further consideration.

<sup>5</sup> The Arthur D. Little report does not indicate if the discharges from the Allen Plant pond (or from the Elrama Plant pond described below) are permitted under NPDES. According to Section 402 of the Clean Water Act all discharges of pollutants to surface waters from point sources must be permitted. The effluent limitation guidelines for steam electric power generators are given in 40 CFR Part 423.

<sup>6</sup> A Registered Trademark.

<sup>7</sup> Registered Trademark.

<sup>8</sup> Note that this exceedance was slight--only 1.4 times the SDWS in upgradient ground water--but was 17 times the SDWS in downgradient ground water.

<sup>9</sup> Seawater could also influence concentrations of sodium; magnesium, and selenium were not found to exceed drinking water standards.

# DATA ON SAMPLE OF COAL-FIRED COMBUSTION WASTE DISPOSAL SITES

PLANT NAME	ST	NUMBER OF GEN. UNITS	POPULATION WITHIN FIVE CONCENTRIC RINGS (KM)					TOTAL POPULATION
			0-1	1-2	2-3	3-4	4-5	
MCWILLIAMS	AL	3	314	0	0	0	1748	2062
INDEPENDENCE	AR	2	0	0	0	818	370	1188
CORONADO	AZ	3	0	0	0	0	0	0
NAVAJO	AZ	3	0	0	0	1016	10	1026
SPRINGERVILLE 1&3	AZ	2	0	0	190	0	0	190
SPRINGERVILLE 2	AZ	2	0	0	190	0	0	190
CHEROKEE	CO	3	626	522	7645	17558	37735	64086
off-site landfill			49	4894	22366	29981	40235	97525
CRAIG	CO	3	480	0	0	0	0	480
off-site landfill			0	0	0	1872	3670	5542
NUCLA	CO	3						
off-site landfill			0	0	0	0	1027	1027
VALMONT	CO	1	0	1644	0	8393	19020	29057
DEERHAVEN	FL	1	0	6	110	1306	353	1775
FJ GANNON	FL	6	0	74	658	4528	7818	13078
LANSING SMITH	FL	2	0	0	0	0	1669	1669
MCINTOSH	FL	1	2176	0	1125	9099	21917	34317
SEMINOLE (FL)	FL	2	0	0	1280	0	0	1280
ARKWRIGHT	GA	4	0	0	1903	657	5356	7916
BOWEN	GA	4	0	0	740	0	158	898
SCHERER	GA	4	0	0	0	0	0	0
COUNCIL BLUFFS	IA	3	0	141	0	1744	441	2326
IOWA FALLS	IA	1	3141	3030	1424	0	0	7595
LANSING	IA	4	0	0	0	0	419	419
LOUISA	IA	1	0	0	0	0	544	544
PRAIRIE CREEK	IA	4	0	2696	7116	12854	16078	38744
off-site landfill			448	5722	17827	16720	15600	56317
STREETER	IA	2	3708	6099	2781	12251	20675	45514
CRAWFORD	IL	2						
off-site landfill			300	10862	27883	29225	54890	123160
PEARL	IL	1						
off-site landfill			0	0	0	0	170	170
WAUKEGAN	IL	2						
off-site landfill			2107	10278	6938	5353	6210	30886
BAILLY	IN	2						
off-site landfill			0	0	2570	1290	8073	11933
CAYUGA	IN	2	0	0	0	1457	0	1457
CLIFTY CREEK	IN	7	0	0	6686	5629	2688	15003
EW STOUT	IN	3	0	678	6604	14770	22169	44221
HT PRITCHARD	IN	4	0	0	0	0	1630	1630
MEROM	IN	2	0	360	0	0	0	360
MICHIGAN CITY	IN	3	0	6605	6617	11564	8107	32893
WHITEWATER VALLEY	IN	2	3423	5361	7558	14346	9374	40062
NEARMAN CREEK	KS	2	0	0	383	12069	14912	27364
HENDERSON ONE	KY	2	2403	5512	4936	8271	369	21491
HENDERSON TWO	KY	2	0	0	0	0	3032	3032
MORGANTOWN	MD	2						
off-site landfill			0	0	0	1189	2367	3556
NANTICOKE	MD	1	300	0	0	766	0	1066
ADVANCE	MI	3						
off-site landfill			0	0	540	313	0	853
COLDWATER	MI	3						
off-site landfill			0	1020	4157	5263	0	10440
JH CAMPBELL	MI	3	0	0	2206	0	0	2206
JH WARDEN	MI	1	1529	971	0	697	358	3555
ALLEN S KING	MN	1						
off-site landfill			374	0	0	0	0	374
HIBBING	MN	3	0	0	0	0	88	88
off-site landfill			1065	3381	6028	3842	3028	17344
LITCHFIELD	MN	1	21	3522	2368	0	810	6721
NORTHEAST	MN	1	0	1446	1797	8704	11600	23547
RED WING	MN	2	0	100	11	913	895	1919
VIRGINIA	MN	3						
off-site landfill			1129	0	3351	5182	7650	17312

PLANT NAME	ST	DRASTIC VELOCITY		DEPTH TO	HYDRAULIC	PERMEABILITY	NET	GROUND-WATER
		CODE OF AQUIFER		GROUND WATER	CONDUCTIVITY	(Gal/day/sq.ft)	RECHARGE	HARDNESS
				(Feet)	(Gal/day/sq.ft)		(inches)	(ppm CaCO3)
MCWILLIAMS	AL	10Ab	-130	5-15	700-1000	1.0E+04	10+	80-120
INDEPENDENCE	AR	6Fa	-100	15-30	1000-2000	1.0E-02	7-10	180-240
CORONADO	AZ	4B	-1485	50-75	1-100	1.0E-03	0-2	180-240
NAVAJO	AZ	4B	-1485	50-75	1-100	1.0E-03	0-2	180-240
SPRINGERVILLE 1&3	AZ	2D	-220	30-50	300-700	1.0E+01	0-2	180-240
SPRINGERVILLE 2	AZ	2D	-220	30-50	300-700	1.0E+01	0-2	180-240
CHEROKEE	CO	6Fb	-100	5-15	1000-2000	1.0E+04	7-10	180-240
off-site landfill		6Fb	-100	5-15	1000-2000	1.0E+04	7-10	180-240
CRAIG	CO	4A	75-7500	75-100	1-100	1.0E+00	0-2	180-240
off-site landfill		4A	75-7500	75-100	1-100	1.0E+00	0-2	180-240
NUCLA	CO							
off-site landfill		4B	-1485	50-75	1-100	1.0E+00	0-2	180-240
VALMONT	CO	6Db	-742.5	10	1-100	1.0E-01	4-7	120-180
DEERHAVEN	FL	11C	300+	0-5	2000+	1.0E+03	10+	>240
FJ GANNON	FL	11D	370-500	5-15	700-1000	1.0E+04	10+	>240
LANSING SMITH	FL	11D	370-500	5-15	700-1000	1.0E+04	10+	120-180
MCINTOSH	FL	11C	300+	0-5	2000+	1.0E+03	10+	180-240
SEMINOLE (FL)	FL	11B	-30	5-15	700-1000	1.0E+04	10+	>240
ARKWRIGHT	GA	8E	-500	5-15	1000-2000	1.0E+01	7-10	80-120
BOWEN	GA	6Fb	-100	5-15	1000-2000	1.0E+04	7-10	80-120
SCHERER	GA	8E	-500	5-15	1000-2000	1.0E+02	4-7	120-180
COUNCIL BLUFFS	IA	7Ea	-30	5-15	700-1000	1.0E-02	4-7	180-240
IOWA FALLS	IA	7Eb	-30	5-15	700-1000	1.0E+05	10+	>240
LANSING	IA	7Ea	-30	5-15	700-1000	1.0E-02	4-7	>240
LOUISA	IA	7Eb	-30	15-30	700-1000	1.0E+04	10+	>240
PRAIRIE CREEK	IA	7Eb	5-15	700-1000	1.0E+04	10+	>240	
off-site landfill		7G	-1500	15-30	100-300	1.0E-02	7-10	>240
STREETER	IA	7Eb	-30	5-15	700-1000	1.0E+05	10+	>240
CRAWFORD	IL							
off-site landfill		7Eb	-30	5-15	700-1000	1.0E+04	10+	>240
PEARL	IL							
off-site landfill		7Aa	-1500	30-50	100-300	1.0E-03	4-7	180-240
WAUKEGAN	IL							
off-site landfill		7C	400	15-30	300-700	1.0E-01	7-10	>240
BAILLY	IN							
off-site landfill		7F	-300	15-30	100-300	1.0E+02	4-7	>240
CAYUGA	IN	7Ea	-30	15-30	700-1000	1.0E-01	4-7	>240
CLIFTY CREEK	IN	7Ea	-30	5-15	700-1000	1.0E-01	4-7	>240
EW STOUT	IN	7Eb	-30	5-15	700-1000	1.0E+04	10+	>240
HT PRITCHARD	IN	7Ea	-30	10-20	700-1000	1.0E-01	4-7	>240
MEROM	IN	7Ac	-3250	30-50	2000+	1.0E-01	4-7	>240
MICHIGAN CITY	IN	7H	-100	0-5	1000-2000	1.0E+04	10+	>240
WHITEWATER VALLEY	IN	7Ac	-3250	30-50	2000+	1.0E-01	4-7	>240
NEARMAN CREEK	KS	7Ea	-30	5-15	700-1000	1.0E-02	4-7	180-240
HENDERSON ONE	KY	6Fb	-100	5-15	1000-2000	1.0E+04	7-10	120-180
HENDERSON TWO	KY	60a	-742.5	15-30	1-100	1.0E-01	4-7	80-120
MORGANTOWN	MD							
off-site landfill		10Ab	-130	5-15	700-1000	1.0E+04	10+	<80
NANTICOKE	MD	10Bb	100-200	0-5	1000-2000	1.0E+01	10+	<80
ADVANCE	MI							
off-site landfill		7Ba	500-1000	5-15	1000-2000	1.0E+04	7-10	180-240
COLDWATER	MI							
off-site landfill		7Ac	-3250	30-50	2000+	1.0E-03	4-7	>240
JH CAMPBELL	MI	7F	-300	15-30	100-300	1.0E+02	4-7	>240
JH WARDEN	MI	7H	-100	0-5	1000-2000	1.0E+04	10+	120-180
ALLEN S KING	MN							
off-site landfill		7Bb	750+	0-5	100-300	1.0E+04	10+	>240
HIBBING	MN	90a	-742.5	15-30	1-100	0	7-10	180-240
off-site landfill		90a	-742.5	5-15	1-100	1.0E-02	7-10	180-240
LITCHFIELD	MN	7Aa	-1500	10-20	100-300	1.0E-03	4-7	>240
NORTHEAST	MN	7Eb	-30	5-15	700-1000	1.0E-03	10+	>240
RED WING	MN	7Ea	-30	10-20	700-1000	1.0E-02	4-7	>240
VIRGINIA	MN							
off-site landfill		90a	-742.5	15-30	1-100	1.0E-02	7-10	180-240



PLANT NAME	ST	NUMBER OF GEN. UNITS	POPULATION WITHIN FIVE CONCENTRIC RINGS (KM)					TOTAL POPULATION
			0-1	1-2	2-3	3-4	4-5	
ASBURY	MO	1	0	0	0	0	0	0
BLUE VALLEY	MO	3	0	0	560	11234	5225	17019
CHAMPAIS	MO	2	0	0	0	0	683	683
HENDERSON (MS)	MS	2	0	0	0	809	1329	2138
BELEWS CREEK	NC	2	0	1009	0	0	0	1009
CAPE FEAR	NC	4	0	0	190	1047	0	1237
CLIFFSIDE	NC	1	0	982	0	0	1412	2394
HESKETT	ND	2	0	0	0	3115	4166	7281
OLIVER COUNTY	ND	1						
off-site landfill			0	0	0	0	0	0
NEBRASKA CITY	NE	1	0	0	0	0	0	0
BL ENGLAND	NJ	2	0	2473	595	3685	14370	21123
RATON	NM	2	1447	3267	3511	0	0	8225
ACME	OH	3	4762	22356	29567	47606	31578	135869
off-site landfill			530	4424	17427	24150	38884	85415
ASHTABULA	OH	5						
off-site landfill			198	939	3940	2494	3732	11303
JM STUART	OH	4	0	0	0	1657	1283	2940
PIQUA	OH	4	1927	7682	6147	5523	1302	22581
POSTON	OH	4	0	0	373	2383	1065	3821
RE BURGER	OH	5						
off-site landfill			0	0	991	0	0	991
MC BECKJORD	OH	6	0	429	0	2266	1785	4480
off-site landfill			429	0	0	3274	5779	9482
WH SAMMIS	OH	7						
strip mine disposal			0	0	0	4045	2443	6488
HUGO	OK	1	0	439	0	0	0	439
HOLTHOOD	PA	1	0	0	1584	797	0	2381
off-site landfill			0	0	1584	797	0	2381
HOMER CITY	PA	3	0	0	0	2772	2544	5316
MITCHELL (PA)	PA	1						
off-site landfill			675	4358	1485	9391	6509	22418
SEWARD	PA	2	0	675	0	0	4222	4897
CROSS	SC	4	0	0	0	0	488	488
URQUHART	SC	3	0	1489	0	662	6348	8499
FOREST GROVE	TX	1	0	0	0	503	1221	1724
GIBBONS CREEK	TX	1						
off-site landfill			0	0	0	0	0	0
JT DEELY	TX	2	492	0	0	1059	938	2489
SAN MIGUEL	TX	2	0	0	97	0	0	97
SANDOW	TX	1	0	0	0	0	0	0
BONANZA	UT	2	0	0	0	0	0	0
CHESTERFIELD	VA	4	0	716	204	2277	4349	7546
POTOMAC RIVER	VA	5						
off-site landfill			1940	9266	19344	24307	35048	89905
CENTRALIA	WA	2						
off-site landfill			1216	2151	3811	6096	4642	17916
COLUMBIA	WI	2	0	0	0	1215	0	1215
GENOA	WI	3	0	283	0	0	787	1070
HARRISON	WV	3	0	1237	2269	2091	2946	8543
KANAWHA RIVER	WV	1	724	1786	2986	2572	3152	11220
MITCHELL	WV	2	0	0	0	2181	1970	4151
MOUNTAINEER	WV	1	0	697	211	4880	255	6043
PHILIP SPORN	WV	5	0	908	0	960	2974	4842
NAUGHTON	WY	3	0	0	0	0	0	0

PLANT NAME	ST	DRASTIC VELOCITY CODE OF AQUIFER	DEPTH TO GROUND WATER (Feet)	HYDRAULIC CONDUCTIVITY (Gal/day/sq.ft)	PERMEABILITY (Gal/day/sq.ft)	NET RECHARGE (inches)	GROUND-WATER HARDNESS (ppm CaCO3)	
ASBURY	MO	6Db	-742.5	15-30	1-100	1.0E+00	4-7	120-180
BLUE VALLEY	MO	7Ea	-30	15-30	700-1000	1.0E-01	4-7	180-240
CHAMOIS	MO	7Ea	-30	5-15	700-1000	1.0E-02	4-7	>240
HENDERSON (MS)	MS	10C	100-200	0-5	1000-2000	1.0E+04	10+	<80
BELEWS CREEK	NC	8C	-3000	30-50	100-300	1.0E-04	2-4	80-120
CAPE FEAR	NC	8E	-500	5-15	1000-2000	1.0E-01	7-10	<80
CLIFFSIDE	NC	8E	-500	5-15	1000-2000	1.0E-01	7-10	80-120
HESKETT	ND	7Eb	-30	5-15	700-1000	1.0E+04	10+	>240
OLIVER COUNTY off-site landfill	ND	7Ae	7.5-750	30-50	1-100	1.0E-03	4-7	>240
NEBRASKA CITY	NE	7Ea	-30	0-10	700-1000	1.0E-02	4-7	180-240
BL ENGLAND	NJ	10C	100-200	0-5	1000-2000	1.0E+04	10+	<80
RATON	NM	68	-130	15-30	700-1000	1.0E+01	4-7	120-180
ACME	OH	7Eb	-300	5-15	700-1000	1.0E+04	10+	>240
off-site landfill		7F	-300	15-30	100-300	1.0E+02	4-7	>240
ASHTABULA off-site landfill	OH	7F	-300	15-30	100-300	1.0E+02	4-7	180-240
JM STUART	OH	7Eb	-30	5-15	700-1000	1.0E+04	10+	>240
PIQUA	OH	7Eb	-30	5-15	700-1000	1.0E+04	10+	>240
POSTON	OH	68	-130	15-30	700-1000	1.0E+02	4-7	>240
RE BURGER off-site landfill	OH	60a	-742.5	15-30	1-100	1.0E-03	4-7	>240
WC BECKJORD	OH	6Fb	-100	5-15	1000-2000	1.0E+04	7-10	>240
off-site landfill		7Ae	7.5-750	30-50	1-100	1.0E-03	4-7	>240
WH SAMMIS strip mine disposal	OH	60a	-742.5	15-30	1-100	1.0E-04	4-7	>240
HUGO	OK	6Fb	-100	5-15	1000-2000	1.0E+04	7-10	80-120
HOLTWOOD	PA	8D	-148.5	5-15	1-100	1.0E-03	4-7	80-120
off-site landfill		8D	-148.5	5-15	1-100	1.0E-03	4-7	80-120
HOMER CITY	PA	60a	-742.5	15-30	1-100	1.0E-03	4-7	>240
MITCHELL (PA) off-site landfill	PA	6A	75-7500	30-50	1-100	1.0E-03	0-2	>240
SEWARD	PA	6Fb	-100	5-15	1000-2000	1.0E+04	7-10	120-180
CROSS	SC	10C	100-200	0-5	1000-2000	1.0E+04	10+	<80
URQUHART	SC	8E	-500	5-15	1000-2000	1.0E-01	7-10	<80
FOREST GROVE	TX	10Ab	-130	5-15	700-1000	1.0E+04	10+	<80
GIBBONS CREEK off-site minefill	TX	10Ab	-130	5-15	700-1000	1.0E+04	10+	<80
JT DEELY	TX	10Ab	-130	5-15	700-1000	1.0E+04	10+	120-180
SAN MIGUEL	TX	10Aa	3000-	100+	300-700	1.0E-02	0-2	120-180
SANDOW	TX	60b	-742.5	15-30	1-100	1.0E-01	4-7	<80
BONANZA	UT	4D	100-300	50-75	100-300	1.0E+01	0-2	180-240
CHESTERFIELD	VA	8E	-500	0-5	1000-2000	1.0E+02	7-10	80-120
POTOMAC RIVER off-site landfill	VA	8D	-148.5	5-15	1-100	1.0E+01	4-7	80-120
CENTRALIA off-site landfill	WA	1Eb	-130	5-15	700-1000	1.0E+04	4-7	<80
COLUMBIA	WI	6Fa	-100	0-5	1000-2000	1.0E-02	7-10	>240
GENOA	WI	6Fa	-100	0-5	1000-2000	1.0E-02	7-10	>240
HARRISON	WV	6Fb	-100	5-15	1000-2000	1.0E+04	7-10	180-240
KANAWHA RIVER	WV	6Fb	-100	5-15	1000-2000	1.0E+04	7-10	180-240
MITCHELL	WV	6Fb	-100	5-15	1000-2000	1.0E+04	7-10	>240
MOUNTAINEER	WV	6Fb	-100	5-15	1000-2000	1.0E+04	7-10	>240
PHILIP SPORN	WV	6Fb	-100	5-15	1000-2000	1.0E+04	7-10	>240
NAUGHTON	WY	48	-1485	50-75	1-100	1.0E-03	0-2	>240

PLANT NAME	DISTANCE TO SURFACE WATER (meters)	SURFACE WATER NAME	MINFLOW (ft <sup>3</sup> /second)	MAXFLOW	PUBLIC WATER SYSTEMS (PWS) WITHIN DOWNGRADIENT PLUME (distance in meters)
MCWILLIAMS	AL	50 Conecuh River	357	1850	-
INDEPENDENCE	AR	340 White River	5740	22600	-
CORONADO	AZ	7900 Carrizo Wash	0	0	-
NAVAJO	AZ	3230 Colorado River	6830	41600	-
SPRINGERVILLE 1&3	AZ	9800 Little Colorado River	0	0	-
SPRINGERVILLE 2	AZ	9500 Little Colorado River	0	0	-
CHEROKEE	CO	80 South Platte River	92.4	676	1700; 1900; 226400
off-site landfill		350 Clear Creek	84.4	552	700; 5500; 6100
CRAIG	CO	2600 Yampa River	202	5270	-
off-site landfill		1850 Yampa River	202	5270	-
NUCLA	CO				
off-site landfill		4400 San Miguel River	77.9	1040	-
VALMONT	CO	12 South Boulder Creek (Valmont Res)	7.68	256	-
DEERHAVEN	FL	1000 Sanchez Prairie Swamp (Turkey Cre	0	0	12500; 122600
FJ GANNON	FL	35 Hillsborough Bay (salt)	0	0	-
LANSING SMITH	FL	30 North Bay (salt)	0	0	-
MCINTOSH	FL	90 Lake Parker	0	0	22600; 122400; 225500; 127000
SEMINOLE (FL)	FL	2200 St. Johns River	3240	12800	6100
ARKWRIGHT	GA	700 Ocmulgee River	1190	5230	-
BOWEN	GA	200 Etowah River	1480	3980	-
SCHERER	GA	125 Ocmulgee River	1160	3970	-
COUNCIL BLUFFS	IA	170 Missouri River	14600	44900	-
IOWA FALLS	IA	15 Iowa River	126	753	-
LANSING	IA	200 Mississippi River	16800	69000	100
LOUISA	IA	970 Mississippi River	32000	102000	-
PRAIRIE CREEK	IA	180 Cedar River	964	5030	-
off-site landfill		620 Cedar River	964	5030	-
STREETER	IA	1150 Cedar River	964	5030	14 @ 4400
CRAWFORD	IL				
off-site landfill		65 Des Plaines River	383	1980	-
PEARL	IL				
off-site landfill		2100 South Fork Mckee Creek	62.7	200	226400; 428400
WAUKEGAN	IL				
off-site landfill		4150 Lake Michigan	0	0	222100; 22600; 126700
BAILLY	IN				
off-site landfill		1200 Deep River (Duck Creek)	46.4	287	326700
CAYUGA	IN	210 Wabash River	2820	15900	-
CLIFTY CREEK	IN	265 Ohio River	26800	257000	4900
EW STOUT	IN	80 White River	583	3900	-
HT PRITCHARD	IN	240 White River	697	4660	-
MEROM	IN	2200 Wabash River (Turtle Creek)	3790	21100	-
MICHIGAN CITY	IN	25 Lake Michigan	0	0	-
WHITewater VALLEY	IN	1300 East Fork Whitewater River	31	269	-
NEARMAN CREEK	KS	550 Missouri River	17500	71600	7400
HENDERSON ONE	KY	80 Ohio River	34100	309000	100
HENDERSON TWO	KY	450 Green River	3520	31800	200
MORGANTOWN	MD				
off-site landfill		3750 Potomac River	7050	21600	-
NANTICOKE	MD	20 Nanticoke River	297	1230	700
ADVANCE	MI				
off-site landfill		220 Lake Michigan (Inwood Creek)	0	0	-
COLDWATER	MI				
off-site landfill		1130 South Lake (Coldwater River)	34	186	-
JH CAMPBELL	MI	420 Pigeon Lake (Lake Michigan)	0	0	-
JH WARDEN	MI	100 Lake Superior	0	0	100 (prob)
ALLEN S KING	MN				
off-site landfill		740 Lake Jane	0	0	124400; 125000
HIBBING	MN	950 Welcome River	18	41.7	221400
off-site landfill		4600 East Swan River	25.2	413	2600
LITCHFIELD	MN	200 Jewitts Creek	2.35	44.4	-
NORTHEAST	MN	200 Cedar River	26.2	137	800
RED WING	MN	180 Mississippi River	8450	36300	-
VIRGINIA	MN				
off-site landfill		800 Pike River	3.84	107	-

PLANT NAME		DISTANCE TO SURFACE WATER (meters)	SURFACE WATER NAME	MINFLOW (ft <sup>3</sup> /second)	MAXFLOW	PUBLIC WATER SYSTEMS (PWS) WITHIN DOWNGRADIENT PLUME (distance in meters)
MCWILLIAMS	AL	50	Conecuh River	357	1850	-
INDEPENDENCE	AR	340	White River	5740	22600	-
CORONADO	AZ	7900	Carrizo Wash	0	0	-
NAVAJO	AZ	3230	Colorado River	6830	41600	-
SPRINGERVILLE 1&3	AZ	9800	Little Colorado River	0	0	-
SPRINGERVILLE 2	AZ	9500	Little Colorado River	0	0	-
CHEROKEE	CO	80	South Platte River	92.4	676	1700;1900;2a6400
off-site landfill		350	Clear Creek	84.4	552	700; 5500; 6100
CRAIG	CO	2600	Yampa River	202	5270	-
off-site landfill		1850	Yampa River	202	5270	-
NUCLA	CO					
off-site landfill		4400	San Miguel River	77.9	1040	-
VALMONT	CO	12	South Boulder Creek (Valmont Res)	7.68	256	-
DEERHAVEN	FL	1000	Sanchez Prairie Swamp (Turkey Cre	0	0	1a2500; 1a2600
FJ GANNON	FL	35	Hillsborough Bay (salt)	0	0	-
LANSING SMITH	FL	30	North Bay (salt)	0	0	-
MCINTOSH	FL	90	Lake Parker	0	0	2a600;1a2400;2a5500;1a7000
SEMINOLE (FL)	FL	2200	St. Johns River	3240	12800	6100
ARKWRIGHT	GA	700	Ocmulgee River	1190	5230	-
BOWEN	GA	200	Etowah River	1480	3980	-
SCHERER	GA	125	Ocmulgee River	1160	3970	-
COUNCIL BLUFFS	IA	170	Missouri River	14600	44900	-
IOWA FALLS	IA	15	Iowa River	126	753	-
LANSING	IA	200	Mississippi River	16800	69000	100
LOUISA	IA	970	Mississippi River	32000	102000	-
PRAIRIE CREEK	IA	180	Cedar River	964	5030	-
off-site landfill		620	Cedar River	964	5030	-
STREETER	IA	1150	Cedar River	964	5030	14 a 4400
CRAWFORD	IL					
off-site landfill		65	Des Plaines River	383	1980	-
PEARL	IL					
off-site landfill		2100	South Fork Mckee Creek	62.7	200	2a6400; 4a8400
WAUKEGAN	IL					
off-site landfill		4150	Lake Michigan	0	0	2a2100; 2a600; 1a6700
BAILLY	IN					
off-site landfill		1200	Deep River (Duck Creek)	46.4	287	3a6700
CAYUGA	IN	210	Wabash River	2820	15900	-
CLIFTY CREEK	IN	265	Ohio River	26800	257000	4900
EW STOUT	IN	80	White River	583	3900	-
HT PRITCHARD	IN	240	White River	697	4660	-
MEROM	IN	2200	Wabash River (Turtle Creek)	3790	21100	-
MICHIGAN CITY	IN	25	Lake Michigan	0	0	-
WHITEWATER VALLEY	IN	1300	East Fork Whitewater River	31	269	-
NEARMAN CREEK	KS	550	Missouri River	17500	71600	7400
HENDERSON ONE	KY	80	Ohio River	34100	309000	100
HENDERSON TWO	KY	450	Green River	3520	31800	200
MORGANTOWN	MD					
off-site landfill		3750	Potomac River	7050	21600	-
NANTICOKE	MD	20	Nanticoke River	297	1230	700
ADVANCE	MI					
off-site landfill		220	Lake Michigan (Inwood Creek)	0	0	-
COLDWATER	MI					
off-site landfill		1130	South Lake (Coldwater River)	34	186	-
JH CAMPBELL	MI	420	Pigeon Lake (Lake Michigan)	0	0	-
JH WARDEN	MI	100	Lake Superior	0	0	100 (prob)
ALLEN S KING	MN					
off-site landfill		740	Lake Jane	0	0	1a4400; 1a5000
HIBBING	MN	950	Welcome River	18	41.7	2a1400
off-site landfill		4600	East Swan River	25.2	413	2400
LITCHFIELD	MN	200	Jewitts Creek	2.35	44.4	-
NORTHEAST	MN	200	Cedar River	26.2	137	800
RED WING	MN	180	Mississippi River	8450	36300	-
VIRGINIA	MN					
off-site landfill		800	Pike River	3.84	107	-

PLANT NAME		DISTANCE TO SURFACE WATER (meters)	SURFACE WATER NAME	MINFLOW (ft <sup>3</sup> /second)	MAXFLOW	PUBLIC WATER SYSTEMS (PWS) WITHIN DOWNGRAIDENT PLUME (distance in meters)
ASBURY	MO	4600	Spring River (Blackberry Creek)	472	1480	-
BLUE VALLEY	MO	1040	Little Blue River	63.4	251	-
CHAMOIIS	MO	40	Missouri River	37700	114000	-
HENDERSON (MS)	MS	1400	Yazoo River (Tchula Lake)	11000	41300	1600
BELEWS CREEK	NC	730	Dan River	323	684	600
CAPE FEAR	NC	50	Cape Fear River	1690	5690	224800
CLIFFSIDE	NC	50	Broad River	1120	2040	-
HESKETT	ND	170	Missouri River	14700	37900	1200
OLIVER COUNTY off-site landfill	ND	990	Nelson Lake (Square Butte Creek)	133	345	-
NEBRASKA CITY	NE	55	Missouri River	17000	52500	-
BL ENGLAND	NJ	50	Great Egg Harbor Bay (salt)	0	0	-
RATON	NM	3700	Raton Creek	0.579	7.37	-
ACME off-site landfill	OH	20	Maumee river	1100	11900	-
ASHTABULA off-site landfill	OH	50	Ottawa River	35	498	-
JM STUART	OH	300	Lake Erie (Cowles Creek)	0	0	-
PIQUA	OH	70	Ohio River	22400	215000	800; 4900
POSTON	OH	50	Great Miami River	157	1740	8500
RE BURGER off-site landfill	OH	250	Hocking River (Hamley Run)	163	1610	400; 2100; 5200; 8500
WC BECKJORD off-site landfill	OH	1475	Pipe Creek	7.76	65.6	-
WH SAMMIS strip mine disposal	OH	80	Ohio River	23000	207000	-
HUGO	OK	1350	Ohio River	23000	207000	-
HOLTWOOD off-site landfill	PA	1200	Ohio River (Croxtton Run)	9850	83300	226100
HOMER CITY	PA	50	Red River	4630	22100	-
MITCHELL (PA) off-site landfill	PA	800	Susquehanna River	19700	66400	-
SEWARD	PA	660	Susquehanna River	19700	66400	-
CROSS	SC	1770	Two Lick Creek	110	619	223700
URQUHART	SC	850	Monongahela River (Peters Creek)	3510	18300	-
FOREST GROVE	TX	10	Conemaugh River	562	3500	-
GIBBONS CREEK off-site minefill	TX	340	Lake Moultrie	0	0	-
JT DEELY	TX	90	Savannah River	6670	14800	-
SAN MIGUEL	TX	180	Walnut Creek	0.12	48.6	-
SANDOW	TX	2200	Navasota River (Panther Creek)	190	1290	-
BONANZA	UT	4450	San Antonio River	303	786	500 (prob)
CHESTERFIELD	VA	1200	La Parita Creek	1.24	12	-
POTOMAC RIVER off-site landfill	VA	100	Alcoa Lake	0	0	-
CENTRALIA off-site landfill	WA	18000	White River	250	2350	-
COLUMBIA	WI	40	James River	3580	13600	-
GENOA	WI	120	Holmes Run (Backlick Run)	18	76.5	-
HARRISON	WV	930	Chehalis River	181	5190	2000 (prob)
KANAWHA RIVER	WV	100	Wisconsin River	4720	14400	-
MITCHELL	WV	50	Mississippi River	15200	62300	-
MOUNTAINEER	WV	400	West Fork River	378	1990	1800 (prob)
PHILIP SPORN	WV	30	Kanawha River	4120	23600	122100; 126700
NAUGHTON	WY	40	Ohio River	10200	86200	7300
		80	Ohio River	14400	122000	-
		90	Ohio River	14400	122000	-
		700	Hams Fork	20.7	829	-

## METHODOLOGY FOR CALCULATING THE COST OF ALTERNATIVE WASTE MANAGEMENT PRACTICES

This appendix discusses how the cost estimates presented in Chapter Six in terms of dollar per ton of waste disposed were calculated for different types of waste disposal. These dollar per ton cost estimates included the costs of current waste disposal practices and the costs of various measures to mitigate potential environmental impacts.

The cost estimates in Chapter Six were developed primarily from two reports:

- Arthur D. Little, Inc., Full-Scale Field Evaluation of Waste Disposal From Coal-Fired Electric Generating Plants, June 1985.
- Utility Solid Waste Activities Group, Edison Electric Institute, and the National Rural Electric Cooperative Association, Report and Technical Studies On the Disposal and Utilization of Fossil-Fuel Combustion By-Products, October 26, 1982.

The Arthur D. Little (ADL) study was funded by the Agency under EPA contract 68-02-3167. Its purpose was to evaluate current coal-fired electric generating plants. Specific tasks involved characterizing coal-fired utility wastes, gathering environmental data, assessing environmental effects, and evaluating the engineering and costs associated with these disposal practices. The Utility Solid Waste Activities Group (USWAG) report was submitted to EPA to assist the Agency in meeting its mandate under Section 8002(n). This report and its supporting technical studies analyzed the environmental and health effects of the disposal and utilization of fossil fuel combustion by-products from electric utility power plants.

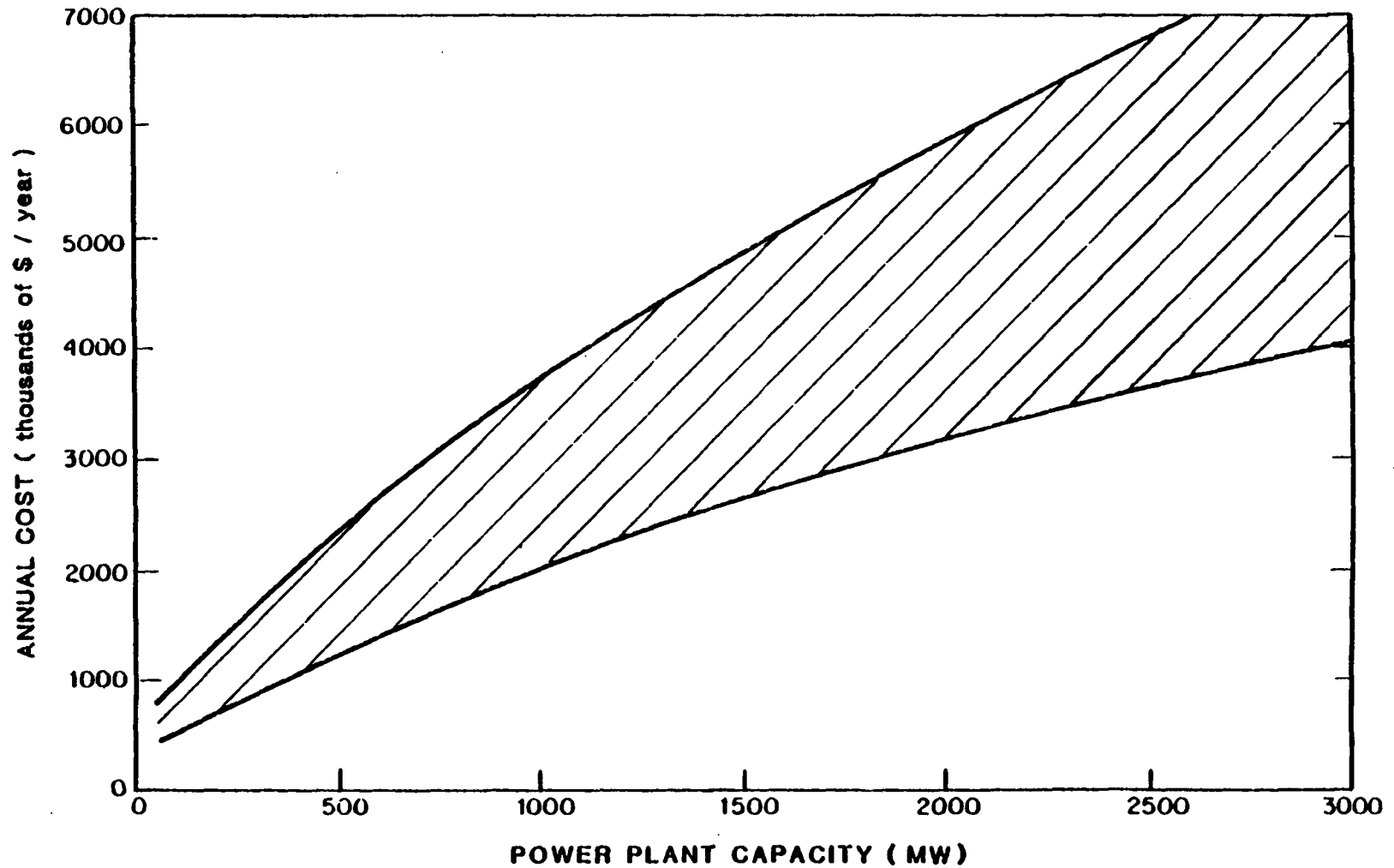
In these two reports, costs were presented for various disposal practices. However, due to differences in analytical methods between the two studies it was often difficult to compare the various cost estimates. To circumvent this problem all disposal cost estimates in these studies were converted to the same basic unit -- dollar per ton of waste disposed. That is, the cost for each type of disposal procedure was expressed in terms of the cost to dispose of each ton of waste generated over the life of the facility. It was felt that this cost measure would allow comparisons to be made between the cost of current waste management practices and the cost of alternative waste management practices.

An example should help illustrate how the dollar per ton cost estimates were developed throughout this report. In the ADL study the total cost of basic waste disposal (i.e., disposal in unlined ponds or landfills) was shown to vary as a function of the size of the electric power plant (e.g., see Exhibit G-1). To convert these costs by power plant size into costs per ton of waste disposed, estimates were made of the amount of waste generated as the size of the power plant varied. There are several variables that can influence the amount and type of waste generated at a power plant, including size of the power plant, ash content of the coal, type of boiler, efficiency of the boiler, utilization rate, and the type of pollution control technologies employed. Despite these many variables, assumptions can be made to estimate the approximate amount of waste that would be generated at a "typical" power plant.

For example, the "dollar per ton of waste disposed" estimates presented in this report generally assume a 500 Mw power plant. This size was chosen to be

EXHIBIT G-1

ANNUAL COST OF FLY ASH PLACEMENT AND DISPOSAL IN AN UNLINED POND  
(late 1982 dollars)



Source: Arthur D. Little, Inc., Full-Scale Field Evaluation of Waste Disposal From Coal-Fired Electric Generating Plants, June 1985.



representative of a "typical" power plant, although the size of each generating unit and the number of units at a site do vary (see Chapter Two for further discussion). To determine the amount and type of waste generated at a 500 Mw power plant, the following assumptions were made:

- Coal Properties -- 2% sulfur, 13% ash, 10,500 Btu/lb.
- Load Factor -- 70% (6132 hours per year)
- Heat Rate -- 10,250 Btu per kilowatt-hour
- SO<sub>2</sub> Removal -- 90% (wet lime scrubbing)
- Lime Stoichiometry -- 1.1
- Fly Ash/Bottom Ash Ratio -- 80%/20%

These assumptions were taken from the ADL study (see p. 1-17, Table 1.7) and result in the annual production of 154,000 tons of fly ash (308 tons/Mw), 38,500 tons of bottom ash (77 tons/Mw), and 132,000 tons, (264 tons/Mw), of dry FGD waste (if the power plant is scrubbing the flue gases).

To determine the cost per ton to dispose of the wastes produced from a 500 Mw power plant using these assumptions, the next step was to obtain the total annual costs for waste disposal from the ADL study (see pages 6-74 to 6-130 of the ADL study). For disposal in unlined ponds these costs were approximately \$1.3 million to \$2.4 million for fly ash and \$275,000 to \$510,000 for bottom ash. For landfill disposal these costs were about \$785,000 to \$5.1 million for fly ash and \$165,000 to \$310,000 for bottom ash. All of these costs were in late 1982 dollars.

The ADL cost estimates (or cost estimates from other studies when applicable) were then converted to fourth quarter 1986 dollars. This was necessary to ensure that all costs reported in this study were consistent with one another. The GNP implicit price deflator was used for this purpose. For the fourth quarter of 1986, the value of this index was 115.2 (1982 = 100; late 1982 = 101.39). The ADL costs were escalated by 13.6 percent to obtain fourth quarter 1986 cost estimates.

In fourth quarter 1986 dollars, the total annual costs for disposal in unlined ponds would be about \$1.4 million to \$2.6 million for fly ash and \$310,000 to \$580,000 for bottom ash. For landfills these annual costs would be \$890,000 to \$1.7 million for fly ash and \$185,000 to \$350,000 for bottom ash.

These annual costs were divided by the total amount of each type of waste produced annually to determine the cost per ton of waste disposed annually at a representative 500 Mw power plant. For ponding these costs are \$9 to \$17 per ton for fly ash (e.g., assuming production of 154,000 tons of fly ash then \$1.4 million ÷ 154,000 tons = \$9.09 per ton) and \$8 to \$15 per ton for bottom ash (assuming production of 38,500 tons of bottom ash). For landfills these costs are about \$6 to \$11 per ton for fly ash and \$5 to \$9 per ton for bottom ash.

For some waste control strategies, such as liner installation, the cost per ton will depend on the size of the disposal area affected. The size of a waste disposal area will vary depending on the amount of waste generated, the type of facility (landfill or pond), depth of disposal, amount of liquid present, and frequency of dredging, among other factors. Given the amount of waste assumed

in this analysis to be generated at a representative 500 Mw power plant, a landfill was assumed to occupy 45 acres at a depth of about 30 meters and to have an average lifetime of 20 years. A wet surface impoundment was assumed to occupy 145 acres at a depth of 10 feet, with dredging occurring every five years.

Using these size estimates for disposal areas, the increase in cost per ton of waste disposed for installing a liner (or for other practices related to the size of the facility) can be calculated. For example, in the ADL study the installed cost of clay liners ranged from \$4.40 to \$15.50 per cubic yard (see Arthur D. Little, Inc., p. 6-132). For a liner 36-inches thick, these installed costs would lead to a cost range of \$21,000 to \$74,000 per acre. For a 45-acre landfill, total costs would range from \$945,000 ( $\$21,000/\text{acre} \times 45 \text{ acres}$ ) to \$3.3 million ( $\$74,000/\text{acre} \times 45 \text{ acres}$ ), or about \$140,000 to \$480,000 on an annualized basis (using a 14.5 percent capital recovery factor, e.g.,  $\$945,000 \times 0.145 = \$137,025$ ). Since 192,500 tons of waste are produced annually, the increase in costs to install a clay liner is \$0.70 ( $\$140,000$  divided by 192,500 tons) to \$2.50 ( $\$480,000$  divided by 192,500 tons) per ton of waste disposed.

Applying this same procedure for a 145-acre wet surface impoundment, total costs would range from \$3.0 million to \$10.7 million, or \$440,000 to \$1.6 million on an annualized basis. This corresponds to about \$2.25 to \$8.10 per ton of waste disposed.

This approach was used throughout Chapter Six to develop the dollar per ton cost estimates for current waste disposal activities and potential alternatives. The technical and economic assumptions used to develop these cost estimates (e.g., the capital recovery factor, disposal area size, etc.) are representative for the electric utility industry. However, actual costs may vary as a result of various site-specific factors that are not addressed in this study.

Chapter Six also provides estimates of the impact of waste disposal on the cost of generating electricity (e.g., see Exhibit 6-9 or 6-10). For these estimates, the cost to generate electricity was assumed to be 18 mills (\$0.018) per kilowatt-hour at existing coal-fired power plants based on the following assumptions:

- A 500 Mw power plant operating in the Midwest.
- No capital charges are included since the capital has already been committed (i.e., it is a sunk cost).
- No flue gas desulfurization equipment is required.
- Capacity factor is 70 percent.
- Heat rate is 10,000 Btu per kilowatt-hour.
- Coal price is \$1.50 per million Btu.
- Operation and maintenance costs are about 3 mills (\$0.003) per kilowatt-hour, with disposal costs ranging from less than 0.5 to 1.0 mill depending on type of disposal practice.

For future coal-fired power plants the assumed generation cost was about 47 mills (\$0.047) per kilowatt-hour based on the same assumptions except:

- Capital costs were approximately \$1,100 per kilowatt, including FGD equipment and associated transmission hookup charges.
- Operation and maintenance costs were about 8 mills (\$0.008) per kilowatt-hour. These costs are higher compared to existing power plants due to the additional operation and maintenance costs associated with the FGD process.

In Exhibit 6-9 costs were also presented for generating electricity with natural gas. At an existing gas-fired power plant, total generation costs were assumed to be about 35 mill (\$0.035) per kilowatt-hour based on the following assumptions:

- No capital charges are included since capital costs are sunk.
- Capacity factor is 70 percent.
- Heat rate is 9000 Btu per kilowatt-hour.
- Gas price is \$3.75 per million Btu.
- Operation and maintenance costs are about 2 to 2.5 mills per kilowatt-hour.

Generation costs at future gas-fired power plants were assumed to be about 49 mills (\$0.049) per kilowatt-hour based on the same assumptions listed above for existing gas-fired power plants except capital costs were included at a cost of approximately \$550 per kilowatt, including associated transmission hookup charges.