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Final Draft

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EXECUTIVE SUMMARY

PART I

Introduction

The Environmental Protection Agency (EPA) issued its Ground-Water Protection Strategy in August, 1984. This guidance document for ground-water classification is a follow-up to the Strategy, and is a major step in EPA's efforts to provide policy direction for EPA programs with ground water responsibility. The purpose of this document is two-fold: (1) to further define the classes, concepts, and key terms related to the classification system outlined in the Ground-Water Protection Strategy, and (2) to describe the procedures and information needs for classifying ground water. Through the release of the Draft Guidelines, public comment is being solicited on the appropriate direction to meeting these purposes.

Through the process of classification, ground-water resources are separated into hierarchical categories on the basis of their value to society, use, and vulnerability to contamination. Ground-water classes will be a factor in deciding the level of protection or remediation the resource will be provided.

Background

The core of the Ground-Water Protection Strategy is a differential protection policy that recognizes that different ground waters require different levels of protection. A three-tiered classification system was established as the vehicle for implementing this policy.

The classification system will, as appropriate, be implemented by EPA program offices and state agencies responsible for EPA delegated programs as changes in program guidance and regulation are made. The differential protection policy, as expressed through the classification system, will assist the programs in tailoring protection policies for ground water. In permit-based actions concerning point sources of pollution, classification will most likely become an additional step in site-specific analysis. Similarly, EPA is considering various approaches for using differential protection and other strategy-related policies for broader-based, nonpoint sources. Two recent EPA rule-making actions-

- one for Superfund and one for radioactive waste disposal--incorporated aspects of the classification system. Other EPA program offices are in different stages of developing approaches to implementing the system. It is important to note that the Guidelines are not enforceable in particular EPA programs until legally incorporated by program guidance regulations, or other appropriate means.

State agencies responsible for managing ground water will not be required by EPA to adopt the classification system for general program use. In fact, many states have already developed ground-water protection approaches tailored to their particular land use and hydrogeologic conditions. However, state agencies carrying out delegated or authorized EPA programs may need to use these guidelines as they are implemented by those programs.

It should be noted that a site located in a designated Safe Drinking Water Act Sole Source Aquifer (SSA) is not automatically placed in Class I. The criteria for SSAs are less rigorous than those of Class I. Greater rigor is needed for classification since, unlike SSAs, Class I will be a decision-making factor in program regulations. SSAs are only considered at the Federal level under financially assisted projects such as farm loans and rural water districts.

At least half of the states are using, or are seriously considering using, some form of a site-by-site or anticipatory classification system. Under its existing programs, EPA will perform site-by-site rather than aquifer or well field classification. However, the classification system presented in this guidelines document attempts to be generally consistent with broader classification systems that may be used by the states. EPA is considering the substitution of state ground-water classification systems for the EPA system wherever possible. In the implementation of its ground-water protection programs, EPA will consider and incorporate, to the extent possible, State Wellhead Protection Areas approved under the Safe Drinking Water Act Amendments of 1986.

The EPA Ground-Water Classification System

The EPA Ground-Water Classification System consists of three general classes of ground water representing a hierarchy of ground-water resource values to society. These classes are:

- Class I - Special ground water

- Class II - Ground water currently and potentially a source for drinking water
- Class III - Ground water not a source of drinking water.

The classification system is, in general, based on drinking water as the highest beneficial use of the resource. The system is designed to be used in conjunction with the site-by-site assessments typically conducted by the EPA program offices in issuing permits and deciding on appropriate remedial action.

Classification Review Area:

A site-by-site approach to classifying ground water necessitates delineating a segment of ground water to which the classification criteria apply. Since EPA is not classifying ground water on a regional or aquifer-specific basis, a Classification Review Area concept is incorporated as a key element in the classification decision. This is, however, strictly an area for review of ground-water characteristics and <u>not</u> an area where regulation will be imposed beyond that of the specific activity under consideration.

The Classification Review Area is delineated based initially on a two-mile radius from the boundaries of the "facility" or the "activity." An expanded Classification Review Area is allowed under certain hydrogeolgoic conditions. Within the Classification Review Area, a preliminary inventory of public water-supply wells, populated areas not served by public supply, wetlands, and surface waters, is performed. The classification criteria are then applied to the Classification Review Area and a classification determination made.

Subdivision of Classification Review Area and Interconnection Concepts:

Where hydrogeologic data are available, the Classification Review Area can be subdivided to reflect the presence of naturally occuring ground-water bodies that may have significantly different use and value. These ground-water bodies, referred to as "ground-water units", must be characterized by a degree of interconnection (between adjacent ground-water units) such that an adverse change in water quality to one ground-water unit will have little likelihood of causing an adverse change in water quality in the adjacent ground-water unit. Each ground-water unit can

be treated as a separate subdivision of the Classification Review Area. A classification decision is made only for the ground-water unit or units potentially impacted by the activity.

The identification of ground-water units and assessment of interconnection between ground-water units may, in critical cases, require a rigorous hydrogeologic analysis. The acceptance of subdivisions will be on a case-by-case basis after review of the supporting analysis.

The recognition of ground-water unit subdivisions to the Classification Review Area establishes a spatial limit for classification and the application of protective management practices. The degree of interconnection to adjacent ground-water units and surface waters is also a criterion for differentiating between subclasses of Class III ground waters.

Ground-water units are mappable, three-dimensional ground-water bodies delineated on the basis of the three types boundaries described below:

Type 1: Permanent ground-water flow divides

Type 2: Extensive, low-permeability (non-aquifer) geologic units (e.g., thick, laterally extensive confining beds) especially where characterized by favorable hydraulic head relationships across them (i.e., the direction and magnitude of flow through the low-permeability unit)

Type 3: Permanent fresh-water/saline-water contacts. (Saline waters being defined as those waters with greater than 10,000 mg/l of Total Dissolved Solids).

The type of boundary separating ground-water units reflects the degree of interconnection between those units. Type 2 boundaries constitute a low degree of interconnection. A low degree is expected to be permanent unless improper management causes the low-permeability flow boundary to be breached. Type 1 and Type 3 boundaries imply an intermediate degree of interconnection. They are prone to alteration/modification due to changes in ground-water withdrawals and recharge.

A high degree of interconnection is inferred when the conditions for a lower degree of interconnection are not demonstrated. High interconnection of waters is assumed to occur within a given ground-water unit and where ground water discharges into adjacent surface waters. A high degree of interconnection implies a significant potential for cross-contamination of waters if a component part of these settings becomes polluted.

Class I - Special Ground Waters:

Class I ground waters are resources of unusually high value. They are highly vulnerable to contamination and are (1) irreplaceable sources of drinking water and/or (2) ecologically vital. Ground water, which is highly vulnerable to contamination, is characterized by a relatively high potential for contaminants to enter and/or to be transported within the ground-water flow system.

In these Draft Guidelines, the Agency is seeking comment on the appropriate approach to defining "highly vulnerable." Public comment will influence the Agency's choice of an approach for the Guidelines when they are issued in final form. To assist in framing the discussion, these Draft Guidelines focus on two options for determining vulnerability. Both of these require consideration of a number of hydrogeologic parameters. Option A would require use of the DRASTIC system (Aller et al, 1985), a numerical ranking system developed by the National Water Well Association under contract to EPA. The DRASTIC system provides a method of scoring an area's "vulnerability" based upon consideration of various parameters such as depth to water, recharge, aquifer media, etc. Using this approach, an area would be considered "highly vulnerable" if its DRASTIC score exceeds levels specified in these Guidelines. Option B does not rely on a set methodology with numerical criteria. Instead, vulnerability would be assessed in a more qualitative manner, relying on best professional judgement. The user might consider specific technical parameters within the DRASTIC system (i.e., depth to water, net recharge, aquifer media, etc.), but would not attribute scores to these parameters or provide numerical cutoffs for defining "highly vulnerable" areas. Other techniques would also be allowable under Option B. Thus, this alternative is considered qualitative in nature since specifics as to methods or criteria are not provided in these Classification Guidelines. Instead, the overall advantages and disadvantages of the general categories of techniques is provided. Comments on these two

options, as well as other options for assessing vulnerability, will be considered by the Agency in determining how best to incorporate this factor in classification decisions.

Ground water may be considered "irreplaceable" if it serves a substantial population and if delivery of comparable quality and quantity of water from alternative sources in the area would be economically infeasible or precluded by institutional constraints.

In these Draft Guidelines, the Agency is also soliciting comment on approaches to judging two aspects of the "irreplaceable" criterion. Option A incorporates a quantitative determination of the population served by the source and the economic feasibility of replacing the source. Under this approach, a drinking water source would be considered "irreplaceable" if it serves at least 2500 people and the annual cost to a typical user of replacing the source exceeds 0.7 to 1.0 percent of the mean household income in the area. Option B focuses on a qualitative assessment of the replaceability of the ground water. Under this approach, the relative size of the population served by the source and the cost of replacing the source would be factors to consider in assessing the source's "replaceability." The Guidelines would not, under Option B, provide a set methodology, nor one or more numerical cutoffs. Again, the determination would focus on best professional judgement. A user following Option B may choose, however, to consider some of the quantitative methods or approaches in Option A, if deemed relevant in a particular classification decision. Comments on these two options, as well as other options for assessing "substantial population" and "irreplaceable" (from an economic [illegible]point), will be considered by the Agency in determin[illegible] [illegible]w best to incorporate these factors in classification de[illegible]sions.

Ground water may be considered ecologically vital if it supplies a sensitive ecological system located in a ground-water discharge area that supports a unique habitat. A unique habitat is defined to include habitats for endangered or threatened species listed or proposed for listing pursuant to the Endangered Species Act (as amended in 1982), as well as certain types of Federally managed and protected lands.

Class II - Current and Potential Sources of Drinking Water and Water Having Other Beneficial Uses:

All non-Class I ground water currently used, or potentially available, for drinking water and other beneficial use is included in this category, whether or not it is particularly vulnerable to contamination. This class is divided into two subclasses; current sources of drinking water (Subclass IIA), and potential sources of drinking water (Subclass IIB).

Ground water is considered a current source of drinking water under two conditions. The first condition is the presence of one or more operating drinking-water wells (or springs) within the Classification Review Area. The second condition requires the presence within the Classification Review Area of a water-supply reservoir watershed (or portion of a water-supply reservoir watershed) designated for water-quality protection, by either state or local government.

The concept of a current source of drinking water is rather broad by intent. Only a portion of the ground water in the Classification Review Area needs to be supplying water to drinking-water wells.

A potential source of drinking water is one which is capable of yielding a quantity of drinking water to a well or spring sufficient for the needs of an average family. Drinking water is taken specifically as water with a total-dissolved-solids (TDS) concentration of less than 10,000 mg/l, which can be used without treatment, or which can be treated using methods reasonably employed in a public water-supply sys[illegible] The sufficient yield criterion has been establish[illegible] 150 gallons/day.

Class III - Ground Water Not a Potential Source of Drinking Water and of Limited Beneficial Use:

Ground waters that are saline, or otherwise contaminated beyond levels which would allow use for drinking or other beneficial purposes, are in this class. They include ground waters (1) with a total-dissolved-solids (TDS) concentration over 10,000 mg/l, or (2) that are so contaminated by naturally occurring conditions, or by the effects of broad-scale human activity (i.e., unrelated to a specific activity), that they cannot be cleaned up using treatment methods reasonably employed in public water-supply systems. Two alternative tests are proposed for making this determination. A refer-

ence-technology test is proposed in the draft and an optional economically-based test is included in Appendix G.

Class III is subcategorized primarily on the basis of the degree of interconnection with surface waters or adjacent ground-water units containing ground water of a higher class. Subclass IIIA ground waters have a high-to-intermediate degree of interconnection to adjacent ground-water units of a higher class or surface waters. In addition, Subclass IIIA encompasses ground waters in those settings where yields are insufficient from any depth within the Classification Review Area to meet the needs of an average size family. Such ground waters, therefore, are not potential sources of drinking water.

Subclass IIIB is restricted to ground waters characterized by a low degree of interconnection to adjacent surface waters or ground waters of a higher class within the Classification Review Area. These ground waters are naturally isolated from sources of drinking water in such a way that there is little potential for producing additional adverse effects on human health and the environment. They have low resource values outside of mining, oil and gas recovery, or waste disposal.

PART II

Classification Procedures

These Guidelines provide a more in-depth discussion of the actual process of site-by-site classification. The process is facilitated through a classification decision chart and associated worksheet. These were developed to provide a systematic approach to classifying ground water based on certain criteria, e.g., presence of wells, ecologically vital areas, water quality, irreplaceability, etc. They are provided as suggested approaches only, since a given setting may be more effectively handled through another sequence of steps.

Classification requires certain information on the character of the Classification Review Area. The emphasis of data collection is on readily available sources. More in-depth analyses are not expected routinely, but, may become necessary for Class I or, especially, Class III areas and for subdivision of the Classification Review Area.

Preliminary data needs include:

- Base map of the Classification Review Area,
- Inventory of public water-supply systems in the review area,
- Delineation of areas served by private wells,
- Demographic information for the public water-supply systems and areas of private wells,
- Survey of ecologically vital areas, and
- Hydrogeologic data sufficient to judge vulnerability of or support interconnection analysis.

The remaining sections of this chapter contain technical guidance for the following:

- Expansion of the Classification Review Area,
- Subdivision of the Classification Review Area and Determination of Interconnection,
- Determining Irreplaceability,
- Determining Ground-Water Vulnerability,
- Determination of Reasonable Treatment, and
- Ground-Water and Surface-Water Interactions.

PART III

The final chapters of this document are appendices which contain the following information:

Appendix A - Glossary

Appendix B - Alternative Options Considered

Appendix C - Sample Applications of Ground-Water Classification

Appendix D - DRASTIC Factors and Ratings

Appendix E - Background Data Regarding Class I and III

Appendix F - Census Bureau Information

Appendix G - Economic Tests for Determining Class I Irreplaceable Waters and Class III-Untreated Ground Waters

GUIDELINES FOR GROUND-WATER CLASSIFICATION
UNDER THE EPA GROUND-WATER PROTECTION STRATEGY

CONTENTS

ACKNOWLEDGEMENTS..... i
EXECUTIVE SUMMARY..... ii
TABLE OF CONTENTS..... xi

PART I
BACKGROUND AND DEFINITION
OF GROUND WATER CLASSES

1.0 INTRODUCTION..... 1
1.1 EPA's Ground-Water Responsibilities 1
1.2 The Purpose of this Document..... 1
1.3 Organization of this Document..... 2
2.0 BACKGROUND..... 3
2.1 Need for Ground-Water Classification..... 3
2.2 Guidelines Development 4
2.3 Implementation in EPA Programs..... 6
2.4 Interaction with State Ground-Water Protection Efforts..... 10
3.0 THE EPA GROUND-WATER CLASSIFICATION SYSTEM..... 15
3.1 An Overview of the Ground-Water Classes and Subclasses..... 16
3.1.1 Class I - Special Ground Waters..... 16
3.1.2 Class II - Current and Potential Sources of Drinking Water and Water Having Other Beneficial Uses..... 20
3.1.3 Class III - Ground Water Not a Potential Source of Drinking Water and of Limited Beneficial Use..... 21
3.2 Classification Review Area..... 22
3.2.1 Technical Basis for Two-Mile Radius..... 23
3.3 Subdivision of the Classification Review and Interconnection Concepts..... 25
3.3.1 Ground-Water Units..... 26
3.3.2 Interconnection..... 27
3.3.3 Illustration of a Subdivision..... 27
3.4 Key Terms and Concepts for Defining Class I..... 30
3.4.1 Highly-Vulnerable Ground Water..... 30
3.4.2 Irreplaceable Source of Drinking Water..... 32
3.4.2.1 Substantial Population..... 33
3.4.2.2 Uncommon Pipeline Distance..... 34
3.4.2.3 Comparable Quality..... 34

TABLE OF CONTENTS (Cont.)

3.4.2.4 Comparable Quantity..... 35
3.4.2.5 Institutional Constraints..... 35
3.4.2.6 Economic Infeasibility..... 36
3.4.3 Ecologically Vital Ground Water..... 37
3.5 Key Terms and Concepts for Defining Class II..... 37
3.5.1 Current Source of Drinking Water..... 39
3.5.2 Potential Source of Drinking Water..... 39
3.5.2.1 Water Quality/Yield Data Needs.... 41
3.5.3 Sufficient Yield..... 41
3.6 Key Terms and Concepts for Defining Class III..... 43
3.6.1 Methods Reasonably Employed in Public Water Treatment Systems..... 43
3.6.2 Insufficient Yield at Any Depth..... 44
3.6.3 Interconnection as a Class III Criterion... 45

PART II
DETAILED CLASSIFICATION PROCEDURES

4.0 CLASSIFICATION PROCEDURES..... 46
4.1 Preliminary Information 52
4.1.1 Base Map of Classification Review Area..... 52
4.1.2 Well Survey..... 52
4.1.3 Demography..... 53
4.1.4 Ecologically Vital Areas..... 53
4.1.5 Hydrogeologic Data..... 54
4.2 Conditions and Procedures for Expanding the Classification Review Area..... 55
4.2.1 Hydrogeologic Settings..... 55
4.2.2 Expanded Classification Review Area Dimensions..... 56
4.3 Subdivision of the Classification Review Area and Interconnection Concepts..... 59
4.3.1 General Hydrogeologic Information Needed for Identifying Ground Water Units and Analyzing Interconnection..... 61
4.3.2 Type 1 Boundaries: Ground-Water Flow Divides..... 62
4.3.3 Type 2 Boundaries: Low-Permeability Geologic Units..... 67
4.3.4 Type 3 Boundaries: Fresh/Saline Water Contacts..... 73
4.3.5 High Interconnection Scenarios..... 80
4.3.6 Example of Subdividing a Classification Review Area..... 80

TABLE OF CONTENTS (Cont.)

4.4 Determination of Irreplaceability..... 88
4.4.1 Substantial Population (Option A)..... 91
4.4.2 Substantial Population (Option B)..... 91
4.4.3 Uncommon Pipeline Distance..... 93
4.4.4 Comparable Quality Analysis..... 95
4.4.4.1 Water Quality Parameters..... 95
4.4.4.2 Sources of Information..... 95
4.4.5 Comparable Quantity Analysis..... 96
4.4.6 Institutional Constraints..... 98
4.4.6.1 Example of Considerations for a More Detailed Assessment..... 98
4.4.7 Economic Infeasibility (Option A)..... 101
4.4.7.1 Annualizing Capital Costs..... 103
4.4.7.2 Using Water Supply Utility Rates and Fees to Estimate Costs of Alternative Water Supply..... 103
4.4.7.3 Household Income of Substantial Population..... 103
4.4.8 Economic Infeasibility (Option B)..... 104
4.4.9 Summary..... 104
4.5 Determining Ground-Water Vulnerability..... 107
4.5.1 Option A: DRASTIC..... 107
4.5.1.1 DRASTIC Methodology..... 109
4.5.1.2 Application of DRASTIC to the Classification Review Area..... 109
4.5.1.3 Limitations to the Application of DRASTIC..... 112
4.5.2 Option B: Qualitative Assessment..... 112
4.6 Determination of Reasonable Treatment..... 115
4.6.1 Standards and Criteria for Treatment..... 115
4.6.2 Treatment Technologies..... 117
4.6.2.1 Regional Availability of Reference Technologies..... 117
4.6.2.2 Treatment Efficiencies..... 120
4.6.3 Methodology for Determining Treatability..... 121
4.6.4 Sample Problem..... 127
4.7 Ground-Water and Surface-Water Interaction..... 130
4.7.1 Ground-Water Discharge to Surface Water..... 130
4.7.2 Surface Water Discharge to Ground Water..... 130
5.0 REFERENCES..... 135

TABLE OF CONTENTS (Cont.)

APPENDIX A: GLOSSARY..... A-1

APPENDIX B: ALTERNATIVE OPTIONS CONSIDERED FOR DEFINING CLASSIFICATION KEY TERMS AND CONCEPTS..... B-1

APPENDIX C: SAMPLE APPLICATION OF THE CLASSIFICATION PROCEDURES..... C-1

APPENDIX D: TABLES OF DRASTIC FACTOR VALUE RANGES AND CORRESPONDING RATINGS..... D-1

APPENDIX E: BACKGROUND DATA: CLASS I AND CLASS III ISSUES..... E-1

APPENDIX F: GENERAL CENSUS BUREAU INFORMATION; NATIONAL CLEARINGHOUSES FOR CENSUS DATA SERVICES; AND BUREAU OF THE CENSUS STATE COORDINATING ORGANIZATIONS..... F-1

APPENDIX G: ECONOMIC TESTS FOR DETERMINING CLASS I - IRREPLACEABLE AND CLASS III - UNTREATABLE GROUND WATERS..... G-1

LIST OF FIGURES

		Page
2-1	Conceptual Framework Between Ground-Water Classification Program Policies for Facility Siting, Engineering, and Operation	5
2-2	Example of State Protection Systems	9
2-3	Idealized Well Field Protection Zones in West Germany	11
3-1	Summary of Ground-Water Classes	17
3-2	Relationship of Classes, Key Terms, and Concepts	18
3-3	Conceptual Classification Flow Chart	19
3-4	Hypothetical Classification Review Area Showing Potential Class Determining Factors	25
3-5	Illustration of a Hypothetical Classification Review Area	28
3-6	Illustration of a Subdivided Classification Review Area	29
3-7	Example Class I - Ecologically Vital Ground Water	38
3-8	Example Class II - Current Source of Drinking Water	40
3-9	Example Class II - Potential Source of Drinking Water	42
4-1	Procedural Classification Chart	47
4-2	Example of Geometry and Dimensions of the Proposed Expanded Review Area and For Karst Settings	58
4-3	Hydrogeologic Sections Showing Flow Systems of Increasing Complexity with Type I Boundaries	64
4-4	Example of Type 1 Flow Divide Boundary	66
4-5	Example of Type 2 Boundary	69
4-6	Example of Type 2 Boundaries Between Aquifers in a Sedimentary Basin	71
4-7	Example of Type 3 Boundary Through an Unconfined Aquifer in a Coastal Setting	76

LIST OF FIGURES (Cont.)

Page

4-8 Example of Type 3 Boundary in an Evaporite/Saline Water Setting..... 77

4-9 Example of Type 3 Boundary Through Basin Fill in a Closed Basin/Arid Climatic Setting..... 79

4-10 Examples of High Interconnection Between Ground-Water Unit and Surface Water..... 81

4-11 Hypothetical Setting for Demonstrating the Subdivision of a Classification Review Area..... 84

4-12 Hypothetical Classification Review Area..... 85

4-13 Subdivision of a Hypothetical Classification Review Area into the Ground-Water Units..... 86

4-14 Criteria for Class I - Irreplaceable..... 89

4-15 Example Class I - Substantial Population..... 92

4-16 Outline of Procedure for Analyzing Potential Institional Constraints to the Use of an Alternative Source of Water..... 100

4-17 Test for Class I - Irreplaceable Ground Water..... 105

4-18 Potential Evaporation Versus Mean Annual Precipitation in Inches..... 108

4-19 Illustration of Drastic Mapping..... 112

4-20 Illustration of Surface Water Recharge to Ground Water for the Edwards Aquifer, Texas..... 132

4-21 Cross-Section of an Alluvial Aquifer Showing Surface Water Recharge from the Mohawk River..... 133

4-22 Ground-Water Isotherms of Mohawk River Basin..... 134

LIST OF TABLES

		Page
4-1	Classification Worksheet	48
4-2	Range of Values of Hydraulic Conductivity and Permeability	74
4-3	Uncommon Pipeline Distance for Different Populations	94
4-4	Population Institional Constraints	99
4-5	Drastic Range Rating for Depth to Water	110
4-6	Summary of Operational Methods for Defining the Key Term "Highly Vulnerable" Ground Water	114
4-7	RMCL & MCL Values for Selected Contaminants	116
4-8	Health Advisories for Selected Contaminants in Water	118
4-9	Application of Treatment Technologies in Public Water Supply Systems, by EPA Region	119
4-10	Description of Treatment Process	122
4-11	Effluent Quality Working Table From Sample Problem	128

PART I

BACKGROUND AND DEFINITION OF GROUND WATER CLASSES

PART I

1.0 INTRODUCTION

1.1 EPA's Ground-Water Responsibilities

EPA currently administers more than eight statutes which direct the Agency toward reducing or eliminating threats to ground water from a large number and variety of sources. This is a far from simple task and is one which commands a major part of the Agency's budget and personnel resources. Changes in statutes and resulting regulations have occurred in the past, and will continue to occur in the future, to further manage these pollution sources. Through EPA's long-range planning efforts and, more recently, an agency-wide direction toward overall risk management, ground-water protection on a cross-media basis, the second "problem" is receiving increased attention.

An important tool in this cross-program phase was made available in August 1984, when EPA released its Ground-Water Protection Strategy. This Strategy represents the official policy of EPA in this field, and followed extensive debate and analysis within EPA, among other Federal and State agencies, and with the public. The goal of the Strategy is to maximize and coordinate protection functions, both within Headquarters and the Regions. It was not meant to resolve all of today's ground-water protection issues, but rather to set up a framework for better overall protection.

Ground-water classification was introduced in the Strategy as a key element in setting priorities for regulatory action prioritizing attention and resource management. As will be discussed more fully in Chapter 2.0, classification was deemed essential, given the potentially enormous numbers of pollution sources matched by the expense of clean-up programs, should contamination occur.

1.2 The Purpose of this Document

This document provides the technical guidelines for implementing the classification system, originally established in the Ground-Water Protection Strategy. By following the procedures and methods outlined, ground water, which may be affected by a facility or activity under EPA review, can be placed within a relevant class or classes, representing an implied hierarchy of protection. While the use of the system by EPA programs is discussed briefly in Section 2.3, this document should be viewed essentially as a set of technical guidelines for ground-water evaluation via classification.

Specific management strategies, "standards", and other program related policies, are outside the subject of this document.

It is also critical to note that EPA will not, as a result of these guidelines, the Strategy, or its current statutory authorities, be classifying large segments of land, aquifers, etc., in-advance of any specific decision. The Agency, or the delegated/authorized States, will only classify the ground water around specific sites or areas where a decision related to a permit, degree of clean-up or regulation, etc., is to be made. These differences are highlighted further in Chapter 2.0.

1.3 Organization of this Document

Chapter 2.0 provides additional background information on the Ground-Water Protection Strategy, including the rationale and use of classification. EPA's site-by-site approach is also contrasted with broader areawide mapping and classification efforts. The remainder of the guidelines document is organized into three major parts. Chapter 3.0 contains an overview of the classification system, and definitions and explanations of key terms and concepts. The procedures for classification are documented in Part II, Chapter 4.0. This chapter is designed for potential users of the system; whereas, the previous chapters provide less detailed information suited for general interest. Chapter 4.0 provides a step-by-step user's manual, covering the recommended sequence of decisions, corresponding data needs, and technical methods for each. A series of Appendices follows in Part III and includes a glossary (Appendix A) and a discussion of the alternative options considered for defining classification key terms and concepts (Appendix B). Appendix C is particularly relevant since it illustrates the classification procedures through a series of sample case studies. The remaining appendices provide background information and important references for performing the classification procedures.

2.0 BACKGROUND

2.1 Need for Ground-Water Classification

The EPA Ground-Water Protection Strategy (August, 1984) consists of four major elements:

- Strengthen State Institutions -- through technical assistance and State grants
- Cope with Unaddressed Sources -- through source-specific protection programs in cooperation with other EPA programs
- Establish EPA Policy for Ground-Water Protection-- through the establishment and implementation of protection policies
- Strengthen EPA Institutions -- through the establishment of Offices of Ground-Water Protection at Headquarters and in the Regions.

These guidelines stem from the third element, and the need to achieve greater consistency in the various programs at EPA with ground-water protection responsibilities. The Agency was concerned that the focus solely on individual polluting activities, rather than on the resource which might be affected, was leading to problems with consistency. Some EPA programs tended to factor-in ground-water considerations to a greater extent than other programs. Some EPA programs implemented specific statutes which themselves held a bias toward one medium, such as surface water, in a way that impacts on ground water were not fully assessed. Complicating the situation was the fact that many of these programs had become well established in their methods of operation.

In light of these factors, EPA adopted a policy for the Ground-Water Protection Strategy that "protection should consider the highest beneficial use to which ground water having significant water resources value can presently or potentially be put." This "differential protection" policy acknowledges that some ground water deserves unusually high protection due to their current use, relative value to society, and vulnerability to contamination. For these ground waters (Class I), management will include extraordinary protective measures. For most ground waters (Class II), the very high "baseline" of protection inherent in EPA's programs will be applied. Ground waters which have lower value to society for water supply or other disposal purposes (Class III), would logically, under this policy, require a

different management approach. Furthermore, the policy asserts that the extremes of the system (i.e., Class I and III) should be restricted to rather infrequent situations, reflecting the importance of effectively managing ground water for its best use.

The Agency recognized that in-advance aquifer classification offers a community or State certain advantages from an overall management perspective. EPA believes, however, that such decisions should be made at the state or local levels of government. The major purpose of these guidelines is, however, to support the site-by-site assessments typically employed in EPA permits, impact statements, and other decisions. Differences among such systems are reviewed in Chapter 2.3.

The Ground-Water Protection Strategy established a more protective category (Class I) than had been in existence prior to 1984. This more protective category will be recognized in a consistent way from program to program. Class III provides for the formalization of where EPA programs can recognize lower resource values -- i.e., not sources of drinking water -- either now or in the foreseeable future.

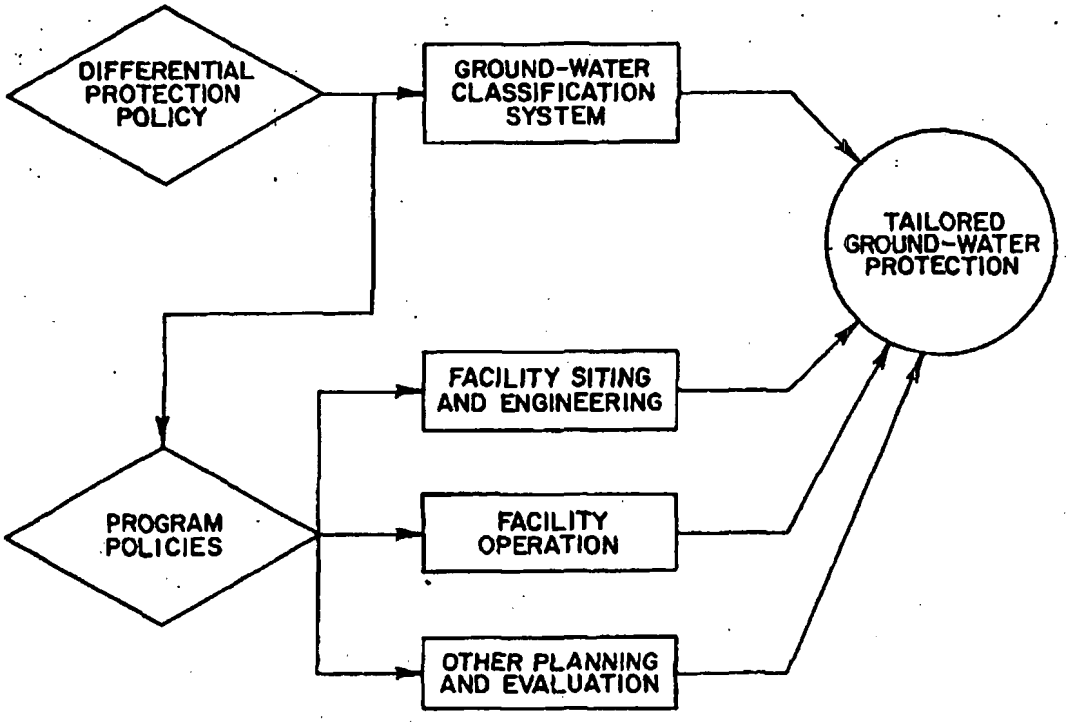
2.2 Guidelines Development

The development of these guidelines began in August, 1984, and consisted of three phases -- definition, testing, and review. Throughout the process, the Office of Ground-Water Protection (OGWP) worked closely with a guidelines work group, consisting of representatives from several states, EPA regions, other EPA programs, and the U.S. Geological Survey.

In the definition phase, key terms and concepts related to the classification scheme described in the Strategy were analyzed in detail. These included key terms and concepts such as "irreplaceable source of drinking water," "ecologically vital," "highly vulnerable," and "current source of drinking water." Several alternative options for defining each term were drawn up, along with data requirements and methodologies for employing each. Many of the alternative options were derived from approaches used by other EPA, state, and local programs to address similar or related concepts. Each approach was examined with respect to its:

- Consistency with statutes, other programs, and with the overall intent of the Strategy;
- Flexibility for accommodating State and region-specific characteristics or concerns;

FIGURE 2-1
CONCEPTUAL FRAMEWORK BETWEEN GROUND-WATER CLASSIFICATION AND PROGRAM POLICIES FOR FACILITY SITING, ENGINEERING, AND OPERATION



- Arbitrariness; and

- Potential difficulties or complexities in implementation.

The next phase involved the preparation of detailed case studies with which to test the initial classification framework. Candidate case studies were canvassed from a variety of sources and a small workshop held to determine the workability of the classification definitions and to select the most relevant and representative samples for the guidance document. The feedback from this phase led to a refinement of the classification system and procedures.

Finally, the project focused on review and revision of several drafts. The public will review and comment on this draft in late 1986. Comments from the public review will be factored into the development of final guidelines in 1987.

2.3 Implementation in EPA Programs

The Ground-Water Protection Strategy provides two key insights on implementation. First, the Strategy establishes the differential protection approach as an official Agency policy. Classification is set as the primary means to implement that policy. Next, the Strategy provides examples of how classification may be used by specific EPA programs to assist in framing various program policies. A conceptual schematic of this approach is shown in Figure 2-1.

In order to implement these classification guidelines (which are not themselves enforceable requirements), EPA programs will need to modify their specific guidance documents and regulations. Decisions as to how they are to be implemented can only be made through EPA program office actions, taking into consideration each program's statutory requirements. Actual implementation may be different than the examples portrayed in the Ground-Water Protection Strategy due to changes in statutes and the need to be consistent with more recent program policies. The approach cited for the Resource Conservation and Recovery Act (RCRA) program in the Strategy, for example, was presented in the framework that existed before the sweeping Hazardous and Solid Waste Act Amendments of 1984 (HSWA). As it responds to HSWA, EPA will develop a coherent approach to ground-water protection that incorporates such Congressionally-mandated requirements under HSWA as the waste-specific "waste bans," location guidance/standards, liner/technology standards, and corrective action requirements. Differential protection and

classification will also be incorporated into this broader context.

Two specific rule-making actions have been completed--one for Superfund, and one under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, or "Superfund"), and one for radioactive wastes. The CERCLA National Contingency Plan (NCP) revised on November 20, 1985 (50 FR 47974) establishes the process for removal and/or remedial actions at Superfund sites (40 CFR Part 300). Revised Section 300.68(e)(2) addressing scoping of response actions during remedial investigations includes an assessment of "(v) Current and potential ground-water use (e.g., the appropriate ground-water classes under the system established in the EPA Ground-Water Protection Strategy" to assist in the determination of what type of action should be taken.

EPA also cites the Strategy in its list of other Federal criteria, advisories, guidance, and State standards to be considered. The list is found in the October 2, 1985, policy on CERCLA compliance with other Environmental Statutes (published as an appendix to the preamble of the NCP). The policy provides that (among other things) the classification factors must be considered in remedial action if it is pertinent. If the Agency finds that they are pertinent in response actions, but does not use them, or uses and alters them, the decision documents must state the rationale. Guidance manuals for implementing the new NCP are under development by the Agency.

The second completed implementation action is the release of the "Environmental Standards for the Management of Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes." EPA's role under the overriding Atomic Energy Act is very limited and is primarily standard-setting. The final rule (40 CFR Part 191; released in the Federal Register on September 19, 1985) includes two standards relative to differential protection:

- A drinking-water-related standard is to be applied to all locations if a "special source" of ground-water is present. "Special sources" are further defined as a major subset within the Class I definition included in these guidelines.

- A "total dose"-related standard is to be applied at the boundary of a "controlled area" for "significant sources of ground water." "Significant" sources are essentially a major subset within the Class II definition included in these guidelines.

At this time, conceptual approaches to implementation are in different stages of development and consideration by programs administering all major ground-water related statutes in EPA. In permit-based, "point-source"-type actions, it is expected that classification will be essentially an additional step in site-specific analysis. Broader-based, non permit/non-point sources are more problematic. In farm-by-farm application of pesticides, for example, there is no regulatory mechanism to evaluate each site-by-site action. EPA is beginning to consider the approaches to implementing differential protection and other Strategy-related policies for these broader sources. Again, the classification guidelines will be implemented as appropriate, given the overall authorities of the Agency under specific statutes.

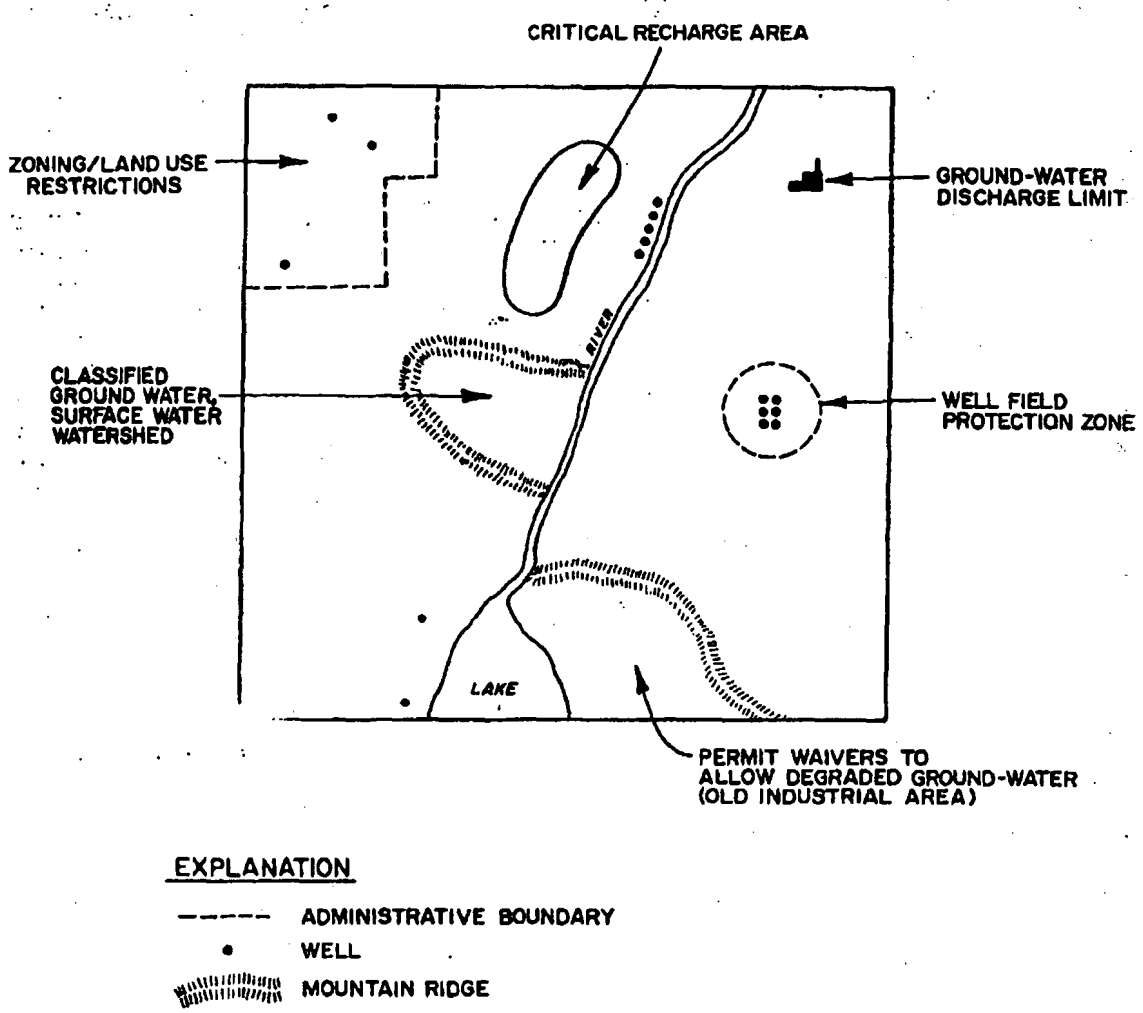
Since neither the guidelines definitions nor the program implementation options have been finalized, it is impossible to predict the numbers of EPA classification decisions which will result or be included in each particular class. Some initial analyses have been performed utilizing aggregated (i.e., not site specific) data on gross hydrogeological and socioeconomic characteristics around a subset of over 1400 RCRA, CERCLA, and UIC facilities. Assuming that the "quantitative" options (all denoted as Option A in Section 3.0 and 4.0) are selected, the range in classification outcomes covers:

Class I	5 to 11 percent
Class II	83 to 94 percent
Class III	1 to 6 percent

Given the different interpretation of the "qualitative options" for Class I terms (each denoted as Option B), no such analysis could be performed. It is important to note, however, these estimates reflect the percentage of classification decisions and not percentage of all United States ground water or aquifers. Additionally, these estimates were made on the basis of several assumptions regarding individual site characteristics. Sensitivity analyses show that the above ranges in percentage values account for most of the uncertainties associated with these assumptions.

It is appropriate to note, however, that well-field protection is typically the "high end" of any classification system as it is most often oriented to current, important public water supplies. Potential drinking water sources, ecologically vital ground waters, and low-quality, non-drinking water sources are not identified or managed in such systems.

FIGURE 2-2
EXAMPLE OF STATE PROTECTION SYSTEMS



A final note: these guidelines may not be used as a defense or guide to future settlements of Federal enforcement or other administrative or judicial cases unless, or until, specific programs issue implementing directives, regulations, or policies on how these concepts are to be applied to specific programs in a consistent manner with their statutory authorities and mandates.

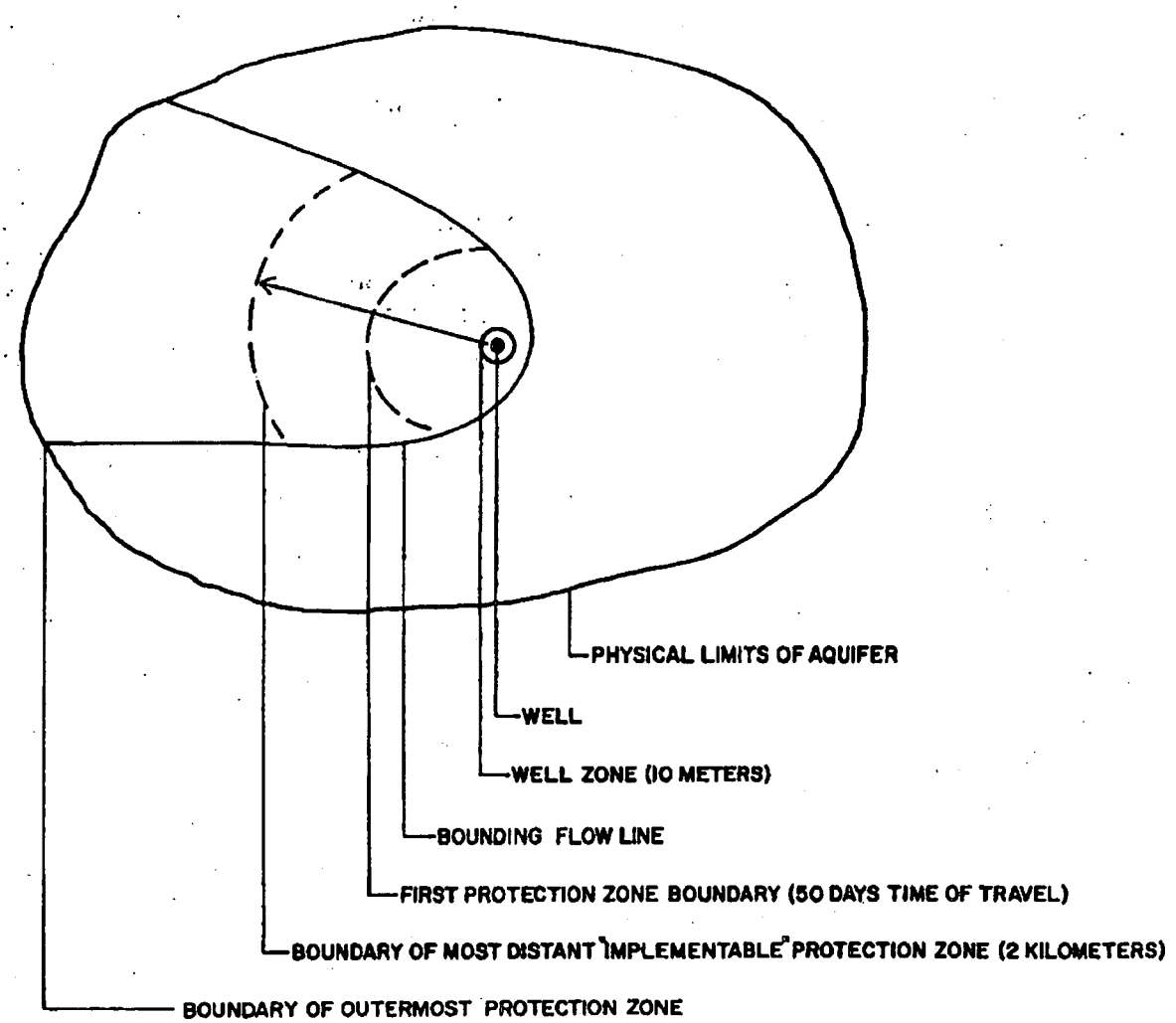
2.4 Interaction with State Ground-Water Protection Efforts

The EPA Ground-Water Classification system will be used as an important tool for decision-making in EPA programs, including those programs delegated to the states. State agencies responsible for ground-water management will not be required to adopt the EPA classification system or another system for general state program use. State agencies implementing delegated or authorized EPA programs will, however, need to use these classification guidelines as appropriate to those programs. Many states have, however, developed ground-water protection approaches that are tailored to their particular land use and hydrogeologic conditions (e.g. generic examples in Figure 2-2). At this time, at least half of the States have in operation, or under serious consideration, some form of site-by-site or in-advance classification system.

It is important to distinguish between these two generic types of classification systems. An in-advance or anticipatory approach to hydrogeologic mapping or aquifer classification is believed by many to be essential for effective local ground-water management (e.g., Conservation Foundation 1985). Through this process, geologic and hydrologic characteristics of currently used or potentially available ground-water sources are assessed through mapping, computer simulation, etc. Plans for water use are drawn-up, and land-use controls either suggested and/or actually put into place. These controls may be fairly sweeping in nature and cover industrial siting, housing development, road construction, etc.

Several Western European countries implement the concept of well-field protection zones (Figure 2-3), often thought of as the most pragmatic approach to anticipatory classification of public water-supply settings (e.g., Milde, et al, 1983). In West Germany, for example, nearly 80 percent of the 14,000 well fields in that country have protection areas in-place or in the process of being established. The key protection area is located within 2 kilometers (about 1.2 miles) from the well. As in most such systems, only a portion of the entire

FIGURE 2-3
IDEALIZED WELL FIELD PROTECTION ZONES IN WEST GERMANY
(AFTER MILDE ET. AL., 1983)



aquifer is given the "special" designation. In Switzerland the distances are shorter (minimum of 200 meters or about 650 feet); those in the Netherlands are time-of-travel based (typically 10 and 25 years travel time). Well-field protection zones are incorporated in some state and local protection systems; most notably, in Florida and the New England states.

There has been considerable activity at the Federal level in the area of enhancing State protection efforts. On June 19, 1986, the President signed into law the Safe Drinking Water Act Amendments of 1986. This law includes two new ground-water provisions, the first of which, (Section 1427), is a demonstration program establishing critical aquifer protection areas (CAPA) within Sole Source Aquifers. This is considered a program which is limited in extent, and geared to demonstrating techniques for protection of certain important ground waters.

The second element of the Amendments requires the States to develop programs to protect the wellhead areas of all public water systems within their jurisdiction "from contaminants that may have any adverse effects on the health of persons." These wellhead protection areas are defined as "any surface or subsurface areas surrounding wellfields through which contaminants are reasonably likely to move and reach a well or wellfield." EPA is required to issue technical guidance within a year after enactment which the States <u>may</u> use (i.e., may <u>not</u> choose to use) for determining the extent of the wellhead protection areas.

The Act specifies that the following elements be incorporated into State programs:

- Duties of State and local agencies and public water supply systems in implementing the program
- Determination of wellhead protection areas for each public well
- Inventory of all potential anthropogenic sources within the protection area
- A program that contains as appropriate, technical assistance, financial assistance, implementation of control measures, education training and demonstration projects to protect the wellhead areas from contaminants

- Contingency plans for alternative water supplies in case of contamination
- Siting considerations for all new wells
- Procedures for public participation.

This program must be submitted to the Administrator of EPA within the three years after enactment and the States are expected to implement this program within two years after it has been approved by the Administrator. The only effect on a State of failing to submit a Wellhead Protection Program, however, is the loss of related funds.

The provision is structured to give all States maximum flexibility in formulating their programs and the Administrator will disapprove a program only if it is not adequate to protect public water wells from contamination. Any disapproval must be made within nine months of submittal; and, should a program be disapproved, a State must modify the program and resubmit their plans within six months.

Once a program is approved, the Administrator shall make 50 to 90 percent match grants to the State for costs for the development and implementation of the State program. The Congress has authorized $20 million for each of FY 1987 and 1988 and $35 million for each FY 1989 through 1991. As of this date, however, no funds for FY 1987 have been appropriated.

It is appropriate to note, however, that wellfield protection is typically the "high end" of any classification system, as it is most often oriented to current, important public water supplies. Potential drinking water sources, ecologically vital ground waters, and low-quality, non-drinking water sources are not identified or managed in such systems.

The important point is that anticipatory classification is best performed and implemented by State and local governments that hold land-use authority. Under its program, existing statutes and budget resources, EPA can only perform site-by-site classification as part of its routine program-by-program effort. The classification system outlined in this guidelines document attempts to be generally consistent with broader anticipatory classification systems. Unlike anticipatory classification, which takes many years (and considerable technical and financial resources) to implement, site-by-site classification can be rapidly factored into EPA

procedures in a way that is legally consistent with Agency authorities. By taking this approach, however, EPA does not wish to discourage anticipatory classification -- an approach which the Agency feels is a very useful one for effective resource management at the State and local levels.

Since a cornerstone of the Ground-Water Protection Strategy is fostering State-specific efforts, EPA is considering the substitution of State ground-water classification systems for the EPA system wherever possible. Given past program precedents, the State system will most likely need to be "equivalent to" or "at least as stringent" as EPA's. Since the implementation of the EPA ground-water classification system is still in the early stages, specific criteria or factors for such evaluations have not been determined. Options for Agency consideration, even though preliminary in nature, will be examined over the course of the next year. Institutional mechanisms at the Headquarters and Regional levels for reviewing such systems will also be considered.

In addition, EPA will be evaluating the legal basis for incorporating State Wellhead Protection areas approved by the Agency under the SDWA Amendments into its operating programs, as well as into this ground-water classification framework.

PART II

DETAILED CLASSIFICATION PROCEDURES

PART II

4.0 CLASSIFICATION PROCEDURES

The previous sections provide both background and overview of the EPA ground-water classification system. The system is based on an analysis of data which is generally available from published sources, telephone or in-person contacts, or other program-related sources, such as permit packages and environmental impact statements. The need for detailed information on the hydrogeologic or socioeconomic properties of an area will increase, for example, where a Class I or Class III designation is possible, or a subdivision of ground waters in the Classification Review Area is being considered. In the majority of decisions, data gathering and interpretation will be simple and inexpensive.

This chapter provides a more in-depth discussion of the actual process of site-by-site classification. The process is facilitated through a classification procedural chart shown in Figure 4-1. A corresponding classification "worksheet" (Table 4-1) follows the sequence of procedural chart steps. Classification will typically begin with step one and continue until a final class determination is made. Both the procedural chart and worksheet were developed to provide a systematic approach to classifying ground water based on certain criteria, e.g., presence of wells, ecologically vital areas, water quality, irreplaceability, etc. They are provided as suggested approaches only, since a given setting may be more effectively handled through another sequence of steps.

It is important to realize that, as a result of the classification procedure, the Agency is not classifying a specific ground-water region, per se. The classification process will assist the EPA programs in such activities as permitting and corrective-action assessments. No mapped unit will be generated, although a Classification Review Area will be employed as an aid in the decision process.

Lastly, the system assumes a broad definition for current use as a source of drinking water (IIA). In the absence of current use, the system will lead to a determination of potential source of drinking water (IIB), unless a lower resource value is demonstrated. Other beneficial uses of ground water will be considered in making Class II determinations.

FIGURE 4-1
PROCEDURAL CLASSIFICATION CHART

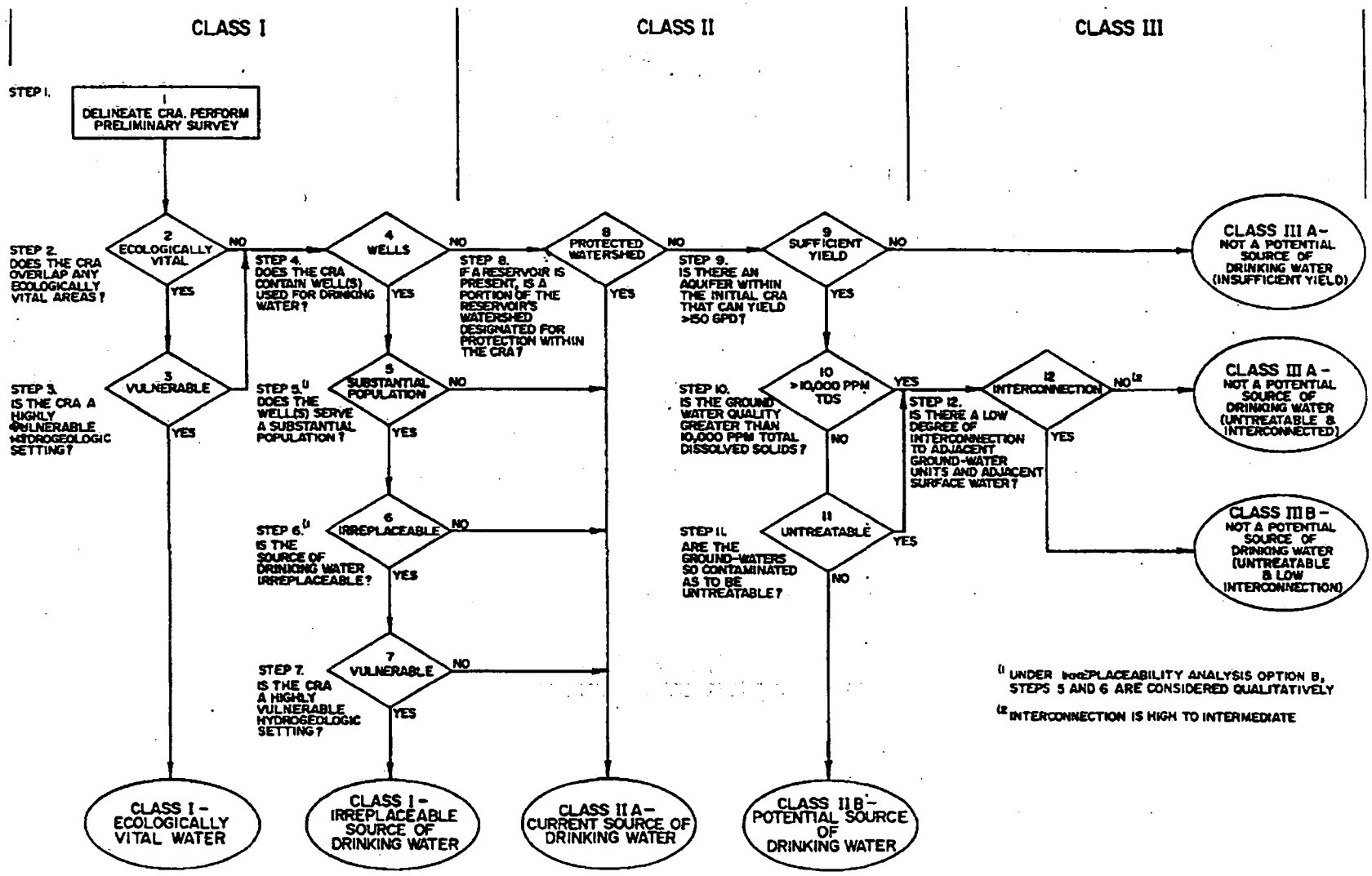


TABLE 4-1
CLASSIFICATION WORKSHEET

Step	Question/Direction	Response/Comment*
1	Establish Classification Review Area (CRA) and collect preliminary information. Optional- Demonstrate subdivision(s) of the CRA	
2	Locate any ecologically vital areas in the CRA.** Does the CRA or appropriate subdivision overlap an ecologically vital area? . Yes, go to next step . No, go to Step 4	
3	Perform vulnerability analysis. Is the CRA or appropriate subdivision a highly vulnerable hydrogeologic setting? . Yes, then the ground water is CLASS I- ECOLOGICALLY VITAL . No. go to next step	
4	Determine location of well(s) within the CRA or appropriate subdivision. Does the CRA or appropriate subdivision contain well(s) used for drinking water? . Yes, to to next Step . No, go to Step 8	

*To be completed when performing classification.
**Steps 2 and 3 may be performed in reverse order.

Step	Question/Direction	Response/Comment*
5*	Inventory population served by well(s). Does the well(s) serve a substantial population? . Yes, go to next step . No, then the ground water is CLASS IIA-CURRENT SOURCE OF DRINKING WATER	
6*	Unless proven otherwise, the drinking water source is assumed to be irreplaceable. Optional-perform irreplaceability analysis. Is the source of drinking water irreplaceable? . Yes, go to next step . No, then the ground water is CLASS IIA-CURRENT SOURCE OF DRINKING WATER	
7	Perform vulnerability analysis. Is the CRA or appropriate subdivision a highly vulnerable hydrogeologic setting? . Yes, then the ground water is CLASS I-IRREPLACEABLE SOURCE OF DRINKING WATER . No, then the ground water is CLASS IIA-CURRENT SOURCE OF DRINKING WATER	

*Under irreplaceability analysis Option B, Steps 5 and 6 are considered qualitatively.

Step	Question/Direction	Response/Comment*
8A	Determine location of reservoirs within the CRA or appropriate subdivision. Does the CRA or appropriate subdivision contain reservoirs used for drinking water? . Yes, go to next step . No, go to Step 9	
8B	Determine status of watershed(s) containing reservoir(s) present in the CRA or appropriate subdivision. Does that portion of the water-shed designated for water-quality protection overlap the CRA or appropriate subdivision. . Yes, then the ground water is CLASS IIA-CURRENT SOURCE OF DRINKING WATER . No, go to next step	
9	Determine yield from ground-water medium (total depth across CRA or appropriate subdivision). Can it yield 150 gallons-per-day to a well? . Yes, go to next step . No, then the ground water is CLASS IIIA-NOT A SOURCE OF DRINKING WATER (INSUFFICIENT YIELD)	

Step	Question/Direction	Response/Comment*
10	Determine water-quality characteristics within the CRA or appropriate subdivision. Is the water quality greater than 10,000 mg/l total dissolved solids (TDS)? (Note: If water quality is unknown, then this question must be answered no.) . Yes, go to Step 12 . No, go to next step	
11	Are the ground waters so contaminated as to be untreatable? (Note: If water quality is unknown, then this question must be answered no.) . Yes, go to next step . No, then the ground water is CLASS IIB-POTENTIAL SOURCE OF DRINKING WATER	
12	Perform interconnectedness analysis. Is there a low degree of interconnection between the ground water being classified and adjacent ground units or surface waters within the initial CRA? . Yes, then the ground water is CLASS IIIB-NOT A SOURCE OF DRINKING WATER (LOW INTERCONNECTION) . No, then the ground water is CLASS IIIA-NOT A SOURCE OF DRINKING WATER (INTERMEDIATE-TO-HIGH INTERCONNECTION)	

4.1 Preliminary Information

An overview of basic information needs for classification is presented in this section. More detailed discussions are provided in the balance of this chapter as well as in the Appendices. The collection of preliminary information is meant to reflect an approach to classification which begins simply and directly. The data should be collected from the most current and best available sources. It should include a well/reservoir survey, demographic information, and identification of ecologically vital areas. Regional hydrogeologic data will be required if an interconnection analysis needs to be made. Otherwise, a general description of the regional geology, geomorphology, and hydrogeology would be useful. Again, the emphasis is on available information rather than on detailed in-field analyses.

4.1.1 Base Map of Classification Review Area

The Classification Review Area is defined by drawing a two-mile radius from the boundaries of the facility or activity area. An expanded review area is allowed under certain hydrogeologic conditions of intermediate-to-high ground-water velocities. These conditions and the procedures to expand the Classification Review Area are presented in Section 4.2. This Classification Review Area may be subdivided based on a hydrogeological analysis of interconnection between adjacent surface waters and ground-water units as described in Section 4.3. A base map illustrating the facility location, and the Classification Review Area boundary is, of course, a vital piece of basic data.

4.1.2 Well Survey

A well survey should include the location, use, and pumpage capacity of existing public water-supply wells or well fields within the Classification Review Area. Public water-supply systems are defined under the Safe Drinking Water Act as those serving more than 25 persons or with more than 15 service connections. Information on the well depth and screened interval depth may be needed if a subdivision of the Classification Review Area is to be made.

A detailed inventory of private residential wells is not necessary. As pointed out in Section 4.4, census data (e.g., densly settled areas) can be a good estimation approach. As a preliminary step, the delineation of areas not served by public water supplies, and the approximate number or density

of homes in the area should be obtained. The simplest well data to be included are the estimated number of wells present, and other general characteristics of private wells in the Classification Review Area.

Well information may be obtained from water authorities, public health agencies, regulatory agencies permitting well drilling, well drillers, or other state or local entities. Sources of the data should be documented and, where the information is not available, it should be so stated.

Water-supply reservoirs designated for water-quality protection in the Classification Review Area need to be identified and described. Again, state and local agencies may be utilized in this capacity. Water-supply reservoir watersheds designated for water-quality protection are specifically recognized in the ground-water classification system.

4.1.3 Demography

Information on populations served by public and private wells will be needed if it is apparent that substantial populations may be involved, which could lead to a Class I decision. A first-cut approximation for public supply wells in the area can be made by dividing the total pumpage capacity by the typical per capita consumption rates for the region. Estimates of the number of private wells in densely settled areas within the Classification Review Area will also be necessary. Densely settled areas can be located on U.S. Census Bureau maps. Procedures for determination of substantial population are provided in Section 4.4.

4.1.4 Ecologically Vital Areas

Identification of areas which may be candidate discharge points for ground water is a first step in locating ecologically vital areas. Such areas may include springs, streams, caves, lakes, wetlands, estuaries, coastlines, embayments, and playas. Once these candidate discharge areas have been identified (since proving discharge may require field studies), the presence of a habitat for a listed or proposed endangered or threatened species (pursuant to the Endangered Species Act as amended in 1982) needs to be examined. The location of any such areas, or any Federal lands managed for ecological values within the Classification Review Area must be identified. The Regional Office of the U.S. Fish and Wildlife Service and the State Endangered Species coordinator

or Heritage Program administrator are two sources for information regarding unique habitats and/or endangered or threatened species. Information about Federal lands may also be obtained from Federal land management agencies such as the National Park Service, U.S. Forest Service, and Bureau of Land Management. The presence of Federal lands is indicated on most state and county road maps and U.S. Geological Survey quadrangle sheets.

4.1.5 Hydrogeologic Data

Regional hydrogeologic information will be needed, to some extent, in order to perform a DRASTIC analysis for the vulnerability criterion; estimates are needed on:

- depth to water
- net recharge
- uppermost aquifer media
- soil media
- topography (slope)
- vadose zone media
- hydraulic conductivity of the uppermost aquifer.

This information is typically reconnaissance in nature and may likely be obtained from county/regional reports and also State geologic surveys. Pertinent information will be obtained from U.S. Geologic Survey cross-sections, topographic maps, stratigraphic sections, county geologic maps, and U.S. Department of Agriculture soil maps.

If interconnectedness of ground water with adjacent ground units and surface waters is to be analyzed, additional detailed h[illegible]ogeologic information is necessary. This might include [illegible]ptive hydrogeologic data, aquifer test data from prev[illegible] studies, semi-quantitative flow nets, computer simulation[illegible] or other relevant information. This information is critical for all Class III demonstrations. Specific considerations for interconnection to adjacent water is described in Section 4.3.

The best available sources of published hydrologic/-geologic information are the U.S. Geological Survey publications, State geological surveys, scientific books and journals, and U.S. Department of Agriculture county soil surveys. Data supporting facility permit applications, Clear Water Act Section 208 studies, as well as Environmental Impact Statements, may also be useful.

4.2 Conditions and Procedures for Expanding the Classification Review Area

Expansion of the Classification Review Area is allowed under certain hydrogeologic conditions. The two-mile radius may be insufficient for determining the use and value of ground water and identifying potentially affected users in hydrogeologic conditions of intermediate to very high ground-water flow velocities where these velocities occur over distances much greater than two miles. In such settings, there is a potential for activity-related contaminants to move beyond a two-mile radius in a relatively short time frame, especially under the influence of large-scale ground-water withdrawals. This section represents qualitative descriptions of those hydrogeologic settings where an expanded review area is appropriate, and the procedures to quantitatively establish the dimensions of the expanded review area based on hydrogeologic characteristics.

An expansion of the Classification Review Area will be triggered upon the determination that the activity under review occurs within two hydrogeologic settings. Because these settings are described qualitatively, some level of hydrogeologic information will be needed to match the real settings to qualitative description.

4.2.1 Hydrogeologic Settings

Two hydrogeologic settings have been identified where expansion of the Classification Review Area is appropriate. They are:

A. Settings (referred to as Karst settings) where the principle aquifer is relatively shallow (<100m) and composed of carbonate rocks, with a well developed system of solution-enlarged openings (secondary porosity). The solution-enlarged openings serve as the main conduits for ground-water flow and are interconnected into distinct but dynamic ground-water basins feeding a complex of cave streams. These settings are often referred to as karst areas or karst aquifers. Flow through the conduit system is extremely rapid, as much as 1800 ft-per-hour (Quilan and Ewers, 1985) over long distances, in some cases up to 15 miles. Settings may be found in the following ground-water regions (after Heath, 1984):

6. Non-Glaciated Central Region
7. Glaciated Central Region
10. Atlantic and Gulf Coastal Plain Region
11. Southeast Coastal Plain Region, and
15. Puerto Rico and the Virgin Islands.

B. Certain settings (referred to as alluvial basin settings) where the general length of ground-water flow paths are significantly greater than the two-mile Classification Review Area radius (i.e., where the distance between perennial streams is greater than four miles). These settings are predominantly alluvial basins and other basins filled with unconsolidated to semi-consolidated materials and are, in addition, characterized by:

- An unconfined aquifer as the dominant aquifer
- Losing streams as the predominant source of recharge
- Transmissivities and flow velocities that are moderate to high (>250 m^2/d and >60 m/yr, respectively)
- Relatively low annual rain fall (less than 20 inches)

The ground-water regions (after Heath, 1984) where these settings can be found include:

2. Alluvial Basin Region
3. Columbia Lava Plateau Region
4. Colorado Plateau and Wyoming Basin Region
5. High Plains Regions, and
6. Non-Glaciated Central Region.

4.2.2 Expanded Classification Review Area Dimensions

The dimensions of the expanded review area are governed by the hydrogeologic characteristics of the region. Flow-system boundaries, flow direction, and flow velocities are the key characteristics.

For Setting A, karst areas, the expansion area dimensions will be based on boundaries of the ground-water basin(s) encompassing the activity. A basin includes all

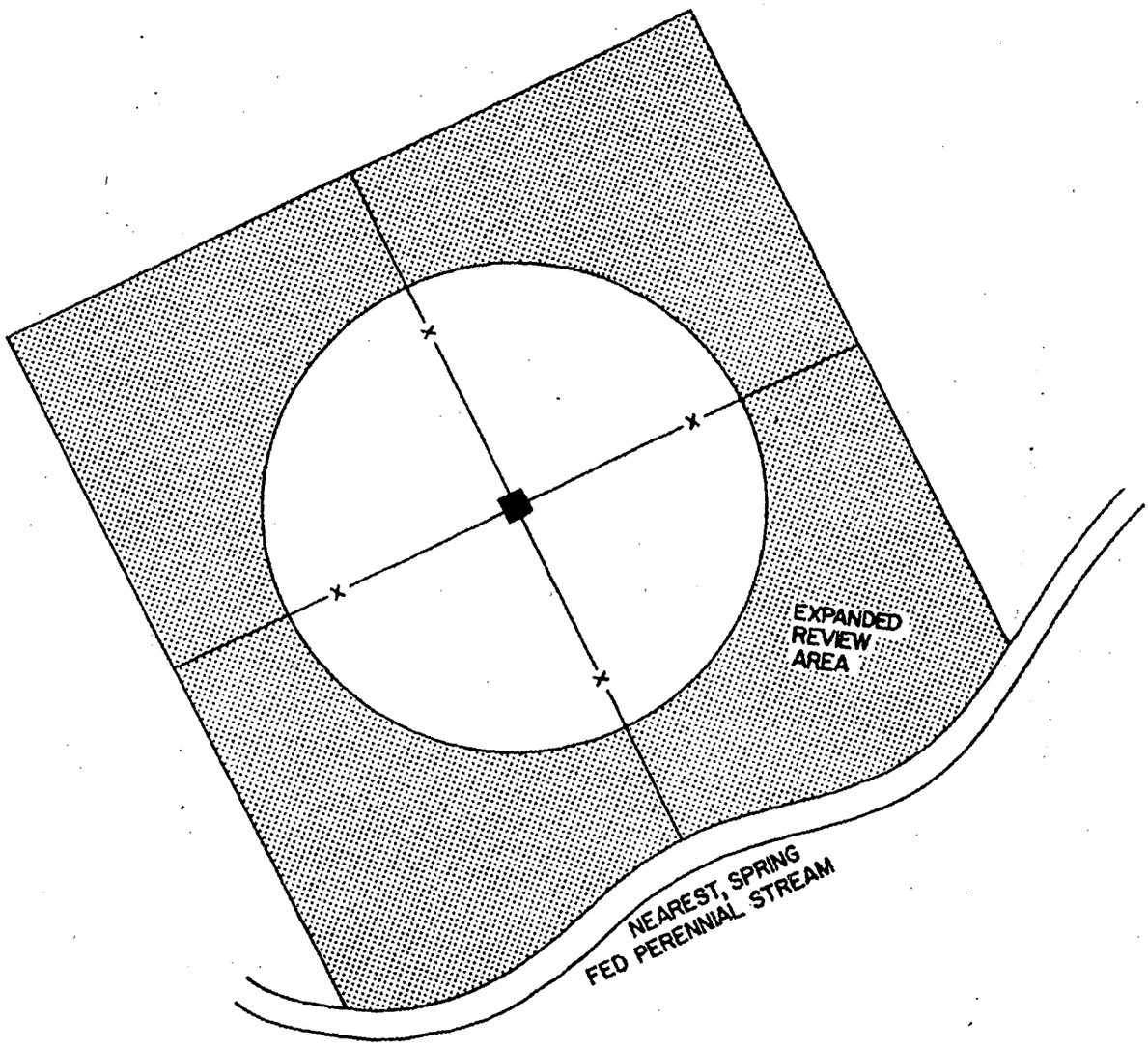
recharge areas supplying the cave stream extending to the perennial stream where the cave-stream discharges. These basins can be mapped using dye-tracing studies and a water-level map. However, due to the expense of such studies, few basins have been mapped. As a surrogate, it is recommended that the distance to the nearest spring-fed, perennial stream be employed to establish the expanded review-area dimensions as shown in Figure 4-2. The reviewer is cautioned that, in some cases, the nearest perennial stream may not be the discharge for the subject ground-water basin. Such an error can be minimized by locating the topographic high (the watershed divide) between the nearest perennial stream and adjacent streams. If the activity is on the same side of the topographic high as the nearest perennial stream, then it is reasonable to assume that the nearest perennial stream is the discharge. If not, then the discharge is likely to be the perennial steam on the same side of the topographic high as the activity/facility. In rare cases, the activity or facility is located on the topographic high. In such a case, the expanded review area should extend to the nearest perennial stream on all sides of the topographic high.

For Setting B, alluvial basins, the dimensions of the expanded review area are based on the average ground-water flow velocity within the basin. The radius is to be extended to a distance that ground water will flow in a period of 50 years. For example, if flow velocities averaged 400 feet-per-year, then the expanded radius would be 20,000 feet, approximately four miles. In the event that ground-water flow velocities are unknown, an expanded radius of five miles is recommended.

Ground-water flow velocities range over several orders-of-magnitude. The highest velocities are those of the karst cave streams. In alluvial basins, it will be unlikely that flow velocities as high as one mile a year will occur except over very short distances not representative of flow throughout the basin.

The dimensions of the expanded review area can be modified to account for the direction of flow. Where flow direction can be reliably determined, only the downgradient portion of the expanded review area need be examined. The expanded review area can also be subdivided according to rules outlined in Section 4.3. Examples of expanded Classification Review Area for both a Karst setting and an alluvial basin setting are provided in Appendix C case studies 10 and 11, respectively.

FIGURE 4-2
EXAMPLE OF GEOMETRY AND DIMENSIONS OF THE PROPOSED EXPANDED REVIEW AREA FOR KARST SETTINGS



EXPLANATION

■ PROPOSED FACILITY

4.3 Subdivision of the Classification Review Area: Identification of Ground-Water Units and Analysis of Interconnection Between Ground-Water Units

The ground-water regime defined in Chapter 3.0 can be subdivided into three-dimensional, mappable ground-water units. The Classification Review Area, regardless of size, may be subdivided to allow more precise definition of the specific ground-water units where classification should be focused. This chapter presents the methods and examples by which subdivisions are identified and how the degree of interconnection between the subdivisions is analyzed.

Subdivision of a Classification Review Area may be carried out to separate ground-water units having different use and value and, therefore, are subject to different degrees of protection. For example, the subdivision of the Classification Review Area will be necessary to justify the following types of conclusions:

- Deep ground-water units with Class IIIB water are overlain at shallow depth by ground-water units with Class I or II water,

- The ground-water unit associated with an activity does not discharge to an ecologically vital area present in the Classification Review Area,

- A shallow, ground-water unit that is a potential source of drinking water (Class IIB) is underlain by a deeper ground-water unit that is currently used as a source of drinking water (Class IIA)

Having identified the ground-water units within the Classification Review Area, the user of this document is ready to classify the waters within the units in accordance with the methods set forth in other sections and schematically summarized in Figure 4-1. The interrelationship between ground-water unit subdivisions and the classification of ground water are as follows:

- All ground water within a ground-water unit has a single class designation.

- Boundaries separating waters of different classes must coincide with boundaries of ground-water units,

- One or more adjacent ground-water units may have the same class designation.

Ground-water units are delineated on the basis of three types of boundaries described below:

Type 1: Permanent ground-water flow divides. These flow divides should be stable under all reasonably foreseeable conditions, including planned manipulation of the ground-water regime.

Type 2: Extensive, low-permeability (non-aquifer) geologic units (e.g., thick, laterally extensive confining beds), especially where characterized by favorable hydraulic head relationships across them (i.e., direction and magnitude of flow across the low-permeability geologic unit). The most favorable hydraulic head relationship is where flow is toward the ground-water unit being classified and the magnitude of the head difference (hydraulic gradient) is sufficient to maintain this direction of flow under all foreseeable conditions. The integrity of the low permeability unit should not be interrupted by improperly constructed or abandoned wells, extensive, interconnected fractures, mine tunnels or other apertures.

Type 3: Permanent fresh water-saline water contacts (saline water defined as those waters with greater than 10,000 mg/l of Total Dissolved Solids). These contacts should be stable under all reasonably foreseeable conditions, including planned manipulation of the ground-water regime.

The degree of interconnection between ground-water units is related to the type of boundary. A high degree of interconnection is assumed for all waters within a single ground-water unit. Adjacent units that are separated by a Type 1 (ground-water flow divide) or Type 3 (fresh water-saline water contact) boundary have an intermediate degree of interconnection. Adjacent units separated by a Type 2 (low-permeability geologic unit) boundary have a low degree of interconnection.

The degree of interconnection across the three boundary types defined here depends on selected key physical and chemical processes governing movement of water and dissolved solute in the subsurface. Under steady/state ground-water flow conditions the principal mechanisms effecting potential contaminant movement across Type 1 (ground-water flow divide) or Type 3 (salinity difference) boundaries would be mechanical dispersion and chemical diffusion. These conditions are considered by EPA to represent an intermediate degree of interconnection. Under transient flow conditions caused by pumpage or accelerated recharge of fluids within the Classification Review Area, there exists the potential to spatially displace a ground-water flow divide or saline/fresh water interface boundary. For this reason EPA believes that foreseeable changes in aquifer stresses and increased ground-water use in the Classification Review Area should be considered in determining the permanence (i.e., location over time) of such boundaries.

The primary mechanism for contaminant transport across a Type 2 boundary is the physical movement of ground water into or from the low-permeability geologic unit. The Agency recognizes that the physical and chemical processes that control fluid and solute transport through low-permeability non-aquifers is not as well understood as it is for aquifers. However, for the purposes of assessing the degree of interconnection, one must be able to infer that the flow rate of water through the non-aquifer is very small relative to the flow rates through adjacent aquifers.

The following subsections present further guidance and examples on how boundaries between ground-water units are identified.

4.3.1 General Hydrogeologic Information Needed for Identifying Ground Water Units and Analyzing Interconnection

The information required to subdivide the ground-water regime into ground-water units generally includes topics within the fields of geology, hydrology, and management of ground-water resources (controls on withdrawals/recharge, properly abandoning deep wells, etc.). The description of the ground-water regime and any potential subdivisions must be as quantitative as possible. The Agency recognizes that the degree of precision with which the Classification Review Area can be subdivided is limited by the abundance and quality of readily available data. Supplementation of the existing data base with field and laboratory investigations both on-site and off-site may be needed to accurately confirm

the existence of subdivisions. The following discussion will serve to guide the types of data collection efforts needed to justify the subdivision of the Classification Review Area.

Background information on geologic formations and occurrence/movement of ground water can be obtained at a regional scale of accuracy from State and Federal agencies. Topographic maps published by the U.S. Geological Survey (USGS) are now available at useful scales for most of the nation. These can help identify ground-water flow directions and flow divides for the uppermost aquifer. Data on the distribution and characteristics of soils are available from the USDA Soil Conservation Service. General information on precipitation, run-off and recharge rates can be obtained from the USGS and can be supplemented by climatic data from weather stations around the country. Ground-water pumpage and locations/depths of wells can generally be obtained from State agencies that issue well permits, or from local Public Health Agencies and water districts.

The first step is to identify all aquifers occurring within the ground-water regime of the Classification Review Area. In areas that have been well studied these will be recognized and documented in government agency reports. In poorly studied areas, proper recognition of aquifers can be inferred from lithologic descriptions of geologic formations, structural features of the area (if flow is mainly through fractured rock), and the depth and design of wells. The areal and vertical extent of hydrogeologic units within the ground-water regime can be shown in a series of cross-sections and maps. For most hydrogeologic settings it will be most useful to interpolate between locations where conditions are known (i.e., wells, outcrops, excavations, etc.) and present variations in thickness and elevations of important units with contour maps prepared at a common scale.

After the identification and graphical representation of the geologic framework it is possible to identify ground-water units within the ground-water regime using the guidance provided in subsequent sections.

4.3.2 Type 1 Boundaries: Ground-Water Flow Divides

The concepts of ground-water flow systems may not be familiar to some readers and needs to be reviewed in order to understand flow divide boundaries between ground-water units. Figure 4-3(a) shows in vertical cross-section a series of adjacent shallow ground-water flow systems for a single-layer, water-table aquifer. The systems are bounded at the base by a physical impermeable boundary. As is typical in

humid regions, the water-table profile conforms to the topographic profile.

The flow net in Figure 4-3(a) clearly shows that ground-water flow occurs from the recharge area in the highlands to the discharge areas in the lowlands (i.e., valleys). Vertical line segments AB and CD beneath the valleys and ridges constitute ground-water flow divides, i.e., imaginary impermeable boundaries across which there is no flow. In the figure, these ground-water flow divides separate adjacent flow systems ABCD and ABEF which, for purposes of subdivision, correspond to ground-water units separated by Type 1 boundaries.

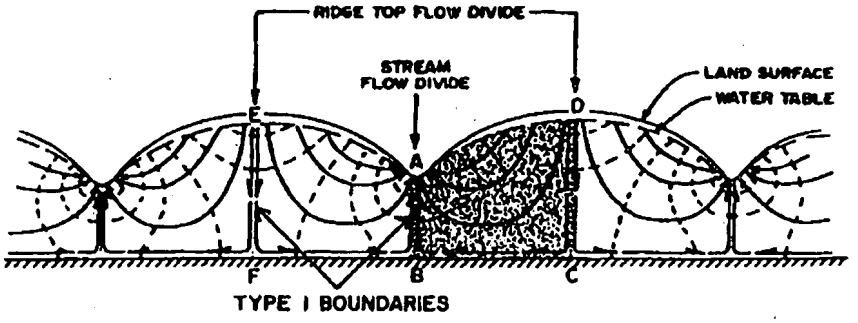
In simplified, symmetrical systems such as those illustrated in Figure 4-3(a), ground-water flow divides coincide exactly with surface water divides and extend vertically to the base of the aquifer. In more complex topographic and hydrogeologic settings these properties may diverge substantially from the situation illustrated.

A comparison of Figures 4-3(a) and 3(b) reveals how flow patterns and divides are altered when the undulations in the water table are superimposed on the regional hydraulic gradient towards a more regional stream and discharge area. Ground-water flow divides in Figure 4-3(b) extend through the full thickness of the aquifer only at either end of the entire flow regime. The full dimension of the flow regime may or may not be encompassed by the two-mile radius. The total length, S in the figures, can range from hundreds to thousands of feet.

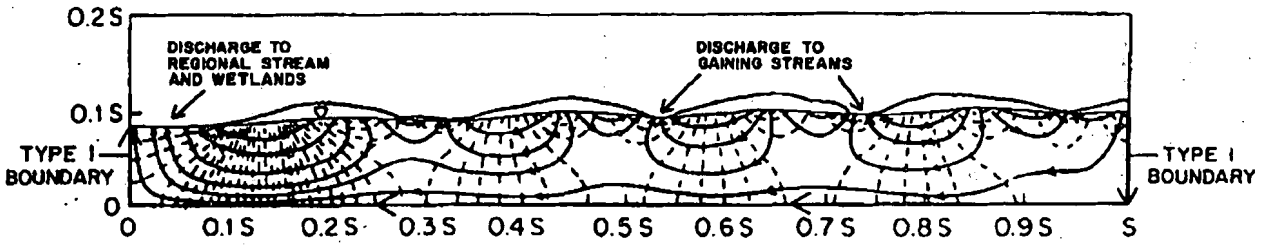
Figure 4-3(c) is an example of more complex conditions in which the flow patterns and flow systems are effected by both topography and regional variations in hydraulic conductivity of layered earth materials. Given adequate data, computerized models of real sites can provide approximations of ground-water flow patterns. In general, the level-of-sophistication employed to demonstrate the presence of a Type 1 boundary should be comensurate with the complexity of the hydrogeologic setting.

The spatial location of the water-table and ground-water flow divides may be stable under natural flow conditions but can be modified by man-made hydraulic stresses, such as large-scale ground-water withdrawals or recharge. In some cases it will be necessary to estimate the permanence (i.e., location with time) and position of ground-water flow divides under stressed conditions from available hydrologic and geologic data and foreseeable changes in water use.

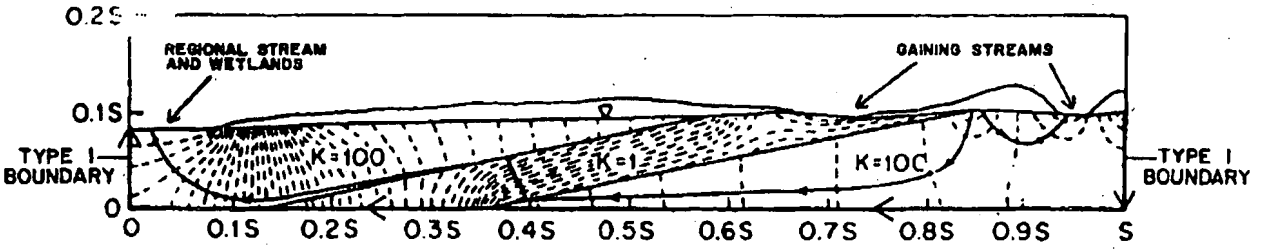
FIGURE 4-3
HYDROGEOLOGIC SECTIONS SHOWING FLOW SYSTEMS OF
INCREASING COMPLEXITY WITH TYPE 1 BOUNDARIES



a) Simple flow systems associated with a water-table aquifer (after Hubbert, 1940).



b) Ground-water flow pattern in a water-table aquifer with local and region charge areas (after Freeze and Whitherspoon, 1967).



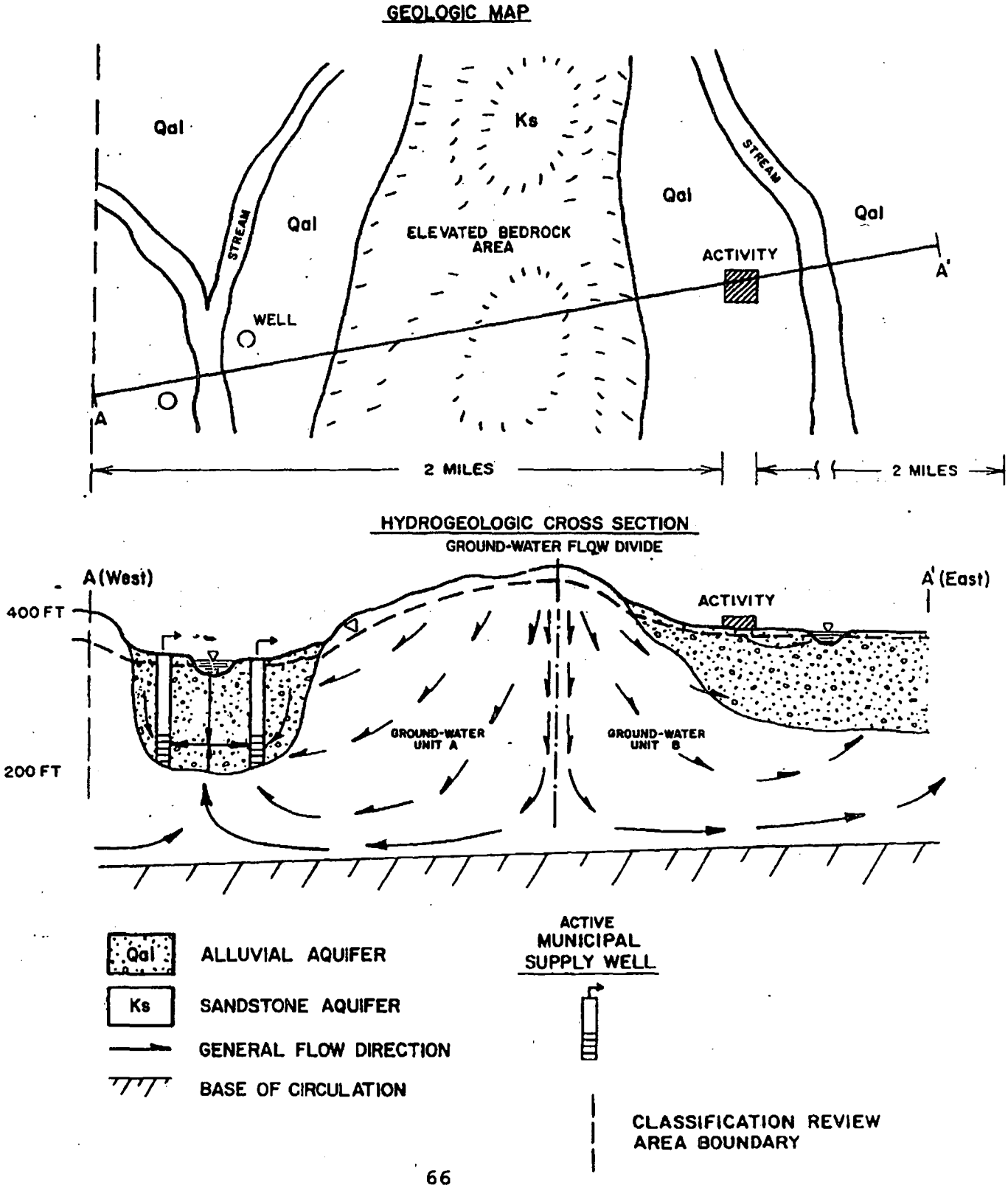
c) Ground-water flow pattern in dipping sedimentary rocks with local and regional discharge areas (after Freeze and Whitherspoon, 1967).

A good example of ground-water units separated by a Type 1 flow divide boundary is shown in Figure 4-4, The setting illustrated consists of two alluvial valleys with high-yield wells completed in sand and gravel deposits, separated by sandstone bedrock that can only provide limited supplies to domestic wells. Ground water in the alluvium is derived from precipitation and from the bedrock, and discharges to the river under natural conditions. Under pumping conditions, the water pumped by the high-yield wells is derived largely from the river, from local precipitation, and from the bedrock. Near the wells in the eastern valley, flow system boundaries are affected by ground-water withdrawals and are stable as long as the well discharges are steady. The ground-water flow divide separating the two valley aquifers is not effected by pumpage, and provides the essential characteristic that allows the delineation of ground-water units A and B.

In order to provide EPA with a defensible ground-water flow-divide delineation, a limited flow analysis will generally be required as a minimum. An acceptable approach is to prepare a water budget for the ground-water unit in order to show a reasonable order-of-magnitude balance on flow into and out of the system. This could involve the preparation of a ground-water flow net (see Glossary for definition) for the uppermost aquifer with accompanying estimates of volumetric flow into and out of the unit. The flow net can be generalized and need not be rigorously correct in a quantitative sense. The analysis should be carried out even though part of the ground-water system continues outside the Classification Review Area, that is, if part or all of the discharge or recharge area of the unit extends beyond the Classification Review Area.

The semi-quantitative flow net of the uppermost aquifer should be supplemented by a vertical hydrogeologic cross-section and supporting data showing that the uppermost aquifer is, in fact, underlain by an extensive aquitard or crystalline rock non-aquifer within the Classification Review Area. The flow net can be based on available water-table elevation data as interpreted from water levels in relatively shallow wells; locations/elevations of springs, wetlands, and perennial streams; and supplemented with topographic elevations. The rates and directions of flow can be estimated in plan view given a water-table contour map and estimates of aquifer thickness and hydraulic conductivity. The conductivity can be obtained from the area-specific reports, field or laboratory tests, or by estimating a range from the scientific literature based on earth material type. Flow patterns inferred from these data must also consider signifi-

FIGURE 4-4
EXAMPLE OF TYPE 1 FLOW DIVIDE BOUNDARY



cant spatial and directional variations in conductivity in areas having a more complex stratigraphic and structural geologic conditions.

At the beginning of the flow analysis, it is important to determine whether the ground-water flow system is in a state of steady or transient flow. Areas that are characterized by a lack of ground-water development and usage can generally be assumed to be in steady state. This will simplify the analysis because the estimate of system discharge can be equated to recharge. If the natural recharge rate compares favorably with a reasonable percentage of mean annual precipitation, the ground-water flow divides can be considered reliable. The applicant can go to the ground-water literature to obtain "reasonable" estimates to recharge in any geographic/ground-water region of the United States (e.g., see USGS Water-Supply Paper 2242 by R.C. Heath, 1984).

In areas characterized by large-scale withdrawals of ground water from shallow or deep aquifers, the flow regime is more prone to be in a transient state. Evidence of transient conditions includes:

- Declining ground-water levels
- Depletion of ground-water storage
- Movement of flow divides

When such evidence of movement exists, it may be necessary to estimate the ultimate steady-state position of the flow divides assuming conservatively large withdrawal rates and small water flow and storage properties.

4.3.3 Type 2 Boundaries: Low-Permeability Geologic Units

The Agency would assign a low degree of interconnection across the low-permeability geologic unit (Type 2 boundary) if the following conditions can be shown:

- The low-permeability geologic unit is laterally continuous beneath the entire area and/or limits the lateral continuity of the more permeable geologic unit

- There are no known wells, mine shafts, etc. that are improperly abandoned or unsealed through the geologic unit

- The geologic unit has a small permeability relative to both adjacent geologic units and to geologic media in general

- The flow of water through the geologic unit per unit area is insignificant relative to the flow of water per unit area through adjacent strata

Low-permeability geologic units include fine-grained sediments and sedimentary rocks, such as clays and shales, as well as crystalline igneous and metamorphic rocks that have few interconnecting fractures. Because these materials have small permeabilities, small quantities of water will be transmitted through them in response to hydraulic gradients. In areas where hydraulic heads beneath or within a low-permeability unit are greater than heads in an aquifer above the unit, the hydraulic gradient has an upward component across the Type 2 boundary. The Agency considers this to be the most favorable head relationship because it further ensures that the direction of ground-water movement at the boundary serves to inhibit the migration of contaminants into and across this type of boundary.

In selected environments, such as deep geologic basins, the applicant is free to make arguments that the flow of fluids is negligibly small through the low-permeability unit. The actual cut-off values of key variables such as permeability, thickness and hydraulic gradient are not specified in these guidelines and are left to professional judgments.

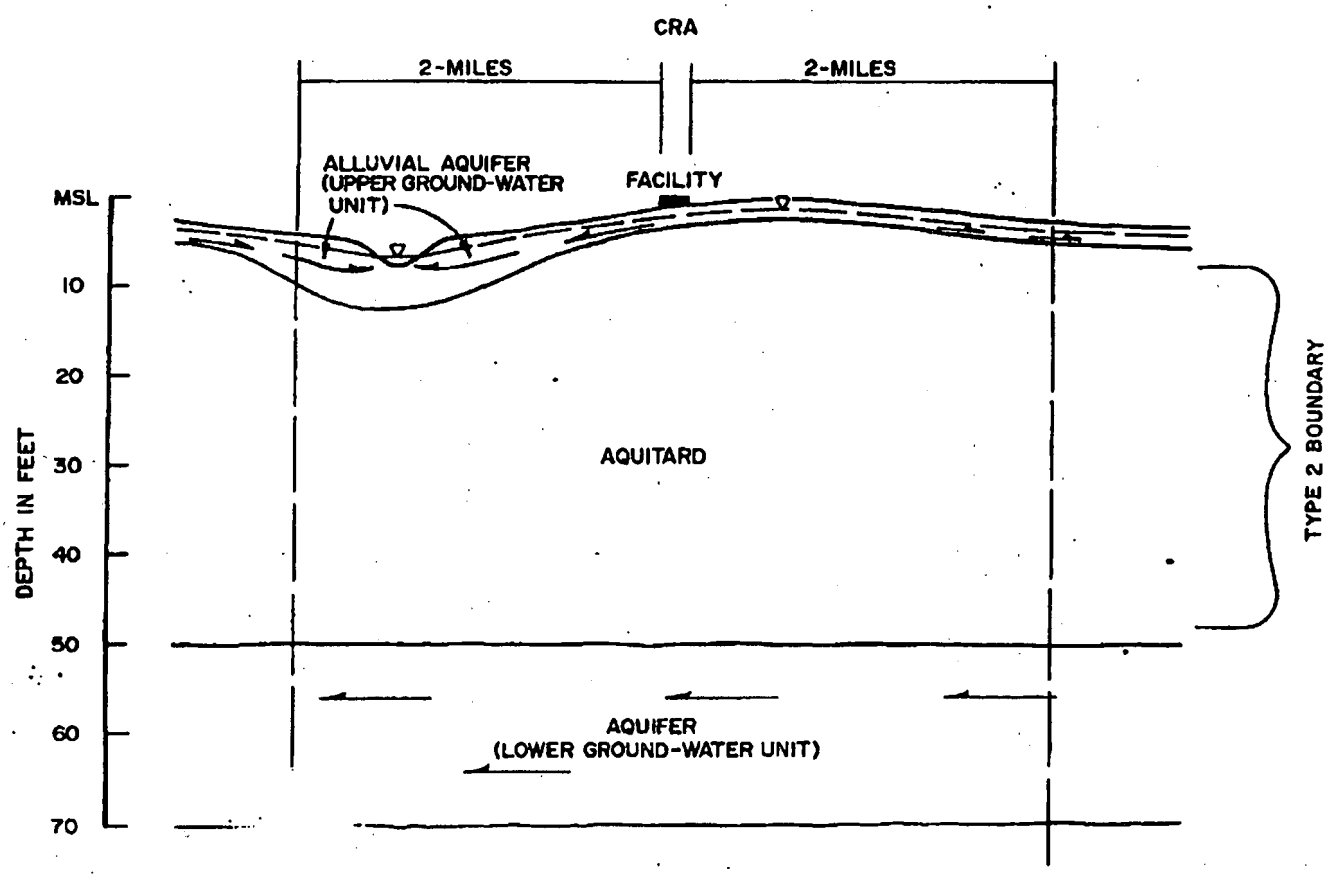
Figure 4-5 illustrates a setting where the presence of a thick, regionally extensive aquitard establishes a low degree of interconnection between a shallow ground-water unit and a deeper underlying ground-water unit (aquifer). This configuration is common in the Atlantic and Gulf coastal plain settings where the lower aquifer is the principal regional aquifer and is a source of water supply. It is overlain by an extensive confining clay that may be tens of feet thick. The shallow ground-water aquifer system supplies only limited amounts of water to wells. The reasons for the low interconnection between aquifers in this setting are as follows:

- the flow of water through the aquitard is exceedingly small,

- the time of travel of water through the aquitard is very large

Sedimentary basins commonly exhibit multiple freshwater aquifers each separated by a regionally extensive low-perme-

FIGURE 4-5
EXAMPLE OF TYPE 2 BOUNDARY



ability confining unit. Figure 4-6 is an example of such a basin where ultimate discharge of the deep fresh water through overlying low-permeability confining units (flow barriers) is to the ocean. Deeper ground waters in these basins will be characterized by a Total Dissolved Solids (TDS) concentrations that may be much greater than the 10,000 mg/l limit for Class III ground waters, and interconnection is considered to be low, even though hydraulic gradients are in the direction of less saline water.

The reasons for the low degree of interconnection are as follows:

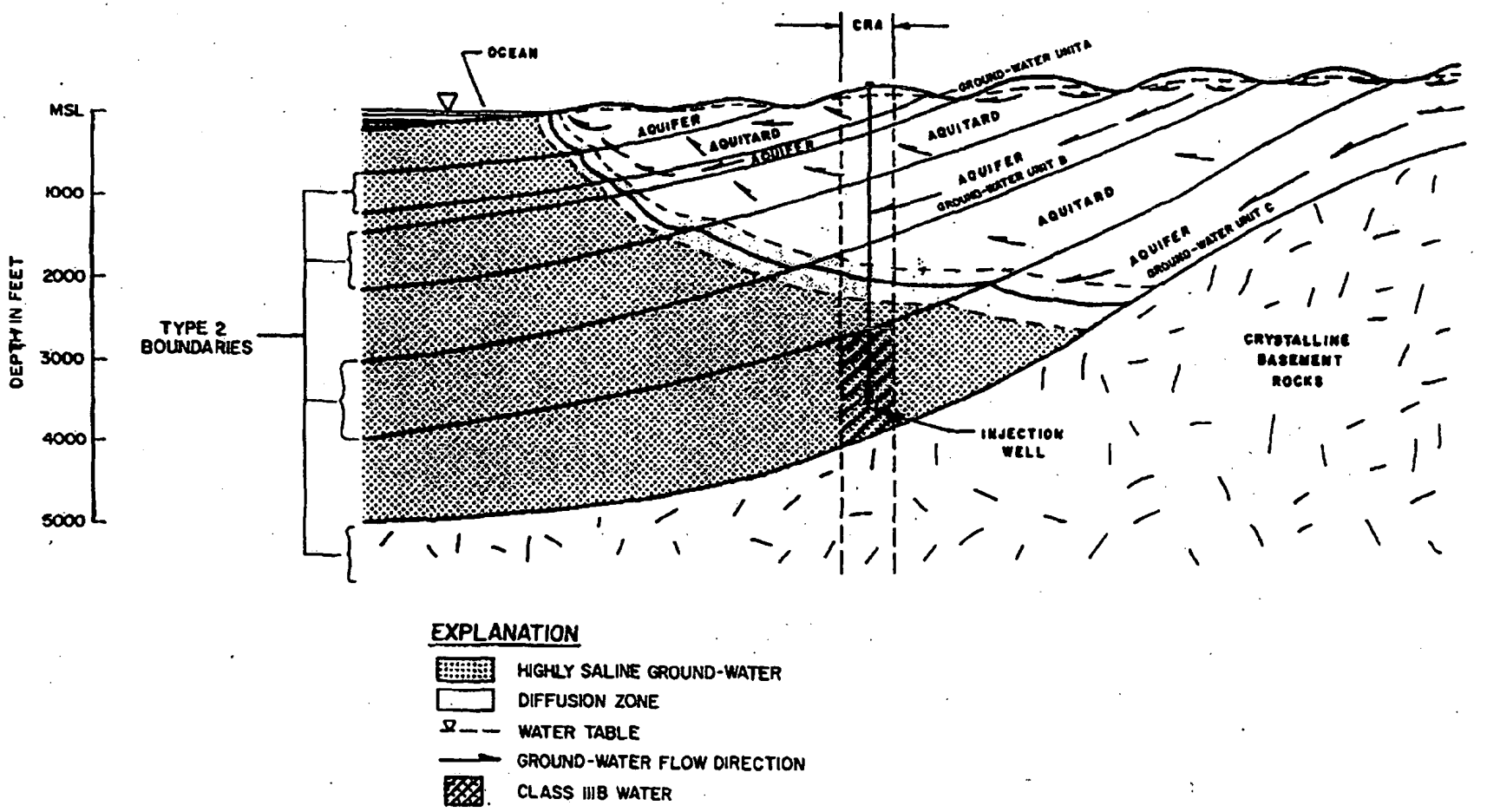
- salts are retained in deep aquifers confined by laterally extensive aquitards,
- the flow of water through the confining units is exceedingly small,
- the time of travel through the confining unit is very large
- the depth to these waters is generally below the bottom of any major water-supply wells in the area.

Deep, confined, saline ground-water units with a low degree of interconnection to overlying fresh ground-water units are currently the primary hydrogeologic setting into which wells can be permitted to inject hazardous wastes under present EPA and state Underground Injection Control (UIC) regulations. These waters are herein defined as Class III, Subclass B ground water. EPA's position is that the interconnection test for such candidate Class IIIB waters will follow those tests for the UIC program, Class I wells.

In general, the demonstration of the existence of a Type 2 boundary requires that one identify and characterize the laterally continuous low-permeability non-aquifer that constitutes the boundary. The following is a list of factors to be considered in making this demonstration:

- Stratigraphic setting and lithologic characteristics
- Structural setting and joint/fracture/fault characteristics
- Hydrogeologic setting and hydraulic head/fluid flow characteristics

FIGURE 4-6
EXAMPLE OF TYPE 2 BOUNDARIES BETWEEN AQUIFERS IN A SEDIMENTARY BASIN



The first distinction should be between whether the non-aquifer is of sedimentary or igneous/metamorphic origin. If it is sedimentary in origin, an identification of the environment of deposition will permit inferences about the expected geometry, thickness, and continuity of individual strata. These inferences should be defended with geologic sections including data from well logs and/or measured sections. The age of the unit, the degree of cementation, and degree of compaction are all qualitatively related to water-bearing characteristics (hydraulic conductivity and porosity).

If the unit is an igneous or metamorphic rock, the continuity and thickness can usually be inferred from geologic maps and reports for the region in which the Classification Review Area exists. Identification of igneous rocks that have tabular geometries such as volcanic flows, ash-fall deposits, or intrusive sills and dikes will allow inferences about thickness and continuity. These may serve as aquifers or aquitards within a sequence of sedimentary rocks. Crystalline "basement" rocks of igneous and metamorphic origin underlie the entire North American continent. In areas where these rocks are fractured and exposed at or near the land surface, they generally serve as poor-yielding aquifers. However, significant circulation can be assumed to be restricted to the upper few hundred feet because the fractures tend to close with depth. In other areas, where these rocks are buried by younger rocks, they can generally be assumed to represent the base of active circulation unless there is evidence to the contrary. In these situations the Type 2 boundary is equivalent to the bottom of the ground-water regime (see Glossary).

A general knowledge of the tectonic setting and structural geologic history of the region will provide insight into the types and frequency of geologic structures to be found in the Classification Review Area. Numerous field studies have shown that significant ground-water flow in consolidated sedimentary and crystalline rocks is controlled by geologic structures. These features include folds, faults and associated joints and fractures in the rock.

Major structures such as fault zones that intersect consolidated rock formations may hydraulically connect multiple aquifers into a system of aquifers. Fault zones in consolidated rocks are known to collect water from large areas and control the locations of ground-water discharge at

major springs. In softer sediments and in some structural settings, fault zones can have the opposite effect by producing barriers to flow. Individual joints and small fractures in consolidated rocks and sediment can be mapped systematically with field studies, however, proof of their absence is the more important element in demonstrating the presence of a Type 2 boundary.

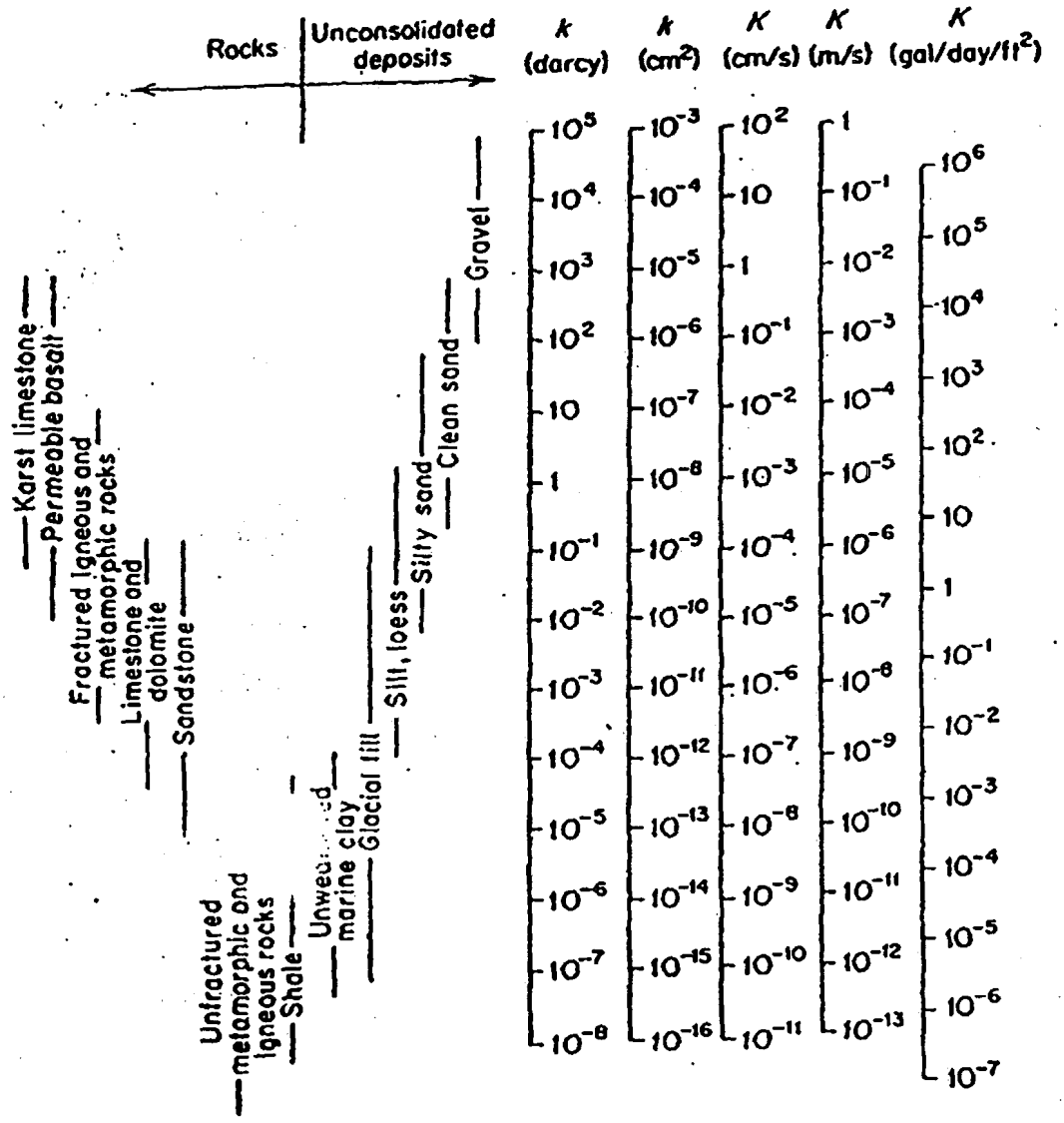
The best evidence of low-permeability non-aquifer conditions constituting a Type 2 boundary are those related to the hydrogeologic setting and measured hydraulic parameters. Table 4-2 shows that the hydraulic conductivity of both sedimentary deposits and igneous/metamorphic rocks can be estimated within several orders-of-magnitude on the basis of lithology alone. In parts of the United States associated with large ground-water usage, there has been a need to understand the ground-water regime and these areas will often have been studied by various government agencies. Consequently, the hydraulic properties of aquifers and aquitards will be known in quantitative terms. In these areas the thickness, lateral extent, and hydraulic conductivity will be documented. A favorable condition would then be associated with a recognized aquitard or aquiclude that is known to be relatively thick, homogeneous, widespread, and poorly permeable. The optimum head condition would be such that vertical hydraulic gradients are directed upward through the unit, i.e., across the Type 2 boundary.

4.3.4 Type 3 Boundaries: Fresh/Saline Water Contacts

Type 3 boundaries between bodies of ground water with contrasting concentrations of Total Dissolved Solids (TDS) most commonly occur within the following types of hydrogeologic settings:

- Sea-water intrusion into fresh-water aquifers in coastal regions,
- Saline waters associated with ancient evaporite deposits in sedimentary basins,
- Saline waters associated with closed topographic basins in arid regions.
- Saline brines in deep geologic basins,
- Geothermal fluids in tectonically active regions,

TABLE 4-2
RANGE OF VALUES OF HYDRAULIC CONDUCTIVITY AND PERMEABILITY
(AFTER FREEZE AND CHERRY, 1979)



In the above settings, the TDS of naturally occurring saline water may be 3 to 10 times greater than the 10,000 mg/l criterion. Owing to natural concentration gradients, a zone of diffusion is normally observable between the saline and fresh ground waters. The 10,000 mg/l TDS isometric surface will generally be situated within the diffusion zone separating the waters of contrasting salinities.

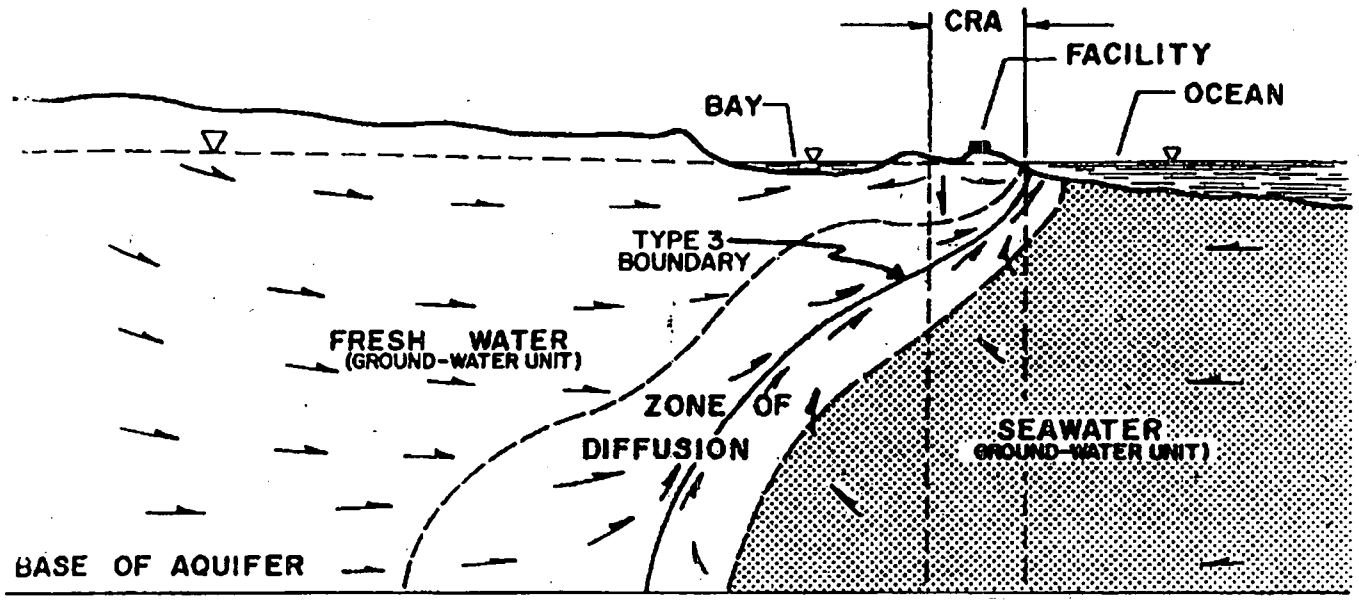
Figure 4-7 illustrates how a wedge of sea water which has intruded into an unconfined aquifer is identified as a separate ground-water unit of higher salinity and density relative to an adjacent ground-water unit, in the same aquifer, containing fresh water. In this setting, there exists a zone of diffusion between two flow systems that contain fresh water and sea water. The salinity boundary would occur along the 10,000 mg/l TDS isometric surface.

Figure 4-8 illustrates a second hydrogeologic setting characterized by the presence of near-surface evaporite deposits overlying deeper bedrock units. Salts are dissolved from the evaporite units by the circulating ground waters and a shallow zone of saline waters coexists with fresh ground waters within the same flow system. However, based on the delineation of a Type 3 boundary, two distinct ground-water units can be identified.

Although the saline water is primarily confined to the low-permeability evaporite formation, this water leaks into the underlying aquifer creating a zone of diffusion within the underlying aquifer. The boundary between the two adjacent ground-water units would be drawn along the 10,000 mg/l TDS isometric surface within the diffusion zone. The diffusion zone would be a stable feature assuming the flow system is in both hydraulic and geochemical steady state. The degree of interconnection between these adjacent ground-water units is defined to be intermediate. The type of setting illustrated in Figure 4-8 is not as common as the coastal intrusion setting illustrated in Figure 4-7, but it is known to exist in selected parts of the United States.

In the above two settings, the intermediate degree of interconnection between ground-water units is due to the limited potential for the exchange of waters across a Type 3 boundary within a diffusion zone. In the first setting, the salt water and fresh water are in separate, but adjacent flow systems. In the second case, the diffusion zone is more extensive and may or may not be within a single flow system. A third case involves a single regional flow system with the diffusion zone in the deeper and more downgradient end of the system.

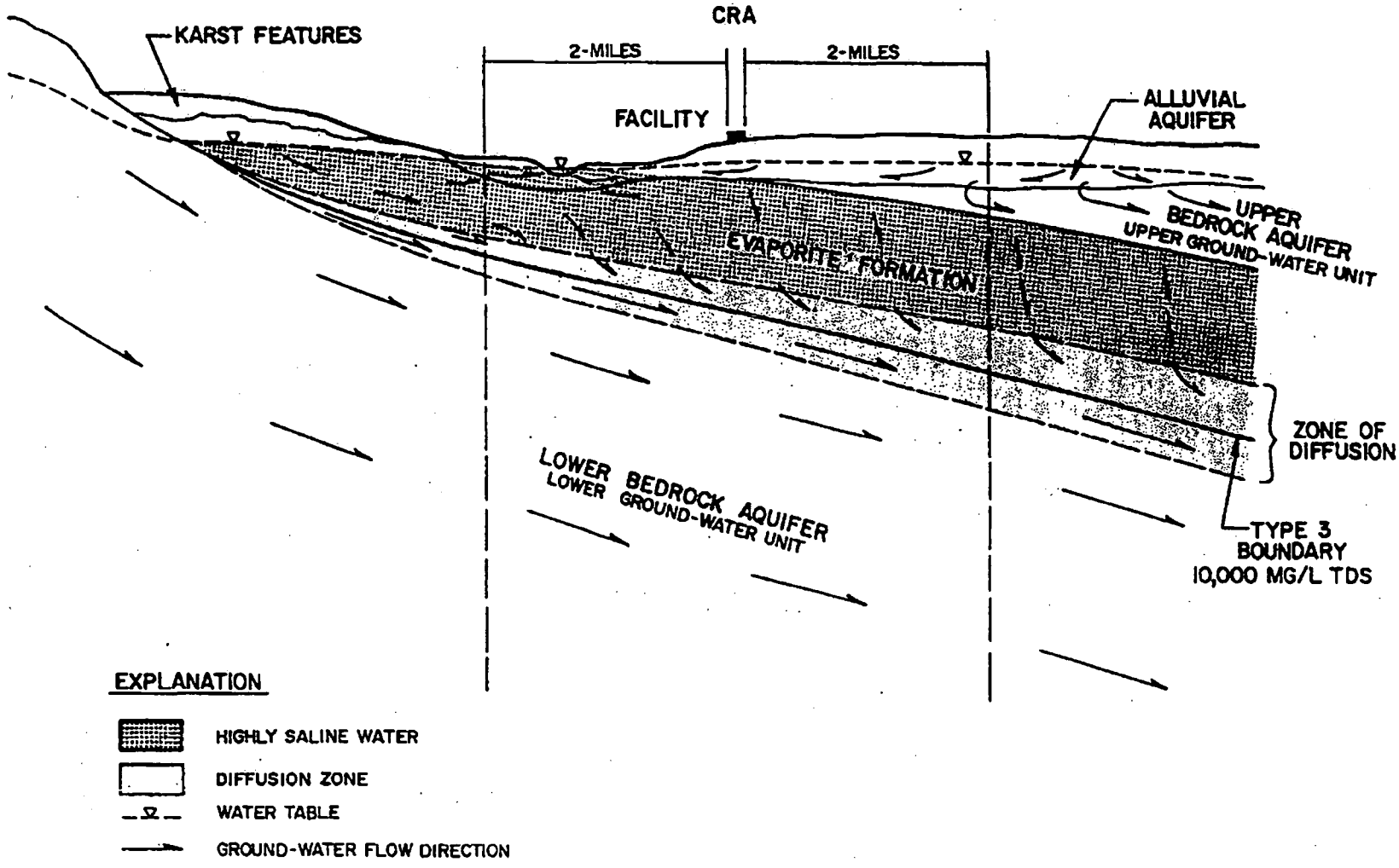
FIGURE 4-7
EXAMPLE OF TYPE 3 BOUNDARY THROUGH AN
UNCONFINED AQUIFER IN A COASTAL SETTING



EXPLANATION

- >30,000 mg/l TDS WATER
- DIFFUSION ZONE
- GROUND-WATER FLOW DIRECTION
- WATER TABLE
- CLASSIFICATION REVIEW AREA
- 10,000 mg/l TDS ISOCONCENTRATION LINE

FIGURE 4-8
EXAMPLE OF TYPE 3 BOUNDARY IN AN EVAPORITE/SALINE WATER SETTING

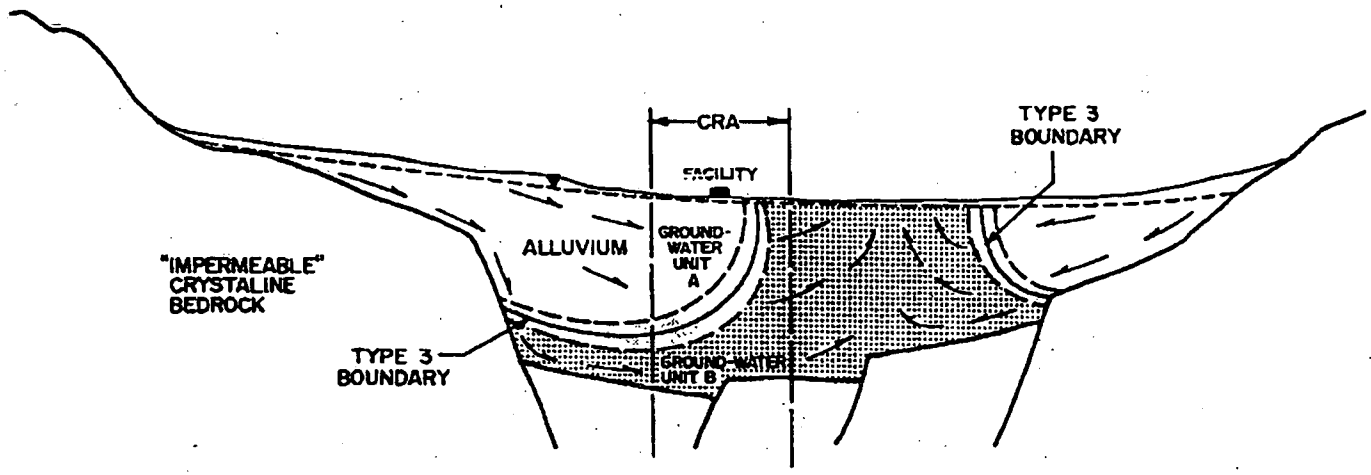


The third setting includes naturally saline ground water contained within topographically-closed structural basins within arid parts of the western United States (e.g., the Great Salt Lake Desert). Figure 4-9 shows an example of such a setting where the water is recharged from runoff from mountain ranges adjoining the basin, circulates to the center of the basin, moves vertically through confining beds, and discharges to playa lakes and the atmosphere. These settings are known to have brine waters greatly in excess of the 10,000 mg/l Class III criteria within the discharge area to depths as great as 2000 feet below land surface.

Distinct ground-water units can be delineated based on the identification of Type 3 boundaries as shown in Figure 4-9. Under natural conditions the diffusion zones encompassing these boundaries are stable and ground-water units A and B can be identified as shown. Large-scale withdrawals from upgradient fresh (Class II) ground water or injection into the saline (Class III) ground-water can laterally displace the diffusion zone. The pumped wells may eventually yield saline water and will cease to be sources of drinking water. Thus, the potential to cause adverse water-quality effects may result from improper resource management.

Type 3 boundaries are the least interpretive of the boundary types because they are simply equivalent to the 10,000 mg/l TDS isometric surface through the ground-water regime. These boundaries are then easily recognized and mapped when TDS data are available for ground waters from various depths and locations in the Classification Review Area. The elevations at which ground-water TDS is equal to or greater than 10,000 mg/l has been mapped and published for selected basins and regions. The principal sources for such data are the USGS and state geological surveys, especially in states having abundant oil and gas resources. In areas of known sea-water intrusion, or upconing of salt water due to pumpage, published data are occasionally available which will show in vertical section or plan view the extent of the salt-water wedge. This may be conservatively taken as the 10,000 mg/l TDS boundary where more specific TDS data are not available. In areas of known high temperature geothermal resources, published data are available to estimate the Type 3 boundary location. Because these areas, are few in number and are limited in areal extent, few will be co-located with potential Classification Review Areas. Equally limited are data bases for saline water settings associated with soluble evaporite deposits. At specific sites in these areas, the relationship between water quality, soluble strata, and ground-water flow directions can be established and the Type 3 boundary mapped. This relationship can be assumed in

FIGURE 4-9
EXAMPLE OF TYPE 3 BOUNDARY THROUGH BASIN FILL IN A CLOSED BASIN/ARID CLIMATIC SETTING



EXPLANATION

- HIGHLY SALINE WATER
- DIFFUSION ZONE
- WATER TABLE
- GROUND-WATER FLOW DIRECTION
- CRA — CLASSIFICATION REVIEW AREA

adjacent areas, where the stratigraphy and flow patterns are known, in order to extrapolate the Type 3 boundary to other parts of the Classification Review Area.

4.3.5 High Interconnection Scenarios

High interconnection of waters is assumed to occur within a given ground-water unit and where ground water discharges into adjacent surface-water bodies. The latter situation is specially relevant in identifying Subclass IIIA ground waters, for occasions where these are not potential sources of drinking water.

Subclass IIIA can be associated with shallow, unconfined, aquifers that underlie broad, urbanized, industrial areas where numerous diffuse sources of contamination have degraded water quality. Figure 4-10 shows hydrogeologic settings that may qualify for Class IIIA (Untreatable). The two examples shown include urban/industrial areas located near major surface waters and overlying alluvial sediments that are saturated at relatively shallow depths. As shown, the degraded water must be contained within a shallow ground-water unit that discharges to the local surface-water body.

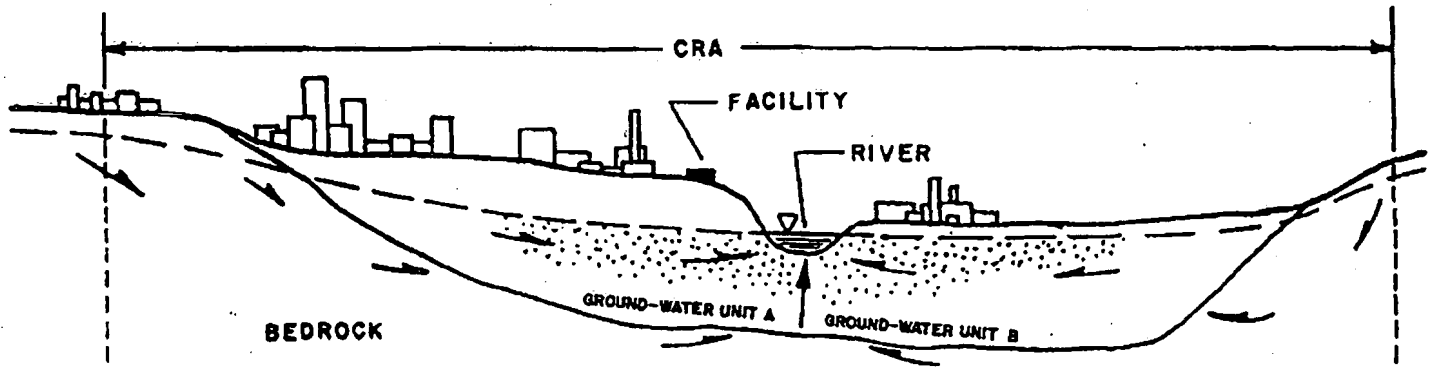
4.3.6 Example of Subdividing a Classification Review Area

Figures 4-11 through 4-13 illustrate how a hypothetical Classification Review Area is subdivided into ground-water units and the potential classification decision for each unit. It should be emphasized that for purposes of an actual classification decision, not all the subdivisions illustrated here would be necessary, as only the ground-water unit relevant to the facility would be classified.

The facility for which a classification decision is needed is located on the floodplain of a perennial stream that flows in a direction towards the viewer in Figure 4-11. The water table is relatively shallow beneath the floodplain and is essentially at the land surface in wetland areas adjoining the stream. The habitat for an endangered species is located in a wetland on the opposite side of the stream from the facility.

The geology of the Classification Review Area consists of essentially flatlying sedimentary formations overlying a crystalline basement composed of undifferentiated granitic and metamorphic rocks. Three local aquifers and two aquitards are recognized in the area. The uppermost aquifer is a water-table aquifer defined as the saturated part of a sand

FIGURE 4-10
EXAMPLES OF HIGH INTERCONNECTION BETWEEN GROUND-WATER UNIT AND SURFACE WATER

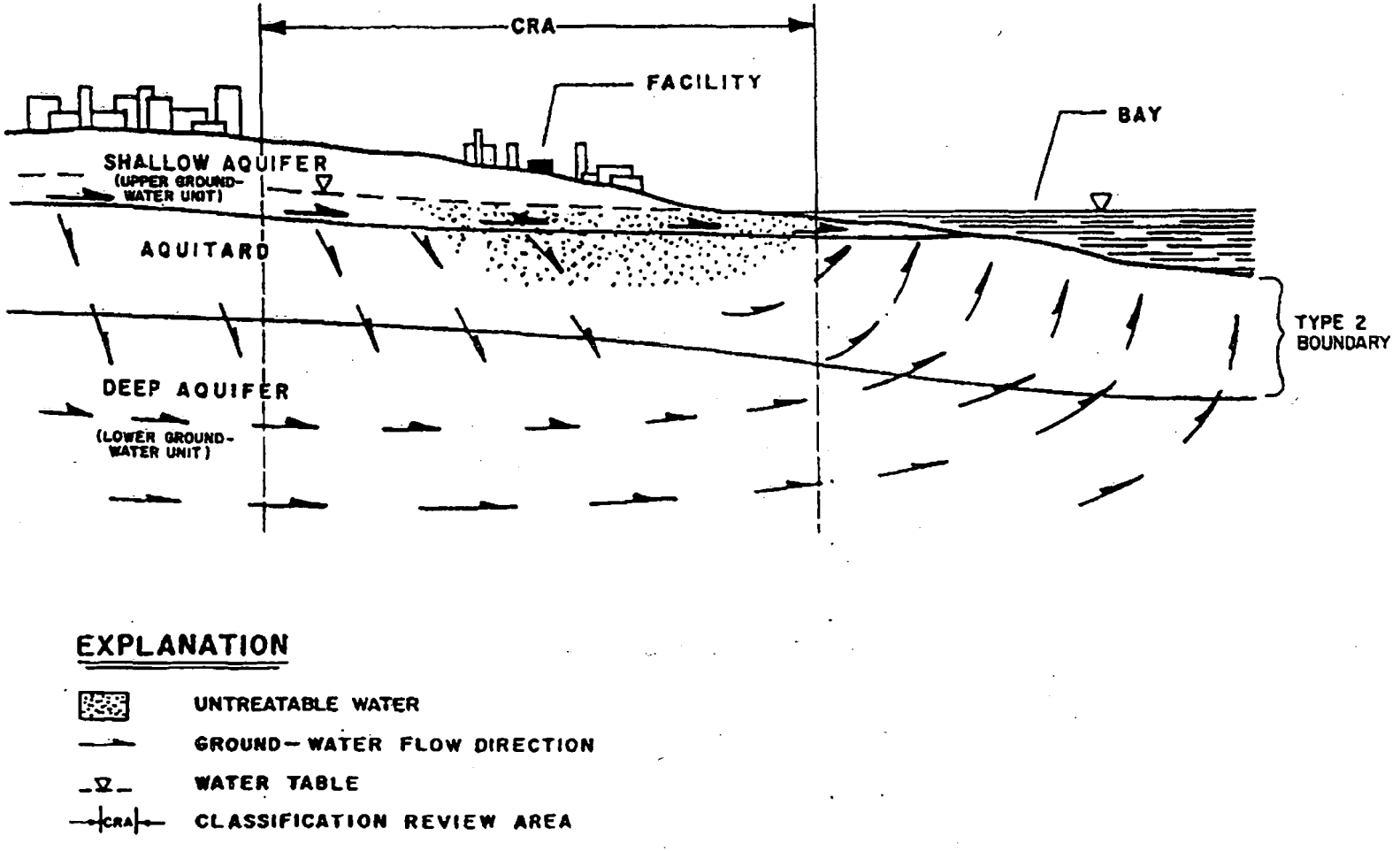


EXPLANATION

- UNTREATABLE WATER
- GROUND-WATER FLOW DIRECTION
- WATER TABLE
- CRA — CLASSIFICATION REVIEW AREA

a) Alluvial aquifer separated into two ground-water units with high interconnection to a river.

FIGURE 4-10 (CONTINUED)
EXAMPLES OF HIGH INTERCONNECTION BETWEEN GROUND-WATER UNIT AND SURFACE WATER



b) Shallow ground-water unit is highly interconnected to bay. The lower ground-water unit is separated from the bay by Type 2 boundary; and, therefore, has a low degree of interconnection even though it discharges to the bay through the aquitard.

and gravel deposit overlying a low-permeability shale formation. This aquifer is recharged by the infiltration of precipitation and discharges primarily to the stream and wetland areas. It is locally used for water supply by domestic wells in a nearby residential development.

Figure 4-11 shows a deeper middle aquifer that is sandwiched between two regionally extensive shales that serve as aquitard confining beds. Ground water is pumped from the middle aquifer at a municipal well which supplies water to a nearby city. The city also receives water pumped from deeper wells in the lower aquifer, however, these wells are located on the other side of the city off the left edge of Figure 4-11. Pumpage from these wells has caused sea water to intrude the lowest aquifer from the ocean located off the right edge of Figure 4-11. The lower aquifer is underlain by crystalline rocks which have low permeabilities and are not used as an aquifer in the area.

Figure 4-12 illustrates the cylinder-shaped volume of earth material that underlies the Classification Review Area. The ground-water regime is defined to include all ground water and earth materials between the water table in the uppermost aquifer and the contact between the lower aquifer and the basement rocks. Figure 4-13 shows how the regime can be subdivided into five ground-water units. For purposes of an actual classification decision, only the ground-water unit that could potentially be affected by the facility would be pertinent.

Ground-water units 1 and 2 are subdivided along a Type 1 ground-water flow divide boundary beneath the sinuous perennial river. This boundary is inferred from a mapping of the flow pattern within the uppermost aquifer. The aquitard beneath the aquifer exhibits no evidence of discontinuities within the Classification Review Area. It is present in all deep wells in the area and consistently shows large vertical gradients across it. Even so, the estimate of the rate of ground-water flow per unit area through the unit (based on these gradients and hydraulic conductivities) is no greater than 10^{-6} cm/sec which is negligibly small relative to ground-water flow rates in adjacent aquifers. Based on these characteristics, the aquitard constitutes a Type 2 low hydraulic conductivity, non-aquifer boundary. The vertical extent of ground-water units 1 and 2 is thus, delineated by the existence of this physical boundary.

Ground water within the middle aquifer is identified as a third ground-water unit with the overlying and underlying aquitards constituting Type 2 boundaries. In addition to the

FIGURE 4-11
HYPOTHETICAL SETTING FOR DEMONSTRATING THE SUBDIVISION OF A CLASSIFICATION REVIEW AREA

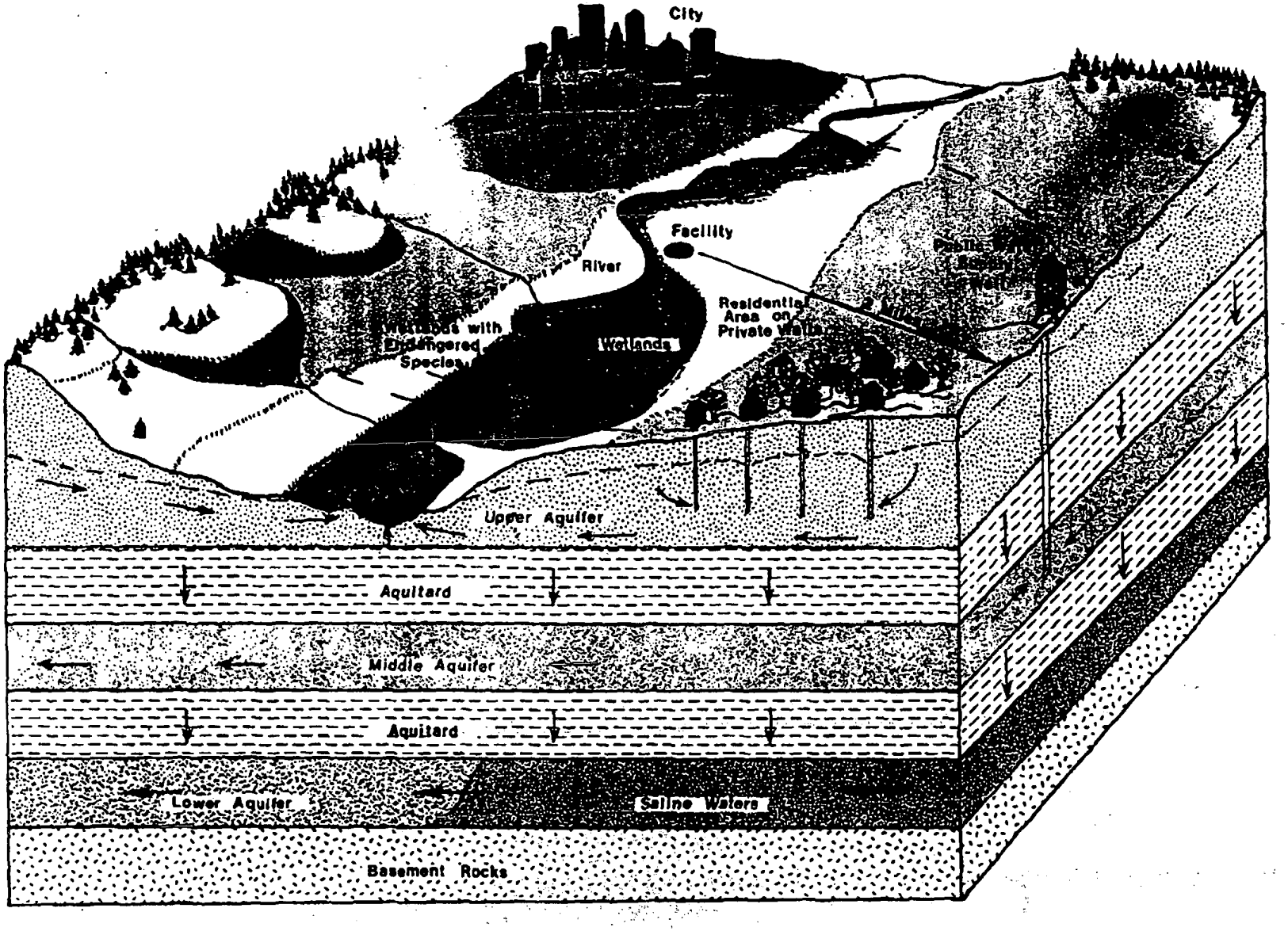


FIGURE 4-12
HYPOTHETICAL CLASSIFICATION REVIEW AREA

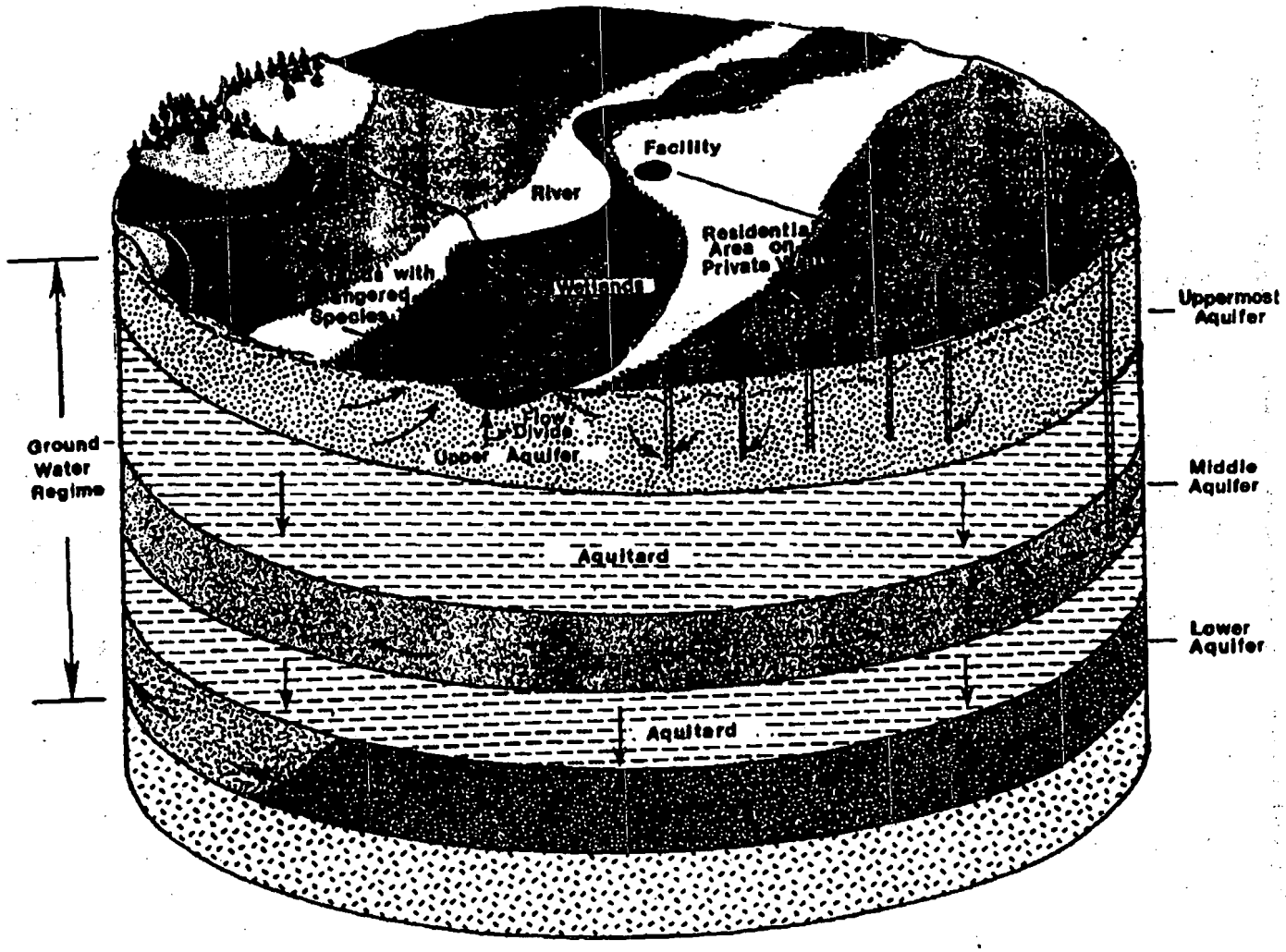
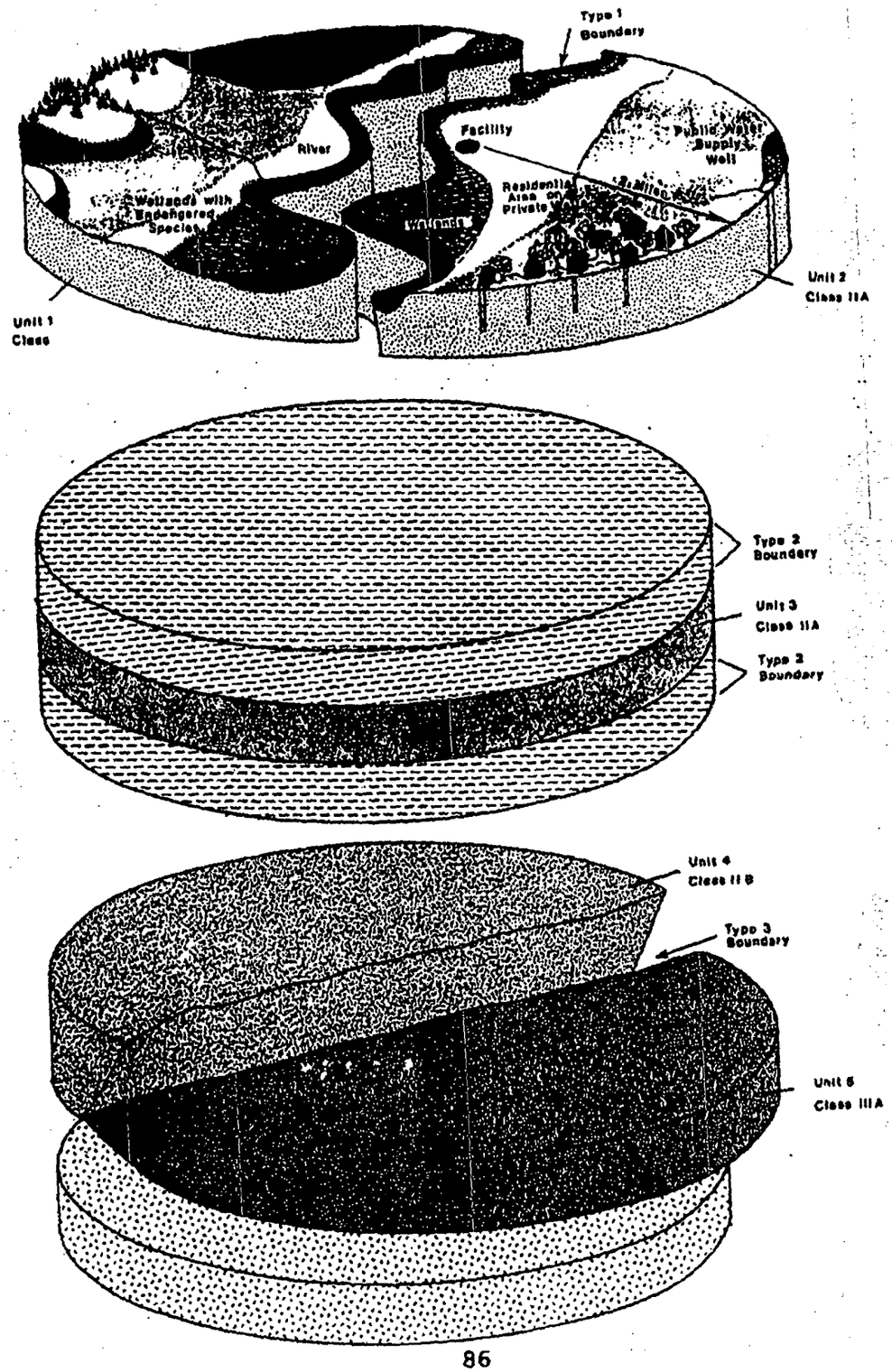


FIGURE 4-13
SUBDIVISION OF A HYPOTHETICAL CLASSIFICATION REVIEW AREA
INTO THE GROUND-WATER UNITS



characteristics described above for the uppermost aquitard, long-term aquifer tests have been performed on the municipal wells completed in the middle and lower aquifer. These tests indicate that less than ten percent of water pumped from the aquifers is derived from the leaking aquitards, thus their designation as Type 2 boundaries is justified.

Ground water within the lower aquifer is generally moving towards a major pumping center located outside of the Classification Review Area. A significant part of the water in this aquifer has been replaced by sea water having TDS concentrations in excess of 30,000 mg/l. The problem has been studied by the U.S. Geological Survey in cooperation with the city. The movement of the interface between fresh and saline water is being monitored with a few deep wells. The approximate location of the interface at the time of subdivision was approximately known and, lacking specific TDS data, is taken as the 10,000 mg/l TDS Type 3 boundary separating ground-water units 4 and 5 on Figure 4-13. Because the actual 10,000 mg/l TDS boundary is probably several hundred feet further towards the well field, use of the interface as this boundary makes ground-water unit 4 larger and unit 5 smaller than it actually may be. These errors are conservative in the sense of providing levels of protection to these waters as determined by class designation.

Based on the above general discussion of classification related criteria the ground-water units may be classified, as shown on Figure 4-13, as follows:

- Unit 1 may be Class I Ecologically Vital Ground Water due to the endangered species habitat within the discharge area, wetland environment and potentially vulnerable condition,

- Unit 2 may be Class IIA, current source of drinking water due to the residential wells screened in this unit,

- Unit 3 may be Class IIA current source of drinking water owing to its use for water supply but is poorly interconnected to the Class IIA water in the uppermost aquifer,

- Unit 4 may be Class IIB potential source of drinking water even though it maybe used for water supply outside the Classification Review Area

- Unit 5 may be Class IIIA, not a potential source of drinking water because it has a TDS above 10,000 mg/l and has a intermediate degree of interconnection with adjacent Unit 4, a potential source of drinking water.

4.4 Determining Irreplaceability

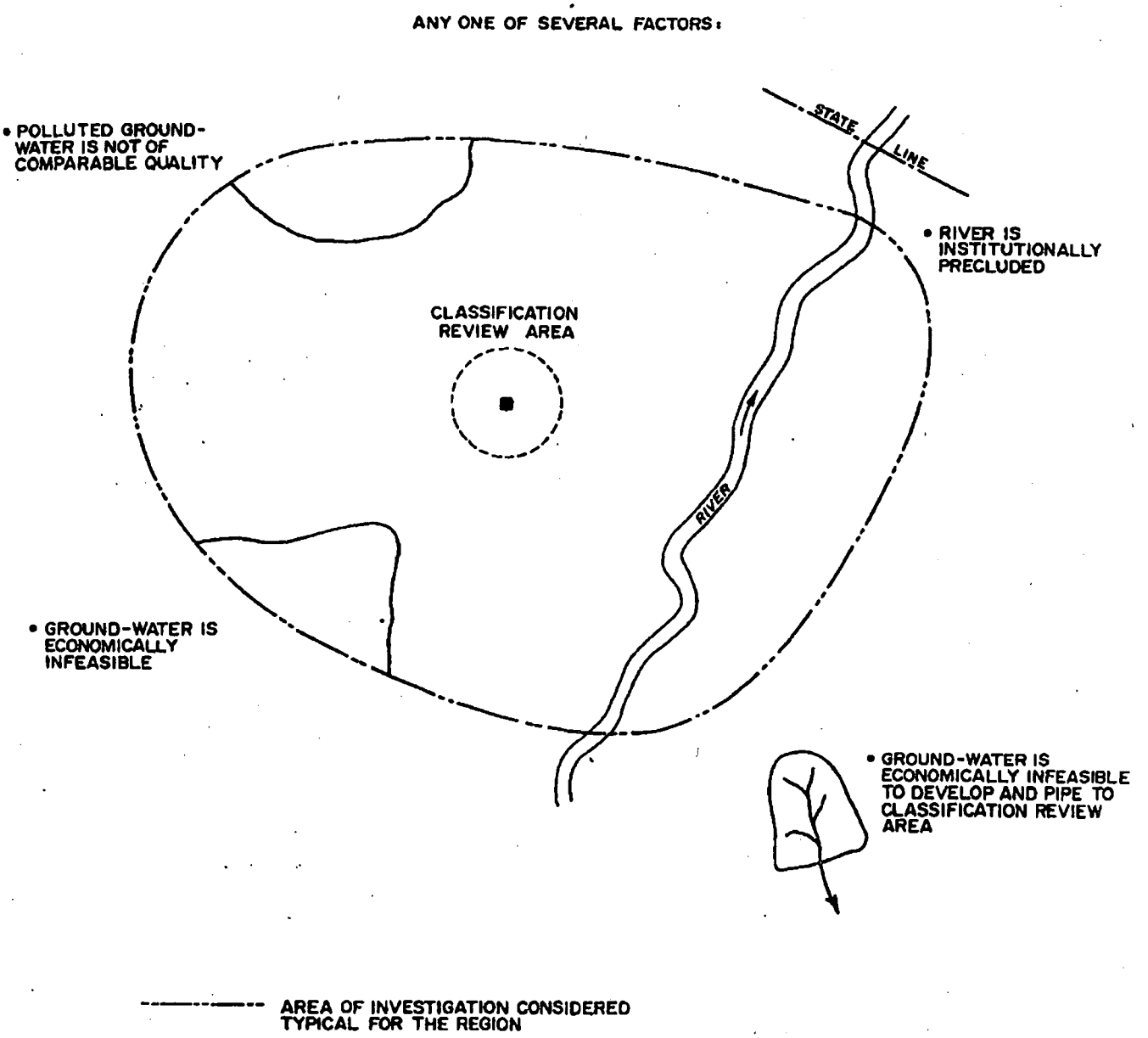
Figure 4-14 displays the general concept of irreplaceability for Class I ground water. The goal is to identify those waters of such relatively high value that unusually high protection is warranted. For the purposes of classification, this is not meant to be an extremely rigorous, costly exercise. In many instances, estimates will suffice. For example, a census of residents should not be performed to determine whether a substantial population is affected -- if available information suggests that current water users approximate the required thresholds, the criterion should be considered satisfied. Similarly, irreplaceability will be assumed unless an analysis is deemed desireable; typically when a permit applicant feels that a Class II situation is truly the case. If an analysis is performed, it should not be necessary to evaluate every possible replacement source; rather, rough estimates developed for no more than a small number of representative replacement water sources should be adequate to indicate the presence or absence of a irreplaceable source. These "shortcuts" are necessary since detailed water-supply alternative studies are inordinately expensive and are reserved for such major projects as large multiple-purpose dams and reservoirs.

A ground water serving a substantial population is considered irreplaceable, if alternatives are not suitable due to any one or more of the following five criteria:

- Use of the alternative source would require piping water over an unreasonable or uncommon distance
- The alternative source is incapable of providing water of quality that is comparable to typical quality of ground water used for drinking in the Region
- The alternative source is incapable of yielding water in sufficient quantity to serve the substantial population
- Access to the alternative source is precluded due to institutional constraints
- Use of the alternative source is economically infeasible.

Again, the general procedure is to first determine if the ground water within the Classification Review Area or the appropriate subdivision serves a substantial population. If

FIGURE 4-14
CRITERIA FOR CLASS I - IRREPLACEABLE



so, then the source is considered irreplaceable until demonstrated otherwise using the above five criteria.

The following sections discuss definitions for the more specific procedures, and key factors related to irreplaceability:

- Substantial population
- Uncommon pipeline distance
- Comparable quality
- Comparable quantity
- Institutional constraints
- Economic infeasibility.

Each of the following sections describes particular methods based on data available from Federal and State agencies and other easily accessible sources. Each section identifies and characterizes relevant data sources. Where appropriate, example calculations are used to illustrate data application and appropriate quantitative methods for determining irreplaceability.

In these Draft Guidelines, the Agency is also soliciting comment on approaches to judging two aspects of the "irreplaceable" criterion. Option A incorporates a quantitative determination of the population served by the source and the economic feasibility of replacing the source. Under this approach, a drinking water source would be considered "irreplaceable" if it serves at least 2500 people and the annual cost of typical user of replacing the source exceeds 0.7 to 1.0 percent of the mean household income in the area. Option B focuses on a qualitative assessment of the replaceability of the ground water. Under this approach, the relative size of the population served by the source and the cost of replacing the source would be factors to consider in assessing the source's "replaceability." The Guidelines would not under Option B, provide a set methodology, nor one or more numerical cut-offs. Again, the determination would focus on best professional judgment. A user following Option B may choose, however, to consider some of the quantitative methods or approaches in Option A, if deemed relevant in a particular classification decision. Comments on these two options, as well as other options for assessing "substantial population" and "irreplaceable" (from an economic standpoint) will be considered by the Agency in determining how best to incorporate these factors in classification decisions.

4.4.1 Substantial Population (Option A)

Under Optional A, ground water is deemed to serve a substantial population if at least twenty-five hundred persons are served by (Figure 4-15):

- centralized public water supply well(s) within the Classification Review Area or appropriate subdivision whether the population lies inside or outside Classification Review Area or

- private wells within the Classification Review Area or appropriate subdivision for persons living in a densely settled area (i.e., census definition based on 1,000 persons-per-square mile) or

- a combination of the above.

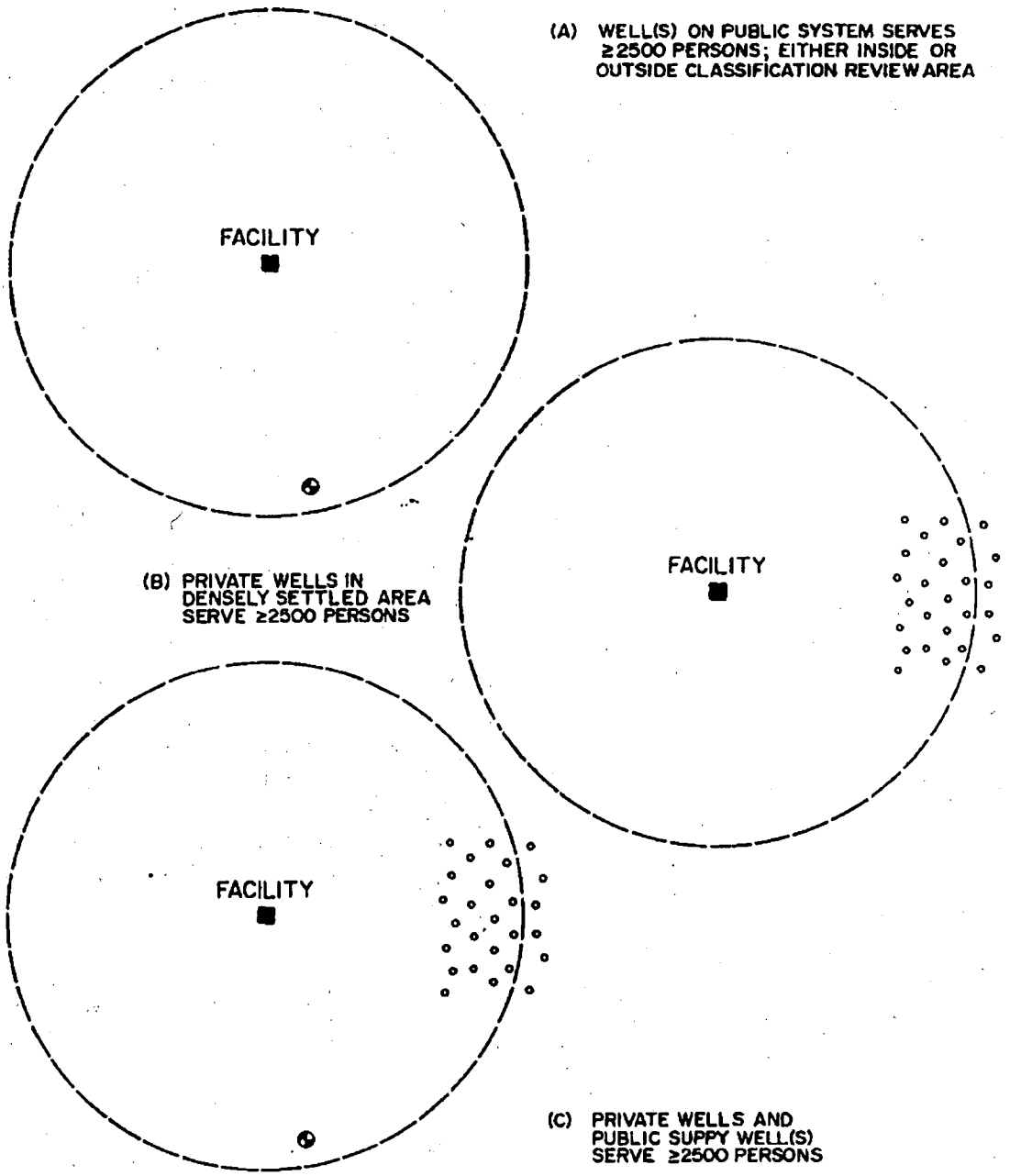
This definition of substantial population is based on numerical thresholds and concepts already used by the Census Bureau. The population data necessary to make these determinations is widely accessible and sufficiently up-to-date.

In most instances, making these determinations will be straightforward. If the well(s) in the Classification Review Area or appropriate subdivision service a public water system, an estimate of the number of user households multiplied by the average number of persons-per-household (2.7 on a national basis, each state or locality may be somewhat different) should approximate the total population served; if the population is served by other water sources, these should be accounted for proportionately. (Water supplied for industrial and agricultural purposes should not be included.) For private well users, it will be necessary both to estimate the population in the Classification Review Area not served by public water systems and, also, to calculate the population density. The EPA maintains a data system called GEMS (for Graphical Exposure Modeling System) which can be used to estimate both population and population densities for a variety of areas around a point (see Appendix E for details).

4.4.2 Substantial Population (Option B)

Option B differs from Option A in that no specific numerical cut-offs are dictated for determining "substantial population" or the "economic feasibility" of replacement. Rather, the relative size of the population served by the source would simply be factors to consider in assessing the source's "replaceability." A determination that a source is "irreplaceable" would require a qualitative assessment of the

FIGURE 4-15
EXAMPLE CLASS I - SUBSTANTIAL POPULATION



technical and economic feasibility of replacing it taking into account all of the factors that may be relevant in any specific case. Some of the same steps in data gathering and analysis included in Option A might be utilized, or alternatively, other procedures could be substituted. The overall approach to determining replaceability would, however, be more qualitative in character, and be more dependant on professional judgment.

4.4.3 Uncommon Pipeline Distance

Designating an uncommon pipeline distance for the Region is an important early step in determining irreplaceability. This uncommon distance will set a hypothetical radial boundary around the site within which an alternative source of water can be located. It, therefore, restricts the number of alternative sources that should be considered in the classification decision. If no alternative institutionally available water source of comparable quantity and quality can be located within a reasonable distance, the ground water in the Classification Review Area should be considered to be Class I irreplaceable. In theory, this is the maximum distance water is currently piped from the raw water source to the distribution system for each population category.

The determination of uncommon pipeline distance depends on many factors, including topography, geology, hydrology, availability of developed water resources (e.g., lakes, reservoirs, etc.), institutional constraints on water development, water demand, and economic resources. As a result, distances can vary significantly. In the semi-arid regions of the West, water may be conveyed 50 miles or more from the source to the distribution system. In the more humid East, however, water is typically piped five miles or less. Piping distances can also range considerably even among neighboring states.

Although it is reasonable to define an uncommon pipeline distance for different population categories, it is in practice, extremely difficult to set rigid criteria. In the absence of an exhaustive survey, guidance on these distances is available in Table 4-3, based on information provided by EPA's research laboratories and the Federal Reporting Data System (FRDS) maintained by EPA's Office of Drinking Water. The distances proposed in Table 4-3 are based on the application of a one percent income threshold that is applied as an economic criterion for other Class I tests. These distances can be calculated for other threshold levels. Working from data provided by EPA's Cincinnati water-quality laboratories, which estimate the costs of piping various quantities of

TABLE 4-3
UNCOMMON PIPELINE DISTANCES FOR DIFFERENT POPULATIONS
(Based on an 1% Economic Threshold)

Population Size	Uncommon Pipeline Distance
<5,000	25 miles
5,000-10,000	35 miles
10,000-25,000	70 miles
25,000-100,000	100 miles
>100,000	150 miles or more

These distances could be computed for different levels of income thresholds (e.g., 0.2%, 0.5%).

water (the size of pipes varied with the amount of water being delivered to a certain size of population), EPA proposes indexing these costs to the amount of dollars expressed by the income threshold for a certain size of population. For example, a population of 2500 persons would exceed their 1% income threshold when the costs of piping water exceed $2.4 million. This dollar amount roughly translates into an average piping distance of 13 miles when estimating the costs of installing and pumping along the pipes of the diameter needed to deliver a sufficient amount of water to 2500 persons. The result of this approximation should be used as general guidance for the lower bound of uncommon pipeline distance.

4.4.4 Comparable Quality Analysis

Once a potential alternative water source has been located, it is important to determine whether the quality is comparable to that of other drinking water in the EPA Region. The term "comparable quality" is defined as a level of water quality that is not substantially poorer than other raw drinking water resources in the EPA Region.

4.4.4.1 Water Quality Parameters

To be considered of comparable quality, the quality of the alternative water resource should be -- within an order-of-magnitude -- as good as or better than, existing drinking water resources, taking into account the precision of the measurement of each parameter. For example, an existing water source may have an average of 93 mg/l TDS, with a range of 75 mg/l to 100 mg/l. An alternative water source may be considered not of comparable quality, if it has an average TDS of 1,300 mg/l with a range of 1,000 mg/l to 1,600 mg/l. For some parameters of interest (e.g., taste, color, odor), the evaluation may be highly subjective. It is again meant to be a relative test which considers a few general categories of parameters (e.g., TDS, organic compounds, heavy metals, radionuclides and other secondary physical/chemical properties).

Existing information on water quality should be used, given the very high cost of new series of sampling and analysis. The comparison is intended to be relative and subject to professional judgment.

4.4.4.2 Sources of Information

At the Federal level, three important sources for water quality information may be consulted: EPA, the Army

Corps of Engineers, and the United States Geological Survey (USGS). Each of these agencies has conducted, or continues to conduct, comprehensive surveys that describe water resources in the U.S. Although not always designed specifically to provide detailed water quality data, these studies provide information sufficient to facilitate the comparable quality considerations of the ground-water classification system.

EPA has funded comprehensive studies of Regional water quality to determine the principal point and non-point sources of pollution. These studies, conducted under section 208 of the Clean Water Act, for example, give a broad overview of water quality (U.S. EPA, 1980b).* They are generally obtainable through the State and local agencies which received the funding. The Army Corps of Engineers conducts similar regional water-resource studies in order to examine water supply and demand within specified river and lake basins in the United States. The most useful resource of data from USGS will often be the published basin-wide investigations of ground- and surface-water resources. USGS also maintains the National Water Data Exchange (NAWDEX) which is designed to assist users in identification, location, and acquisition of information on water resources. The National Water Well Association (NWWA), Worthington, Ohio, maintains a library of all USGS and State Geological Survey information on water supply and quality. Using automated searching capabilities, the NWWA can identify and list all publications concerning a specific geographic area.

On a more local level, regional planning boards and councils of government, may also have information on potential drinking water supplies and river, lake, and stream, quality in their regions. State agencies that administer environmental protection, land use planning, agricultural, geological survey, public health, and water programs, are excellent information sources. State universities (particularly land-grant universities) may sometimes serve as repositories of information concerning ground- and surface-water supplies.

4.4.5 Comparable Quantity Analysis

Within a reasonable distance range, as determined by the "uncommon pipeline" distance analysis, a number of alternative sources of water may be identified. These sources may include both surface or ground water. Common examples of surface water that can be considered as a replacement source re rivers, streams, natural lakes, and impoundments. Alternative ground-water sources may be located in the same

aquifer, or in another nearby aquifer, horizontally or vertically separated from the source aquifer.

Determining whether the alternative source, or sources, can yield adequate quantity requires three analytical steps:

- determine current users' present water-supply needs
- characterize potential sustainable water yield of alternative source
- compare potential supply and current demand.

Each of these steps is discussed briefly below.

Step 1: Determine current supply needs of water users

If the ground water to be classified supplies a public water system, current supply needs will be known by the water utility. If the ground water to be classified serves a substantial population using private wells, current water needs must be estimated using population figures and assumptions concerning typical water use.

Step 2: Characterize potential sustainable water yield of alternative water supply

This information is best obtained from the previously mentioned, published studies. In addition, routine water shortages in communities currently served by an alternative source, for example, would indicate that the alternative source may not (conceptually) be able to provide water for an additional population increment. Rapidly falling groundwater levels over time also indicate that an alternative source may not be capable of consistently providing sufficient yield year-round. However, levels which are not falling may also indicate a source which is unavailable for additional usage, but one which is being properly managed. In cases where the ability of an alternative source to meet the needs of the substantial population is unclear, a more quantitative analysis may be necessary.

Step 3: Compare alternative water supply and existing water demand

In cases where the alternative source is located in a water-rich area, the comparison of user needs and source yield may be done on an annual basis. The comparison should be conducted on a monthly basis where the alternative source is ground water under existing or potential stress or where

the alternative source is a surface water with considerable month-to-month variability in flow. Important sources for water-quantity information include local water utilities, State water agencies, and the U.S. Geological Survey.

4.4.6 Institutional Constraints

Institutional constraints involve legal, administrative, and other similar forms of control over access to water. For purposes of this Guidance, the Agency has adopted the following definition of institutional constraint:

> An institutional constraint is a situation in which, as a result of a legal or administrative restriction, delivery of replacement water may not be assured through simple administrative procedures or market transactions.

While a detailed examination of legal and institutional issues is rarely called for, a preliminary review should indicate whether an institutional constraint is present. The following discussion presents a breakdown of potential institutional constraints and a general procedure for determining whether a binding institutional constraint is present in a particular situation. Appendix E provides a more detailed description of constraints as well as information sources.

The Agency has analyzed the potential constraints and determined which are probably binding, which may be binding in some cases or possibly binding, and which are unlikely to be binding. For a straight-forward assessment, comparison of the constraints affecting a particular source of water, the list of constraints presented in Table 4-4, should suffice. In those cases where a detailed assessment is warranted, the procedure outlined in Figure 4-16 is suggested.

4.4.6.1 Example of Considerations for a More Detailed Assessment

A potential source of replacement water (e.g., the Rio Grande River) may be subject to an international treaty (e.g., the 1944 Treaty between the United States and Mexico on Utilization of the Waters of the Colorado and Tijuana Rivers and of the Rio Grande) limiting the amount of water that may be withdrawn by users in the United States, and to an Interstate Compact limiting the amount of water that may be used within a particular state. In addition, that portion of the river flow assigned to a particular state may already be fully taken up by other users. Finally, the

TABLE 4-4

POTENTIAL INSTITUTIONAL CONSTRAINTS

Probably Binding Constraints

- Water is subject to international treaty
- Water is subject to interstate water apportionment compact
- Water is allocated by the U.S. Supreme Court as a result of litigation among states
- Water is subject to Federal or Indian reserved right

Possibly Binding Constraints

- Water is allocated by litigation among persons
- Water is allocated by permit
- Water is allocated by local water district or another local authority

- Amount of water that may be used is limited:
  - by public trust doctrine
  - by instream flow protection requirements
  - by state law
  - by permit
  - by local management authority
  - by prior appropriation(s) that are all for highest beneficial use
  - by Federal navigational servitude
- Place of use of water is limited:
  - by st[illegible] law
  - by [illegible]
  - by [illegible] authority

Constraints Unlikely to be Binding*

- Water is subject to prior appropriation (unless for highest beneficial use)
- Water is subject to riparian right
- Physical access to property is restricted:
  - by property rights of other persons limiting rights-of-way for pipes, ditches, conduits, etc.
  - by Federal or State statutes requiring environmental impact assessment or establishing other procedural requirements.

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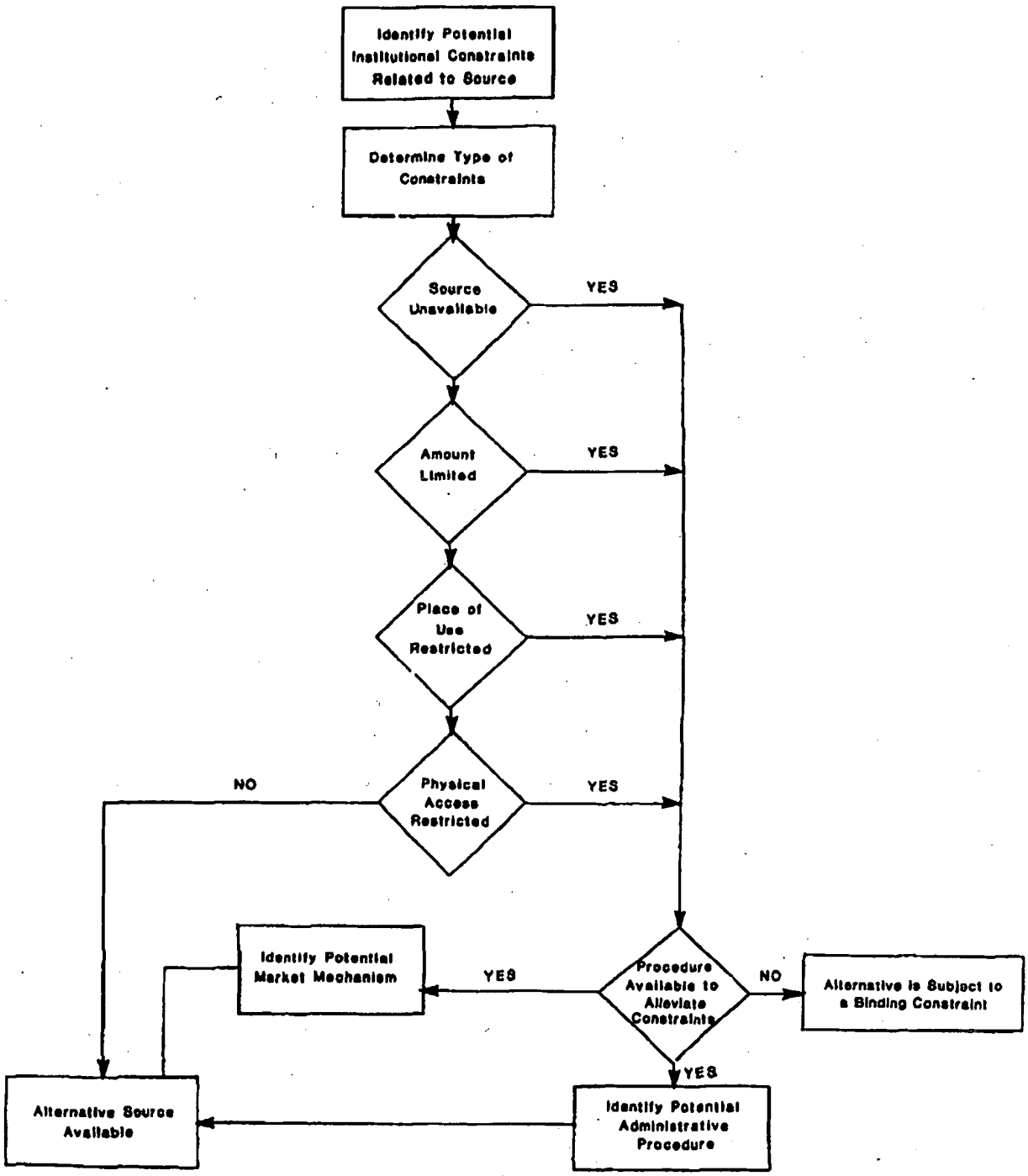
*Upon application of simple administrative procedures or market transactions.

FIGURE 4-16
OUTLINE OF PROCEDURE FOR ANALYZING POTENTIAL INSTITUTIONAL CONSTRAINTS TO THE USE OF AN ALTERNATIVE SOURCE OF WATER



use for which the water is being considered as a potential alternative source may be situated some distance from the river and require a right-of-way in order to get access to the water.

In this situation, the treaty, the interstate compact, the water allocation system, and the property rights of other persons, are all potential institutional constraints. Each should be considered separately. The treaty and the interstate compact may be impossible to avoid or change through simple administrative procedures. A phone call to the State office in charge of water allocation would probably indicate that the water allocation could potentially be revised by a simple administrative procedure; or, that market transactions can be used to change the current allocation of water. Similarly, informal contact with a State Attorney General's office, should indicate that the problem of access potentially could be resolved through purchase of an easement or right-of-way; or, that the administrative process of eminent domain potentially could be used to provide access to the water. In such situations, a binding institutional constraint would probably not be present, despite the potential constraints that were identified.

4.4.7 Economic Infeasibility (Option A)

The Agency has defined economic infeasibility of an alternative water source principally in terms of community ability to pay. This does not in any way imply that the Agency expects that communities will be required to replace water supplies or pay for such replacements. Again, this is a relative test to determine the extent to which ground waters potentially affected by a facility/activity are truly "special". The definition states that access and use of an alternative water source is economically infeasible, if the annual cost to a typical user (i.e., a household) for that alternative exceeds 0.7 to 1.0 percent of the mean household income in the community. Determining whether an alternative water source is economically infeasible requires that a rough estimate of the costs of the alternative water system be generated. These costs are then compared to household income to determine the relative "burden" of the alternative supply.

Following is a list of the major replacement cost items, categorized according to the type of cost incurred: capital costs, operation and maintenance (O&M) costs, and others. Approximations of these costs will suffice for the purposes of classification:

- Capital costs:
  - Well field development
  - Raw water intake structure (wells)
  - Water treatment facility
  - Pumping stations
  - Storage
  - Transmission system
  - Rights-of-way
  - Land
  - Relocation of utilities

- O&M costs:
  - Labor, equipment
  - Utilities
  - Parts/inventory
  - Administration

- Other costs:
  - Architectural and engineering fees
  - Legal and administrative fees

There are ample sources of information that may be used for estimating costs. These include Federal and State agencies, architectural and engineering consulting firms (A/E firms), trade associations, and local water utilities (ACT Systems, Inc., 1977, 1979; Temple, Barker and Sloane, Inc., 1982; AWWA, 1981). Costs can vary somewhat from one region of the country to another. For purposes of classification, only a general estimate is needed and, initially, there is no need to undertake a detailed cost estimation study.

Various EPA reports on water supply and waste-water treatment are also a good source of information on costs (e.g., Culp, et al, 1978). The results of such studies are presented in the form of tables and cost curves, subdivided into construction costs and O&M costs. This data can be updated simply to allow for inflation and geographical variations by energy and labor costs.

Another useful data source is the NWWA Nationwide Water Well Drilling Cost Survey (NWWA, 1979). The results of this survey are summarized in the form of tables giving drilling, as well as casing costs, as a function of the well diameter, hydrogeologic conditions, and other factors. Although this survey dates back to 1979, it is the most recent available from NWWA. The data in the survey should be escalated to account for inflation. Cost indices published quarterly by Engineering News Record give a very recent indication of construction, operation, labor, and other costs.

The remaining portion of Section 4.4 provides useful supplementary information for most classification decisions. More advanced procedures for use in special cases, are provided in Appendices E and G.

4.4.7.1 Annualizing Capital Costs

Capital costs are the initial costs of investments needed to develop a new drinking water source. They may include architectural and engineering fees, as well as legal, real estate or other fees incurred as part of planning, constructing, and implementating a new water system for this analysis.

For purposes of determining economic feasibility, capital costs must be annualized before they can be added to O&M costs to obtain the total annual costs of the alternative. Capital costs are annualized by multiplying by an annualization factor:

Capital Costs x Annualization Factor (AF) =
Annualized Capital Costs

The annualization factor divides the total capital costs into equal annual payments that would be required if the capital expenditures were financed using a standard fixed-rate mortgage. As a first cut, a factor of 0.1 can be used. A more refined factor should not be necessary but can be computed according to Appendix E.

4.4.7.2 Using Water Supply Utility Rates and Fees to Estimate Costs of Alternative Water Supply

In some circumstances, the cheapest alternative water supply available to a community will be a nearby water-supply utility. The alternative water-supply system may be modeled after an existing system that serves a community in the same region that is similar in both population size and characteristics. In such cases, the cost of the alternative supply may be estimated using the rates and fees charged by the existing utility to its service population.

4.4.7.3 Household Income of Substantial Population

The final step in determining economic infeasibility involves comparing the annual costs of the alternative water system to average household incomes in the

community. Income data is generally available in two forms: per household income and per capita income. The two may be used interchangeably, by factoring in the average number of persons per household. In addition, income is sometimes reported as "personal income" or "money income." Household money income should be the income figure used for this exercise and is available from a number of sources.

4.4.8 Economic Infeasibility (Option B)

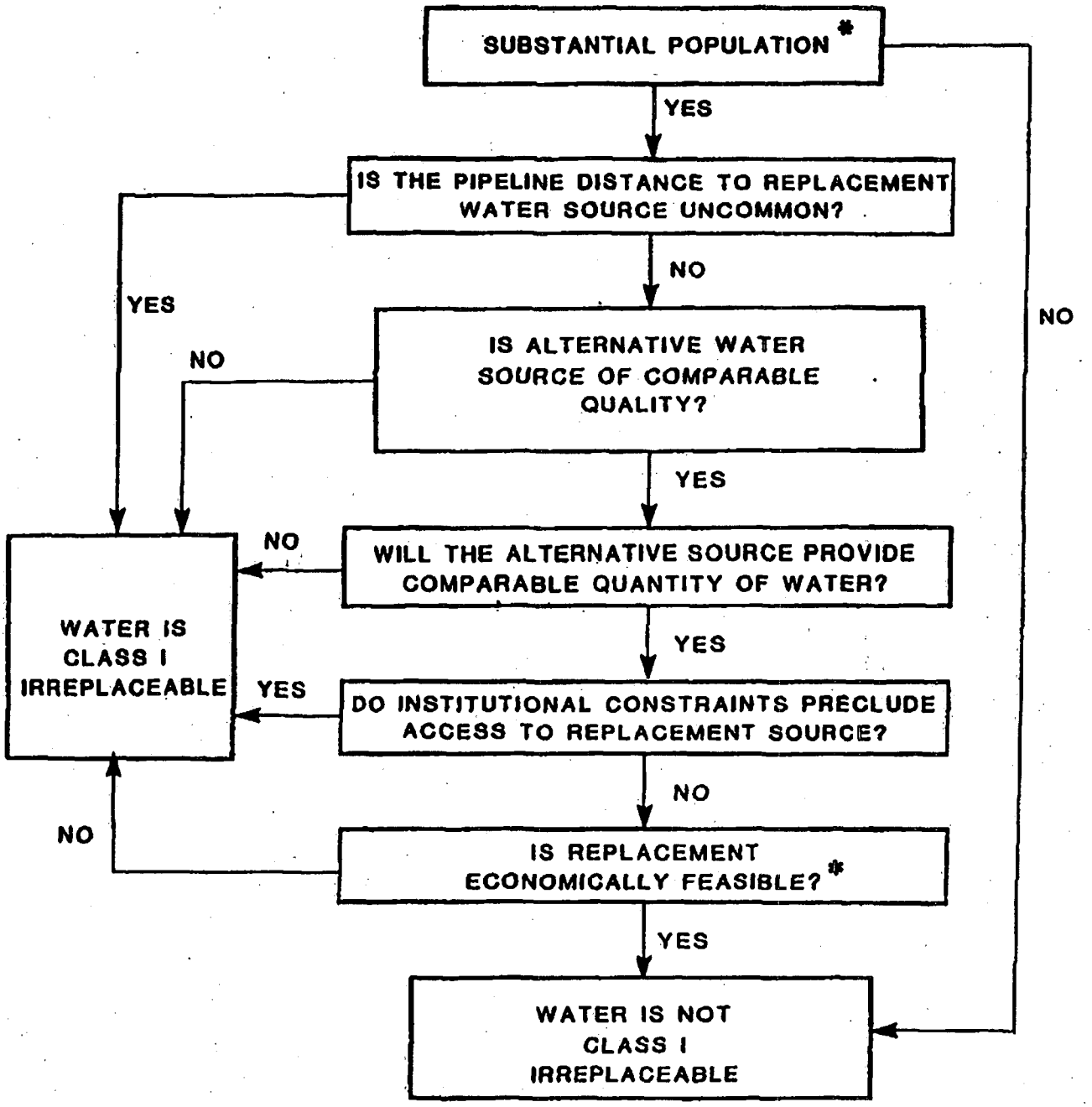
Option B differs from Option A in that no specific numerical cut-offs are dictated for determining "substantial population" or the "economic feasibility" of replacement. Rather, the relative size of the population served by the source would simply be factors to consider in assessing the source's "replaceability." A determination that a source is "irreplaceable" would require a qualitative assessment of the technical and economic feasibility of replacing it taking into account all of the factors that may be relevant in any specific case. Some of the same steps in data gathering and analysis included in Option A might be utilized, or alternatively, other procedures could be substituted. The overall approach to determining replaceability would, however, be more qualitative in character, and be more dependant on professional judgment.

4.4.9 Summary

The criteria for Class I irreplaceability may be best summarized through a hypothetical example. Consider the city of Waterfed, an urban area with a population of 25,000, that receives its water from a public well system. The water meets primary drinking water standards and is of good chemical [illegible]y. The average daily usage is 7 million gallons-p[illegible].

There is an alternative to Waterfed's central well field. For the sake of simplicity, assume that this source is either representative of other sources, or is the only alternative drinking water source within a reasonable distance of the city. If the alternative is to serve as a replacement, it must satisfy the set of criteria which is depicted in Figure 4-17. The first criteria is that the alternative water source must be of comparable quality to water in the surrounding area. If the alternative source were substantially inferior to Waterfed's water and conventional treatment could not improve the quality to a comparable level, the city's ground water would be considered Class I irreplaceable. In this case, the alternative is inferior in terms of organic materials, but is substantially equiva-

FIGURE 4-17
TEST FOR CLASS I - IRREPLACEABLE GROUND WATER



* UNDER OPTION B, THESE STEPS ARE CONSIDERED QUALITATIVELY

lent in terms of heavy metals and other inorganics, radionuclides, and other physical and chemical properties. The level of organic contamination is not unusual in the Region. Conventional water treatment can remove the organic contaminants; and, Waterfed's water, therefore, is not Class I Irreplaceable by this criterion.

The next criteria area to address is the comparable quantity of water. If the alternative cannot provide Waterfed with the 7 million gallons of water it needs every day, the ground water would be classified as Class I.

The next criteria area addresses established laws, administrative systems, or other forms of social control over access to water which may preclude the use of the potential replacement water source. If there are any institutional restrictions that do not allow the replacement water to be obtained through administrative procedures or market transactions, Waterfed's well water would be considered Class I. No such barriers exist, and Waterfed's well water is not Class I irreplaceable by this criterion.

If Waterfed's water is not to be considered Class I irreplaceable, replacing the city's well water must be an economically viable option. Under Option A, the annualized replacement cost to a typical user must be within or greater than 0.7 to 1.0 percent of the mean household income in the community to be Class I. Waterfed's mean household income is $20,000 per year and there are 9,100 households. If the annualized cost of replacing the city's ground water is within or greater than the range of $1.27 - $1.82 million ($20,000 times 9,000 times 0.7 - 1.0 percent), the water may be designated Class I irreplaceable under this option. Based on rough estimates, the capital cost for constructing the pipeline to pump water from the alternative source is approximately $2 million. Using the simplified annualization factor of 0.1 yields an annualized capital cost of $200,000. The annual operating and maintenance costs are likely to be between $150,000 and $200,000, yielding a total annualized replacement cost of between $350,000 and $400,000. Since this is at most, 0.31 percent of the mean household income, Waterfed's current water source is replaceable and, therefore, is, in the final analysis, not Class I irreplaceable. There is no need to perform a more detailed economic analysis.

Under Option B, these or other cost/ability-to-pay factors would be addressed in a more qualitative fashion. Such analyses may indicate, for example, that the area is not "water-short" and that the community generally seems able to afford such services as water supply improvement. Thus, the supply is considered "replaceable" under Option B as well.

4.5 Determining Ground-Water Vulnerability

Class I ground waters are characterized in part by the condition of being highly vulnerable to contamination. They represent hydrogeologic settings in the Classification Review Area with a high potential for contaminant entry and transport in the ground-water flow system. In these Guidelines, the Agency is seeking comment on approaches to defining "highly vulnerable" ground water. To assist in framing the discussion, two options are presented. The first relies on a numerical ranking scheme known as DRASTIC whereas the second utilizes a qualitative, non-specific approach.

4.5.1 Option A: DRASTIC

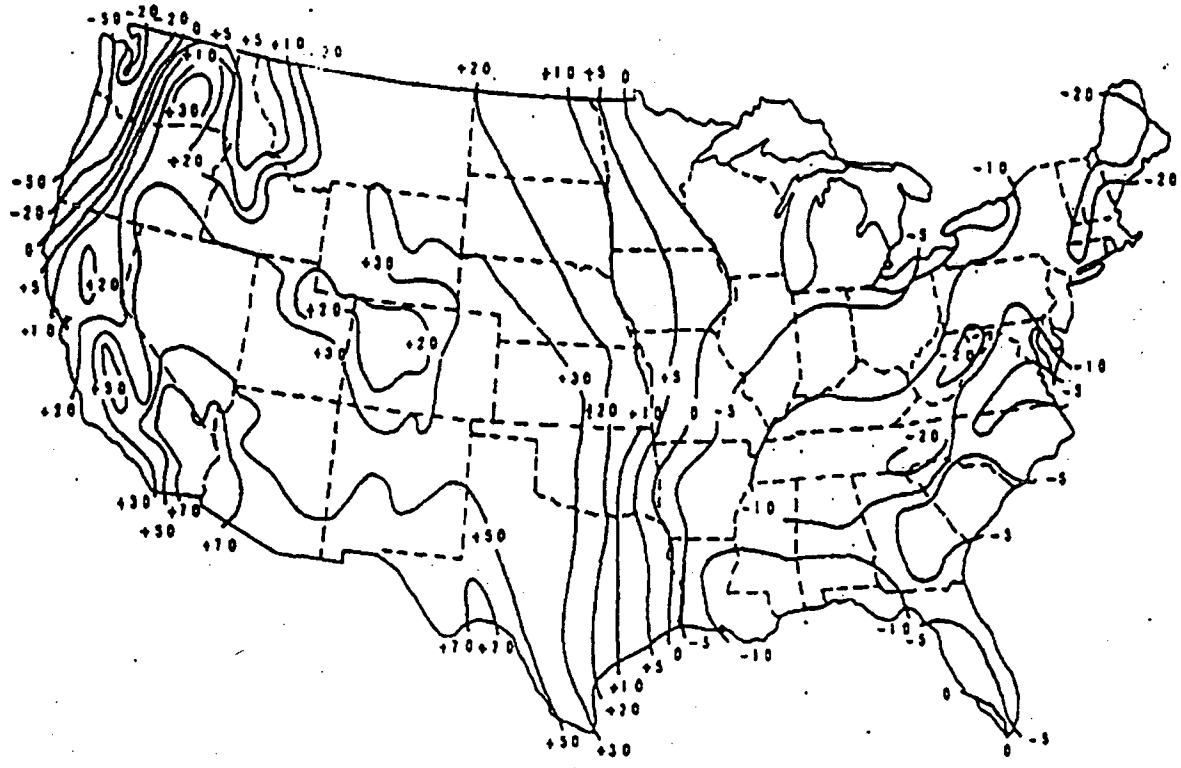
The DRASTIC methodology which forms the core of Option A was developed by the National Water Well Association under contract to EPA's research program (Aller et al., 1985). A DRASTIC assessment allows the ground-water pollution potential of any hydrogeologic setting to be systematically evaluated with existing information anywhere in the Nation. The system focuses on ground-water impacts, not impacts on specific uses for drinking and other purposes.

Detailed instructions for using the DRASTIC methodology are provided in a Robert S. Kerr, Environmental Research Laboratory Report (EPA/600/2-85/018) entitled "DRASTIC: A Standardized System for Evaluating Ground Water Pollution Potential Using Hydrogeologic Setting," (Aller et al, 1985). The reader is referred to this manual for general guidance on using the method.

A two-tier DRASTIC criteria is proposed within Option A. The tiers are distinguished according to hydrologic regions. In regions where estimated annual potential evapotranspiration exceeds mean annual precipitation, the DRASTIC criterion for highly vulnerable is 120. In regions where estimated annual potential evapotranspiration does not exceed mean annual precipitation, the DRASTIC criterion for highly vulnerable is 150. Figure 4-18 shows the relationship between annual potential evapotranspiration and mean annual precipitation.

DRASTIC was not developed especially for this classification system, though the concept of using existing data on a reconnaissance basis is similar. It was intended to serve as a screening tool to compare areas larger than 100 acres within a region. The following sections provide a general description of DRASTIC and caveats limiting its application to identify highly vulnerable ground water.

FIGURE 4-18
POTENTIAL EVAPORATION VERSUS MEAN ANNUAL PRECIPITATION IN INCHES
(FLACH, 1973)



+ Potential Evapotranspiration more than mean annual precipitation

− Potential Evapotranspiration less than mean annual precipitation

4.5.1.1 DRASTIC Methodology

DRASTIC is an acronym representing seven key hydrogeologic factors correlated to the potential for ground-water contamination listed below:

D - Depth to the water table
R - Net Recharge to ground water
A - Aquifer media
S - Soil media
T - Topography (slope of the land)
I - Impact of the vadose zone
C - Hydraulic Conductivity of the subject ground-water flow system

The DRASTIC methodology consists of several steps leading toward a single DRASTIC index number. In the first step, each factor is given a rating between 1 and 10 (except for net recharge, which is rated between 1 and 9) depending upon the range of parameter values within a hydrogeologic setting. Consider the range of values for depth to water, and corresponding ratings, shown in Table 4-5. A setting with a depth to water of 28 feet would be rated as a 7. (Tables listing the range of values and corresponding ratings for each factor are provided in Appendix D.)

In the second step, each factor rating is multiplied by a factor weight to give a factor index. For instance, the weight for depth to water is 5 and, thus, if the rating is 7, the factor index is 35 (7 times 5). For the final step, the individual factor indices are added together to arrive at the DRASTIC index.

The [illegible] of confidence in a DRASTIC index number is a function [illegible] reliability of the hydrogeologic information used to ra[illegible] each factor. In settings where the hydrogeologic information is well established, due to localized ground water and geologic studies, for example, the index will have a narrow confidence band. As in any procedure involving professional judgment, a more experienced or better trained evaluator will provide a more accurate portrayal of ground-water vulnerability to contamination.

4.5.1.2 Application of DRASTIC to the Classification Review Area

DRASTIC can be applied to the Classification Review Area using one of two approaches. In the most general approach, the ranges of each DRASTIC factor can be estimated from available information and a single DRASTIC index generated

TABLE 4-5
DRASTIC RANGE RATING FOR DEPTH TO WATER
(FROM ALLER ET AL, 1985)

Depth to Water (Feet)	
Range	Rating
0-5	10
5-15	9
15-30	7
30-50	5
50-75	3
75-100	2
100+	1
Weight: 5	

for the entire Classification Review Area. The average rating for each factor would be chosen where the range in the values of actual factor parameters spans two or more ratings. For example, if the depth to water across the Classification Review Area ranged from 5 to 30 feet, then two ratings would be bracketed (see Table 4-5), ratings of 9 through 7. An average rating of 8 would be chosen. This approach does not allow for the differentiation between hydrogeologic settings within the Classification Review Area where the range in values of factor parameters may not be so variable.

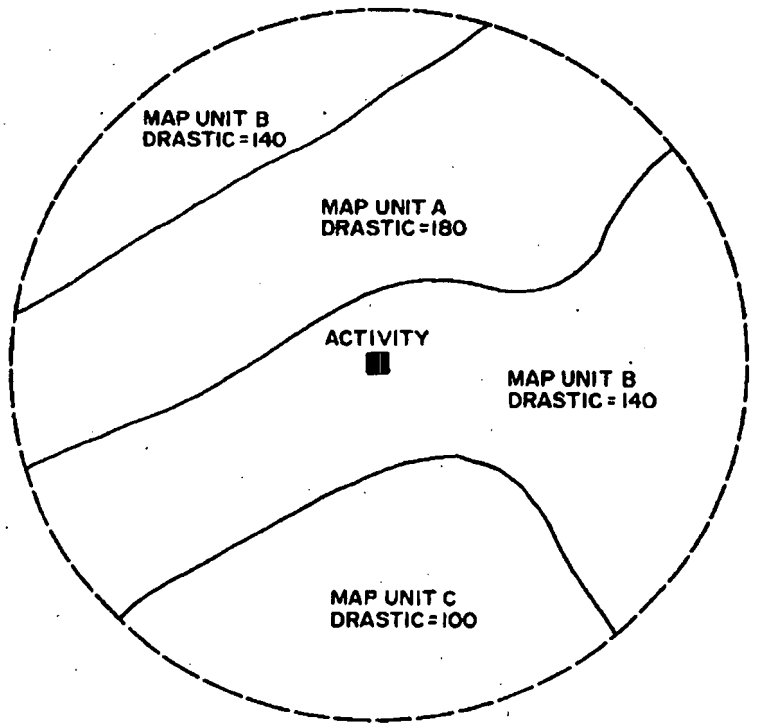
The second approach is to map out the major hydrogeologic settings that have significantly different DRASTIC indices within the Classification Review Area. Differences in DRASTIC indices in the range of 10 to 20 or more index points are considered significant. Where DRASTIC units are mapped out, an area weighted, average index can be computed. However, if the activity occupies any portion of a DRASTIC map unit with an index greater than the "highly vulnerable" criterion, or, if more than 50 percent of the Classification Review Area exceeds the criterion, the setting should be designated as highly vulnerable.

As an illustration of the mapping approach, consider the proposed activity shown in Figure 4-19. Within the Classification Review Area, three hydrogeologic settings have been mapped and labeled: A, B, and C. The DRASTIC index for each hydrogeologic setting is 180, 140, and 100, respectively; while, the area for each setting is 20 percent, 45 percent, and 35 percent, respectively. The weighted average DRASTIC index is calculated as follows:

Map Unit	DRASTIC Index	Proportion of Area	Area Weighted Index
A	180	.20	36
B	140	.45	63
C	100	.35	35
		Weighted Index	134

For this illustration, the map-unit, area-weighted DRASTIC index of 134 is less than the highly vulnerable criterion of 150. If map-unit A had been greater than 50 percent of the Classification Review Area, or, if the activity had occurred in map unit A, the designation of highly vulnerable would have been automatic.

FIGURE 4-19
ILLUSTRATION OF DRASTIC MAPPING



EXPLANATION

——— CLASSIFICATION REVIEW AREA BOUNDARY

0 1 2 MILES

4.5.1.3 Limitations to the Application of DRASTIC

DRASTIC has been designed to account for a number of different conditions, among which are multiple aquifers and confined aquifers. There is also a separate index designed strictly for agricultural analyses.

The DRASTIC methodology allows for the depth-to-water rating to be adjusted for confined aquifers. With this technique, different aquifers within the Classification Review Area could receive a different DRASTIC index. Generally, the deeper aquifers will be less vulnerable. However, contaminants entering in a vulnerable recharge area may reach even the deepest aquifer given sufficient time. The system typically favors the uppermost aquifer in determining vulnerability and a single DRASTIC index attributable to the Classification Review Area, or subdivision of the Classification Review Area. This is generally consistent with Agency's philosophy that the primary aquifers threatened by the bulk of EPA regulated programs are those under table conditions. Where the uppermost aquifer is found to be vulnerable, all ground water with a high degree of interconnection to the uppermost aquifer is to be considered highly vulnerable. Confined aquifers with a low-to-intermediate interconnection to the uppermost aquifer are considered less vulnerable.

The DRASTIC method also establishes a separate and different set of factor weights for agricultural activities. Because the Agency has decided to consider vulnerability as independent of activity, only the regular factor weights will be applied.

4.5.2 Option B: Qualitative Assessment

In this option, the user of Guidelines would select the most appropriate operational tools for assessing vulnerability. The selection might be based on factors such as site setting, professional experience of the user, the availability of data, or previous program experience. In some cases, general comparisons of the hydrogeologic setting to others where vulnerability is a concern might suffice. The analysis might end at that point, or a detailed mapping or flow net analyses might commence. Option B is called "qualitative," since these Guidelines would not include referred tests of methods to follow, or other numerical criteria/decision steps.

There are five general categories of vulnerability methods which have been analyzed in the context of these

Guidelines. Within each of the five broad categories is a series of sub-approaches that could be used. Although discussed in Appendix B, the five are summarized in Table 4-6. As one moves from the "qualitative description" approach through to the "integrative criterion", sophistication generally increases along with cost and complexity. The qualitative approach could include some of the DRASTIC factors as well. Rather than utilize the ranking and weighing scheme discussed in the previous section, or all of the seven DRASTIC factors could be reviewed for a given area, and professional judgment used accordingly.

TABLE 4-6
SUMMARY OF OPERATIONAL METHODS FOR DEFINING THE KEY TERM
"HIGHLY VULNERABLE" GROUND WATER

METHODS	EXAMPLES OF "HIGHLY VULNERABLE"	COMMENTS
1. Qualitative description of highly vulnerable hydrogeologic settings	Highly vulnerable settings: a. unconfined aquifers overlain by sandy, highly permeable soils, or b. karst terrain, or c. ground-water recharge areas	Simple to use; requires judgement to match real settings to qualitative descriptions and a need for lengthy process to inventory descriptions of hydrogeologic settings judged to be highly vulnerable.
2. Single independent factor and criteria.	Vadose zone thickness less than 150 feet <u>or</u> hydraulic conductivity $>1 \times 10^{-4}$	Simple to use; difficult to establish single criterion which is realistically applicable across the country.
3. Multiple independent	Vadose zone <150 feet, hydraulic conductivity $>1.0 \times 10^{-4}$ cm/sec, <u>and</u> recharge >5 inches per year	Improvement over single factor; in use by States; assumes each factor equal weight; assumes failure to meet any factor criterion will result in a determination of highly vulnerable; interrelationships between factors is ignored.
4. Numerical rating (weighted and non-weighted). For example, DRASTIC, a rating scheme developed by the National Water Well Association (Aller et al, 1985); other examples: . The hazard-ranking system for CERCLA (40 CFR 300, Appendix A); and . Legrand's standardized system for evaluating waste-disposal site (Legrand, 1980).	DRASTIC index greater than 150 over CRA	A more sophisticated method allowing for factor weighting and a single score or index. Weighted factors are added. States often moved in this direction after considering multiple factor approach; provides for professional judgment in selecting specific ratings; sometimes critized for being too "simplistic" for site-specific geotechnical assessment
5. Integrative criterion. Time-of-travel for a selected distance or time to reach an exposure point.	Average time-of-travel greater than 1/2 foot per day over CRA	Allows for factor weighting and a single score. Considers the interrelationships between factors. Very data intensive. Yields a single score. Not suited to mapping large areas.

4.6 Determination of Reasonable Treatment

The ground-water classification system indicates that Class III ground waters are those which (1) contain greater than 10,000 mg/l total dissolved solids (TDS); (2) are yielded in insufficient quantities to satisfy the needs of an average household; or (3) are so contaminated that they cannot be cleaned up using treatment methods reasonably employed in public water systems. An approach to define the latter based on a comparison to "reference technologies" is provided in this section. An alternative approach, new to this draft, is available for consideration and review. Although the test is somewhat more complete and, perhaps, expensive to perform, it is believed to be more rigorous and definitive in its application. The alternative which can eventually replace, or be used in conjunction with "reference technologies" is fully discussed in Appendix G.

4.6.1 Standards and Criteria for Treatment

The above definition implies that an analysis of treatment methods should consider relevant "standards and criteria" for long-term drinking water use. No one set of such "numbers" are available and thus, some professional judgment may be required.

Under the Safe Drinking Water Act, for example, EPA has issued National Interim Primary Drinking Water Regulations (NIPDWR). These regulations set maximum contaminant levels (MCLs) for a number of inorganic, organic, and microbiological contaminants in drinking water. These values are based on both health factors and technical/economical feasibility. MCLs for selected parameters can be found in Table 4-7.

In addition to MCLs which are enforceable standards, RMCLs or recommended maximum contaminant levels are set reflecting EPA's goal of no known or anticipated adverse health effects. Both RMCL and MCL values are updated periodically. For example, proposed RMCL values for eight volatile organic chemicals are published in the Federal Register (1985). It is the objective of the agency to set MCLs as close to RMCLs as possible.

EPA provides drinking water suppliers with additional guidance under the authority of the Safe Drinking Water Act. EPA is now in the process, for example, of developing RMCLs for additional contaminants to serve as guidance for establishing new drinking water MCLs. The Agency is accelerating the pace of both RMCL and MCL issuance. Other chemicals addressed under the Clean Water Act (CWA) may be inter-

TABLE 4-7
RMCL & MCL VALUES FOR SELECTED CONTAMINANTS[1]

Contaminants	RMCL (mg/l)	MCL (mg/l)
Inorganic Species:		
Arsenic	0.05	0.05
Barium	1.5	1
Cadmium	.005	0.010
Chromium	.12	0.05
Fluoride	-	1.4-2.4
Lead	0.020	0.05
Mercury	.003	0.002
Nitrate (as N)	10	10
Selenium	.045	0.01
Silver	-	0.05
Organic Species:		
Benzene	0	-
Vinyl Chloride	0	-
1,1-Dichloroethylene	0.007	-
1,1,1-Trichloroethane	0.20	-
p-Dichlorobenzene	0.750	-
Trihalomethane	-	.1
Lindane	-	0.004

[1]Sources: Federal Register, Vol. 50, No. 219, Nov. 13, 1985. p 46889, p 46958, p 46957.
Guidance on Feasibility Studies Under CERCLA, June 1985, U.S. EPA, Cincinnati, Ohio

mittently encountered in a water system, and are believed to pose a risk for the near term, yet are currently unregulated in drinking water. The guidelines for these are developed by the Office of Drinking Water in the form of Health Advisories. The health advisories are not mandatory for public water systems, but provide information for emergency situations. (Health Advisories are available on some contaminants where no MCLs or RMCLs are published, Table 4-8.) They are calculated at three exposure levels: one day, seven or ten days, and longer term (1 to 2 years). A margin of safety is factored in to protect the most sensitive members of the general population (U.S. EPA, 1985; Federal Register, 1985).

Finally, the RCRA program in developing its Alternate Concentration Limits (ACLs), and in responding to the land disposal bans portion of the RCRA amendments of 1984, will be examining the applicability of other sets of criteria and standards for both carcinogenic and non-carcinogenic contaminants. These will likely be useful for addressing the large number of contaminants without current MCLs, RMCLs, or health advisories.

4.6.2 Treatment Technologies

Many different treatment technologies are currently used for treating surface and ground waters which serve as public drinking water supplies. These technologies can be classed into five general categories: volatile organic chemicals removal; non-volatile organic chemicals removal; metals removal; non-metallic inorganic chemicals removal; and disinfection. Some technologies are effective in reducing only a few types of contaminants, while others may efficiently treat several contaminant classes simultaneously. Although most processes are designed to treat a single "class" of contaminants, many will provide some beneficial, non-design removal of other contaminant classes. (Appendix E briefly describes each of several generic treatment technologies with reference to their appropriate usage and limitations.)

4.6.2.1 Regional Availability of Reference Technologies

Table 4-9 presents the use of various treatment technologies by EPA Region. Most of the reference technologies are currently in use at public water supply systems in all regions of the country, however, not necessarily in hazardous-waste applications (e.g., carbon adsorption is sometimes used in taste and odor applications and not for removal of volatile organics). The exceptions to this are

TABLE 4-8
HEALTH ADVISORIES FOR SELECTED CONTAMINANTS IN WATER

CHEMICAL	Health Advisories mg/l		
	1-day	10-day	Longer Term
Benzene		0.23	0.07
Carbon Tetrachloride	0.2	0.02	
Chlordane	0.0625	0.0625	0.0075
1,1-Dichloroethylene	1.0		0.07
1,2-Dichloroethylene	4.0	0.4	
1,2-t-Dichloroethylene	2.7	0.27	
Dichloromethane	13	1.3	0.15
Ethylene glycol	19.0		5.5
Formaldehyde	0.030	0.030	
n-Hexane	13	4.0	
p-Diozane	5.68	0.598	
Methyl Et[illegible]tone	7.5	0.75	
Polychlorin[illegible]d biphenyls (PCB)	0.125	0.0125	
Tetrachloroethylene	2.3	0.175	0.02
Toluene	21.5	2.2	0.34
1,1,1-Trichloroethane			1.0
Trichloroethylene	2.0	0.2	0.075
Xylenes	12	1.2	0.62

[a]Total trihalomethanes refers to the sum concentration of chloroform, bromodichloromethane, dibromochloromethane, and bromoform.

TABLE 4-9
APPLICATION OF TREATMENT TECHNOLOGIES IN PUBLIC WATER SUPPLY SYSTEMS, BY EPA REGION[a]

	Number of Systems Identified									
	I	II	III	IV	V	VI	VII	VIII	IX	X
Technologies Applied in All Regions										
Aeration[b]	6	28	21	58	96	9	40	8	17	2
Carbon Adsorption	7	12	8	4	13	3	1	4	4	2
Chemical Precipitation	28	55	67	109	227	25	96	35	37	12
Chlorination	43	99	96	161	292	70	86	64	119	55
Flotation[e]	30	64	94	186	217	58	90	70	80	31
Fluoridation	30	38	42	97	211	15	57	23	9	12
Granular Media Filtration	20	48	61	107	185	32	65	44	62	24
Technologies Applied in Some Regions										
Air Stripping[c]	3	3	4	2	0	0	0	0	2	0
Desalination	0	0	0	5	0	6	0	1	8	20
Ion Exchange	0	5	3	2	28	1	2	2	0	1
Ozonation	0	0	1	2	0	0	0	0	0	0
Technologies Generally Not Applied[d]										
Distillation	0	0	0	0	0	0	0	0	0	0
Wet Air Oxidation	0	0	0	0	0	0	0	0	0	0
Biological Treatment	0	0	0	0	0	0	0	0	0	0

[a] This table is based primarily on data available in the 1981 AWWA Survey of Public Water Supply Systems, and supplemented with case studies drawn from the available literature. The data reflect only the use of the technologies in water utilities, and to not represent usage patterns of those technologies for wastewater or industrial process water treatment. Data describing 1500-1600 public water systems were consulted.

[b] The AWWA Survey includes air stripping in this category.

[c] Plants were identified independent of the AWWA survey.

[d] No evidence of application of these technologies was found in the set of 1500-1600 public water systems examined.

[e] Includes technologies using skimming, diffused air, diffused oxygen, and pressurized gases.

desalination, ion exchange, and ozonation; these treatment technologies may be considered reasonably employed in certain Regions. Air stripping, which is most often used for removal of volatile organic solvents from ground waters, should be considered "available" for Class III analyses, despite its limited use in public water supply systems.

Other treatment technologies may be applicable in the future, but are not now considered readily available or reasonably employable. Distillation techniques have long been employed for treating industrial process water, for example, but is generally reserved for such water, for example, but is generally reserved for such areas as water-short islands. Biological treatment techniques have been used for in situ clean up of ground waters and although efforts to develop biological treatment technology is not applicable or reasonably employable. Wet air oxidation techniques are used in industry for removal of organics from process wastewater. Efforts to develop this technology for application in water treatment are also underway, but the techniques should not be considered reasonably employable.

The reference list of these technologies are used to define the set of available water treatment technologies. A partial bibliography of resources and references is given in Appendix E.

4.6.2.2 Treatment Efficiencies

Evaluation of treatment efficiencies for a single contaminant or group of contaminants requires the evaluation of interferences and interaction of contaminants. General background data on treatment performance indicate ranges of values for efficiency. For example, EPA's Treatability Manual for Priority Pollutants (U.S. EPA, 1980), presents examples of typically achievable contaminant removal efficiencies for a range of contaminants and technologies.

More precise determination requires pilot testing or comparison by experts with other similar waste streams. Appendix E indicates the general level-of-success the various treatment technologies have with frequently encountered waste streams. Removal efficiencies are not reported in the literature for all contaminants, as experience using certain technologies is not available.

Contaminant concentration, physical conditions (e.g., pH, temperature), solution chemistry, and the presence of competing or interfering contaminants can all contribute to the large variations in removal efficiencies that are

reflected in the literature. For situations in which a more accurate assessment of treatment efficiencies is desired, the user of these guidelines may wish to refer to a partial bibliography of sources listed at the end of Appendix E.

Table 4-10 lists some of the major advantages, disadvantages, and limitations associated with each treatment process. For developing process configurations, it is usually desirable to remove the contaminants first that they may interfere with subsequent processes. For example, if a system uses both granular media filtration for solids removal and ion exchange for softening, the filtration stage should precede the ion exchange stage in order to assure that potential resin-fouling solids are eliminated from suspension. As another example, plants with solvent contamination will air strip or carbon adsorb the organics prior to chlorination, to prevent the formation of halogenated organics which are less efficiently removed.

4.6.3 Methodology for Determining Treatability

To determine if a ground water can be cleaned up using treatment methods reasonably employed by public water systems, the permit reviewer may wish to follow the steps described below.

1. Describe the contamination problem.

The description of the contamination problem should include information on the natural or background water quality, the extent of contamination, and the physical factors influencing both ground water and treatment. The natural quality of a ground water may be inferred from historical data or by comparison to background ground waters in the site vicinity.

Contaminants in the ground water of concern should be specified and the range in concentrations noted. In particular, if the type and concentration of contaminant vary spatially, this should be indicated as it has design implications for treatment configurations. The analyses used and the range of sampling and measurement error should also be provided to assist the reviewer in understanding the degree of certainty of contamination. It is important to address the areal extent of contamination to be sure it meets the basic notion that contamination is not related to an individual facility or activity.

The physical parameters of concern include flow patterns, climatology, and other site-specific issues. Many of

TABLE 4-10
DESCRIPTION OF TREATMENT PROCESS

Air Stripping/Aeration		
Advantages	**Disadvantages**	**Limitations**
Low capital and O&M	Temperature sensitive (cold) contaminants	Removes only volatile
High removal efficiencies for some contaminants	May result in air pollution or a need for Emission Control	Suspended solids in influent may lead to removal efficiency loss due biological growth (air stripping only)
Pretreatment is generally not required for ground water		
Equipment can be purchased off the shelf		

Carbon Adsorption		
Advantages	**Disadvantages**	**Limitations**
Low energy requirements	Management of spent can be expensive and problematic - Regeneration - Disposal - Replacement	For organics removal where concentrations are high, frequent carbon regeneration necessary
High removal efficiencies for a wide range of contaminants over a broad concentration range	High capital and operating costs	Suspended solids should not exceed 50 mg/l Oil and grease should not exceed 10 mg/l Requires steady hydraulic loading

TABLE 4-10 (Cont.)

Advantages	Disadvantages	Limitations
Equipment is readily available and easy to operate	Generates large quantities of sludge which must be treated and disposed	Frequent laboratory testing is required to maintain high efficiencies
Low energy requirements	ent quality may vary considerably due to uncontrollable circumstances	pH dependent
Low capital and O&M costs		No concentration limit

Desalination[1]

Advantages	Disadvantages	Limitations
Excellent removal of charged anions and cations	High energy requirements	Suspended solids must be low to prevent fouling
Good removal of high molecular weight organics	Requires extension pilot analyses for each system	Operating temperatures must be between 65°F and 85°F
Effective treatment for removal of dissolved solids	Highly sophisticated instrumentation and control	
	Generates a concentrated brine which may require further treatment	
	Pretreatment almost always required	
	High capital and O&M costs	

[1]Reverse osmosis, ultrafiltration

TABLE 4-10 (Cont.)

	Granular Media Filtration (e.g., sand filters)	
Advantages	Disadvantages	Limitations
Highly reliable	Process generates a backwash which must	Influent suspended solids should not
Relatively simple; easy to operate and control		Requires fairly steady hydraulic loading
Multiple media can be used to improve efficiencies		
	Ion Exchange	
Advantages	Disadvantages	Limitations
Synthetic resins can tolerate a wide range of temperature and pH	General concentrated regenerant brine which must be disposed	Influent concentrations should not exceed 4,000
Can remove a variety of cationic and anionic inorganic and organic contaminants	Generates concentrated regenerant brine which must be disposed	S.S. should not exceed 50 mg/l
Low energy requirements	Generally, but not always high capital and O&M	Influent should not contain chemical oxidants (e.g., ozone)

TABLE 4-10 (Cont.)

Ozonation		
Advantages	Disadvantages	Limitations
Reduces chemical residuals generated (particularly, no chlorinated hydrocarbons	capital and high energy	Treats only contaminants which can be oxidized
No dissolved solids generation	Requires high level of training and safety precautions for operation	Does not remove iron-cyanide complexes
Easily implemented	May require substantial	Narrow range of removal - e.g., not effective for contaminants with density greater than water
Usually highly effective for hydrocarbons with densities near or less than water	Generates large quantities of sludge to be treated and disposed	
Low capital & O&M		
Low energy requirements		

the treatment processes are highly sensitive to temperature fluctuations; therefore, ambient temperature ranges become important in selecting appropriate technologies or housing requirements. The climate in the area of concern, including data on the freeze/thaw cycles, and any storm or wind events that may affect the treatment processes must also be considered. Other site-specific considerations may become important on a case-by-case basis.

2. Determine the desired effluent quality

To determine the desired quality of the treated water following completion of all treatment processes, acceptable concentrations for each contaminant must be addressed. Relevant Federal Criteria include the MCL, the RMCL, and the longest-term Health Advisory for each contaminant. These values are sometimes unavailable for certain contaminants due to insufficient data.

3. Define the applicable treatment technologies

For each contaminant present, certain treatment technologies may be particularly applicable. Refer to Table 4-8 and Table 4-9 and supplementary information in Appendix E to identify regionally available removal technologies for each contaminant. This list of technologies should be considered the universe of available processes for treating the ground water.

4. Compile regionally available process configurations

Before assessing ground water treatability, the permit reviewer must define a set of treatment process configurations that may be used to remove contaminants from the ground water. These process configurations should be developed considering efficient contaminant removal to the minimum level required. Any combination of the treatment processes should be considered readily available nationwide.

5. Evaluate treated water quality

To evaluate typically achieved water quality using any given treatment process configuration, the concentration of specific contaminants in the ground water/influent, levels of background water quality parameters (pH, TDS, etc.) and the removal efficiencies of each contaminant using each treatment process ideally should be known.

Background data/manuals on treatability developed by EPA can be consulted for initial guidance on treatment perform-

ance. For example, typical removal efficiencies are indicated in EPA's Treatability Manual for Priority Pollutants (U.S. EPA, 1980). A qualified water treatment engineer could also determine the relative effectiveness and a probably range of effluent quality levels achievable for many frequently encountered contaminant mixes. Interference effects possibly, from adverse levels of various contaminant combinations, background water-quality parameters (e.g., pH, or heavy metals, varying concentrations), can affect the efficiency of treatment processes. Because of this, in complex mixtures or where little experience exists, the lack of bench or the pilot scale treatability studies may limit the ability of the engineer in developing an estimate.

6. Determine if desired water quality is met.

Once the approximate effluent concentration of each contaminant has been evaluated for a given treatment process, these can be compared to the appropriate water quality standard. If all effluent concentrations are less than the desired water quality, the ground water can be cleaned up using treatment methods reasonably employed in public water supply systems. If some effluent contaminant concentrations exceed desired water quality, the treatment process configuration does not adequately clean the ground water, and an alternative configuration should be evaluated for contaminant treatability. If all available treatment process configurations do not remove contaminants to the levels which meet desired water quality, the ground water cannot be cleaned up using treatment methods reasonably employed in public water supply systems. These will then be candidates for Class III.

4.6.4 Sample Problem

The following example is illustrative in nature and is not meant to represent conditions at any specific facility.

A permit applicant has asked to site a facility in Region IV, and has made the claim that the site location will only affect Class III ground water. The chemical contaminants in the ground water, listed in Table 4-11, are apparently from multiple sources and occur throughout the Classification Review Area.

The desired water quality levels are listed in Tables 4-7 and 4-8. For cadmium and selenium the applicant defines the desired maximum effluent contaminant concentrations to be equal to the MCLs as presented in Table 4-7. For carbon tetrachloride, desired effluent quality is derived from the ten-day Health Advisory (the only available), while for

TABLE 4-11
EFFLUENT QUALITY WORKING TABLE FROM SAMPLE PROBLEM

Contaminant	WQ_i[a]	WQ_d[b]	Treatment Process Removal Efficiencies[c] Process A	Process B	Process C	Process D	Process E	Process F	WQ_o[d]	Desired Water Quality Achieved?
Process Configuration A			Air Stripping	Chemical Precip.	Filtration	--	--	--		
Trichloroethylene	8.2	0.075	98	60	7				0.066	Yes
Tetrachloroethylene	20.0	0.2	98	95	0				0.02	Yes
Carbon Tetrachloride	65.0	0.02	98	95	90				0.007	Yes
Toluene	110.0	0.34	95	75	65				0.48	No
Cadmium	0.5	0.01	0	90	70				0.015	No
Selenium	2.0	0.01	0	70	60				0.24	No
Process Configuration B			Air Stripping	Chemical Precip.	Filtration	Desalination	--	--		
Trichloroethylene	8.2	0.075	98	60	7	7			0.066	Yes
Tetrachloroethylene	20.0	0.02	98	95	0	80			0.004	Yes
Carbon Tetrachloride	65.0	0.02	98	95	90	7			0.007	Yes
Toluene	110.0	0.34	95	75	65	50			0.24	Yes
Cadmium	0.5	0.01	0	90	70	60			0.006	Yes
Selenium	2.0	0.01	0	70	60	97			0.007	Yes

[a] WQ_i = the influent contaminant concentration, in mg/l

[b] WQ_d = the desired maximum effluent contaminant concentration, in mg/l

[c] Removal efficiencies report in percent

[d] WQ_o = the calculated effluent contaminant concentration, in mg/l

toluene, trichloroethylene, and tetrachloroethylene a long-term Health Advisory was used.

The treatment processes that most readily removes such volatile organics such as carbon tetrachloride, tetrachloroethylene, and toluene include carbon adsorption and air stripping. Metals, such as cadmium and selenium, can be removed using chemical precipitation, desalination, and ion exchange. Granular media filtration would probably be considered for removal of residual particulate matter, following a chemical precipitation step, particularly if desalination, carbon adsorption, or ion exchange processes followed. All of these processes are currently in use in public water supply systems in Region IV.

Achievable effluent quality must be evaluated for each treatment process configuration to determine if the ground water can be treated to meet desirable levels. Process and contaminant specific removal efficiencies are provided for all six contaminants. (Please note: these values are to illustrate the process and are not intended to be actual efficiencies.) As indicated by calculated WQ_o values and comparing them with WQd values (Table 4-10), treatment process configuration A can result in removal of trichloroethylene, tetrachloroethylene, and carbon tetrachloride to acceptable levels. However, levels of cadmium, selenium, and toluene following treatment using process configuration A can not meet the desired water quality. Therefore, the applicant must consider an additional treatment process configuration.

Removal efficiencies for the process configuration B including air stripping, chemical precipitation, filtration, and desalination can achieve acceptable water quality levels for all contaminants. Thus, according to this methodology, this ground water is not Class III because it can be cleaned up using treatment methods reasonably employed in public water supply systems.

An alternate economically-based test for determining the treatability of potential Class II ground water is proposed in Appendix G.

4.7 Ground-Water and Surface-Water Interaction

Interconnected ground water and surface water may be managed or regulated for different, and sometimes conflicting, uses. The Agency recognizes that the interconnection and interaction between ground water and surface water necessitates coordination between efforts to classify and manage both kinds of water resources.

Two conditions involving the interaction between ground water and surface water deserve consideration in ground-water classification. One condition is the recharge of ground water from a surface-water body. The other is the discharge of ground water to surface water.

4.7.1 Ground-Water Discharge to Surface Water

Ground-water discharge to surface-water bodies occurs in many hydrogeologic settings and is the dominant condition in high rainfall areas. Where poor quality ground-water discharges to surface water, a potential to impact the quality of those surface waters exists. The classification system accounts for three conditions where ground water is interconnected to surface waters and where surface-water quality may be degraded:

- Class I Ecologically Vital Ground Water - Ground waters providing base flow to, or supporting water levels for, unique terrestrial or aquatic habitats associated with water bodies;

- Class II Current Source of Drinking Water - Ground waters currently used as a source of drinking water, ir ng those ground waters which discharge to a d g water supply reservoir with a protected wat ned

- Class III Ground Waters Not a Potential Source of Drinking Water - Saline or regionally contaminated ground waters that are interconnected to adjacent ground waters or surface waters.

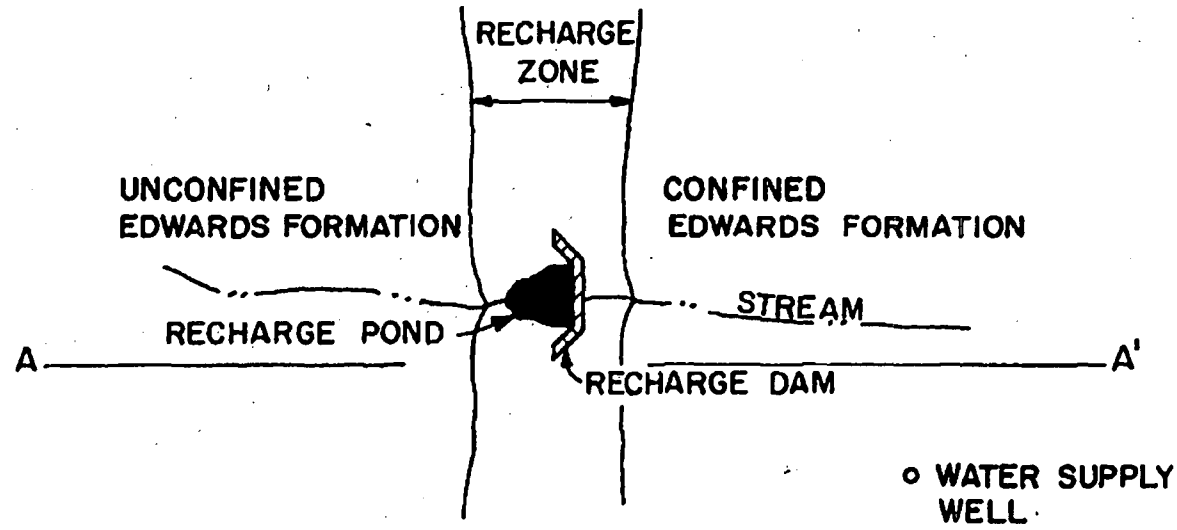
4.7.2 Surface Water Recharge to Ground Water

The recharge of ground water from a surface-water body is the natural and prevalent means of ground-water recharge in the drier western states, but can also occur in high rainfall-rich areas due to the pumping or ground water in

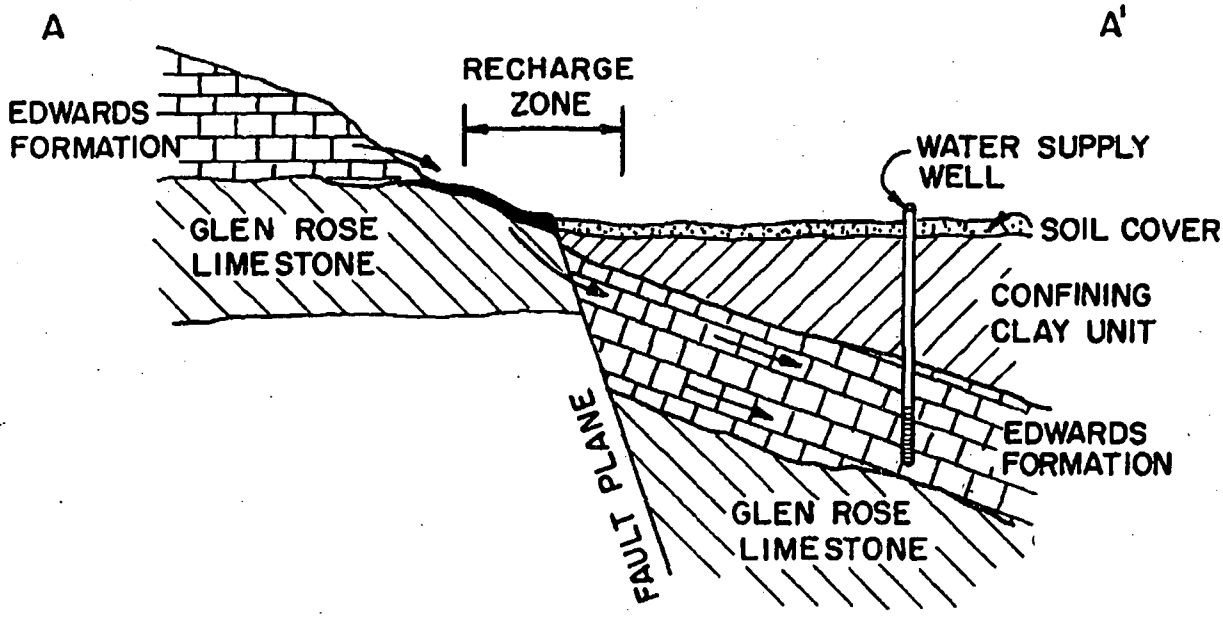
close proximity to the water body. An example of surface-water recharge to ground water concerns the use of stream impoundments to accelerate recharge. Figure 4-20 shows such an impoundment, referred to as a recharge basin on a stream crossing the recharge zone of the Edwards Aquifer in Texas. Another example is the recharge of Mohawk River waters into a sand and gravel aquifer which supplies well fields serving the cities of Rotterdam and Schenectady, New York, as demonstrated in Figure 4-21. The following Figure 4-22 indicates that the warmer river water enters the aquifer, mixes with the cooler ground water, and is subsequently withdrawn by the wells.

The potential for poor quality surface water to degrade ground-water quality is implied in these examples. They further demonstrate the need to consider surface-water use and quality in managing ground-water quality where surface-water bodies provide significant recharge. The classification system by itself, however, is not intended to be the focus for managing such settings.

FIGURE 4-20
ILLUSTRATION OF SURFACE WATER RECHARGE TO
GROUND WATER FOR THE EDWARDS AQUIFER, TEXAS



PLAN



CROSS-SECTION

FIGURE 4-21
CROSS-SECTION OF AN ALLUVIAL AQUIFER SHOWING
SURFACE WATER RECHARGE FROM THE MOHAWK RIVER

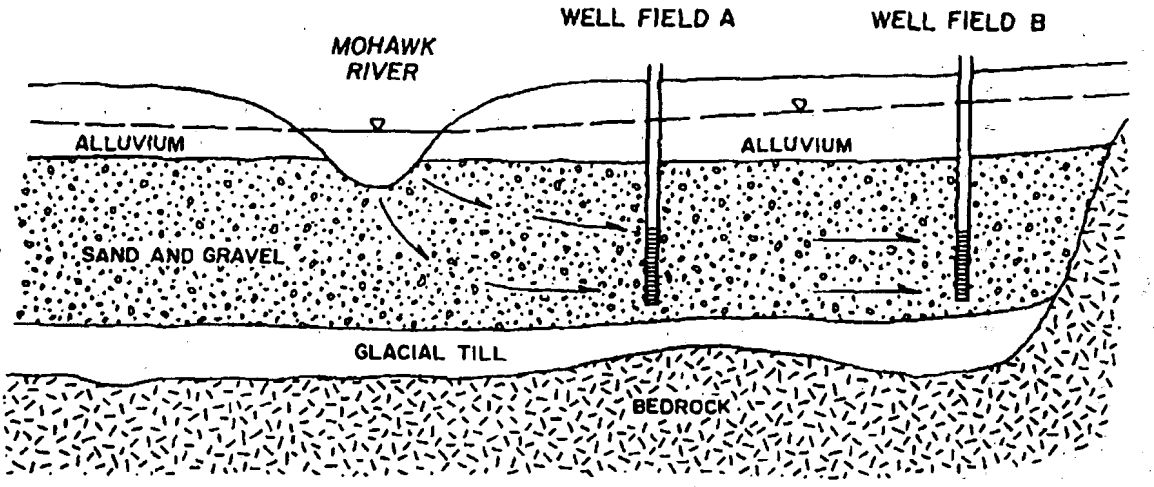
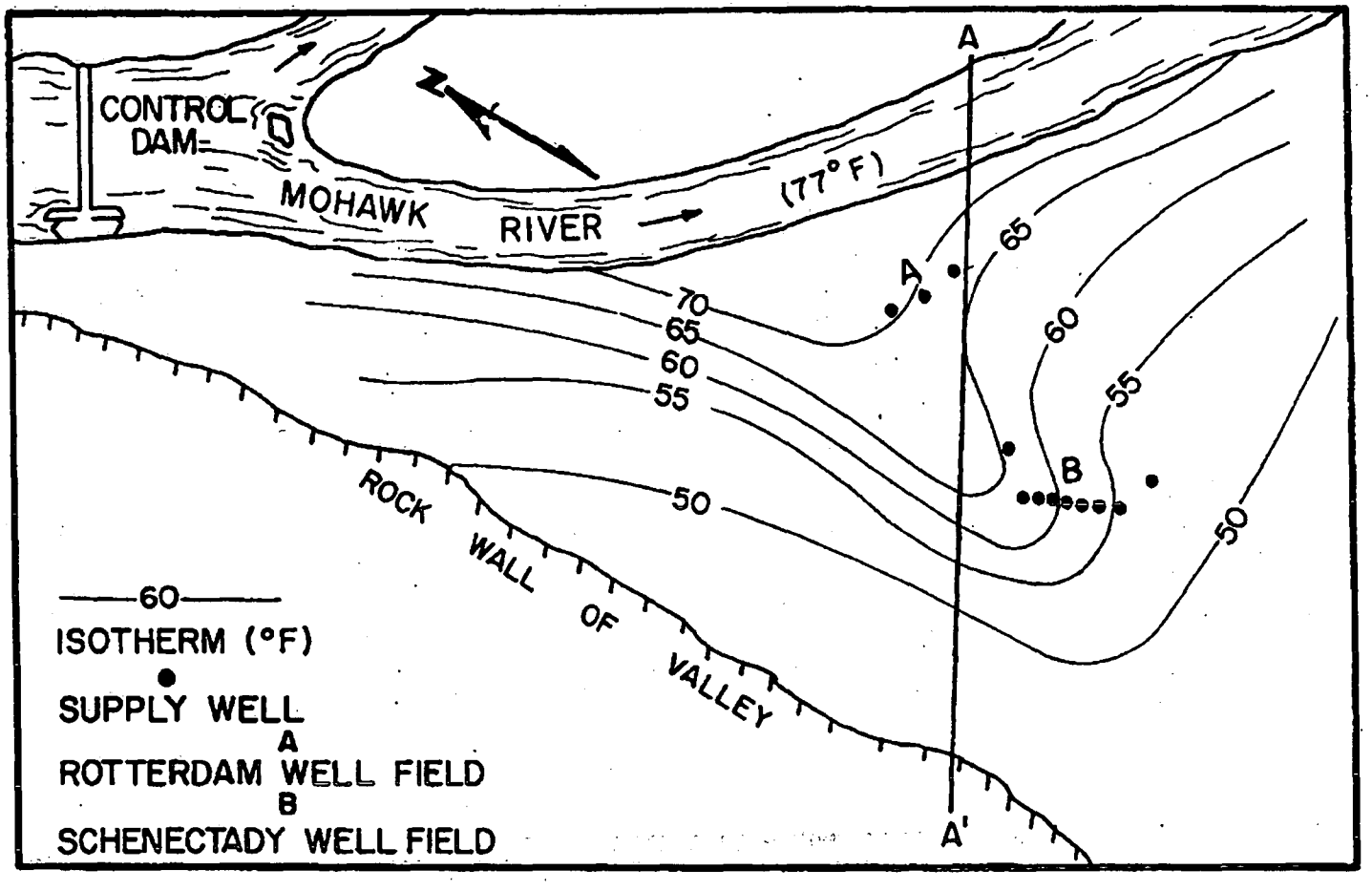


FIGURE 4-22
GROUND-WATER ISOTHERMS OF MOHAWK RIVER BASIN



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PART III

APPENDICES

APPENDIX A

GLOSSARY

APPENDIX A
GLOSSARY*

AQUIFER - A geologic formation, group of geologic formations, or part of a geologic formation that yields significant quantities of water to wells and springs.

AQUIFER SYSTEM - A heterogeneous body of intercalated permeable and less permeable material that acts as a water-yielding hydraulic unit of regional extent.

AQUITARD - A confining bed that retards, but does not prevent the flow of water to or from an adjacent aquifer; it does not readily yield water to wells or springs.

CONE OF DEPRESSION - A depression in the POTENTIOMETRIC SURFACE of a body of ground water that has the shape of an inverted cone and develops around a pumped well.

CONFINED CONDITIONS - Exists when an aquifer is confined between two layers of much less pervious material. The pressure condition of such a system is such that the water level in a well penetrating the confined aquifer usually rises above the top of the aquifer.

CONTAMINANT PLUME - Irregular volume occupied by a body of dissolved or suspended pollutants in ground water.

CRA - Abbreviation of Classification Review Area.

DISCHARGE AREA - A discharge area is an area of land beneath which there is a net annual transfer of water from the satu[illegible] zone to a surface-water body, the land surface or [illegible]oot zone. The net discharge is physically manifested by an increase of hydraulic heads with depth (i.e., upward ground-water flow to the water table). These zones may be associated with natural areas of discharge such as seeps, springs, caves, wetlands, streams, bays, or playas.

ECOLOGICAL SYSTEM (ECOSYSTEM) - An ecological community together with its physical environment.

ECOLOGY - The science of the relationships between organisms and their environment.

*For general information only -- not to be viewed as suggested or mandatory language for regulatory purposes.

ECOSYSTEM - See ECOLOGICAL SYSTEM.

FLOW NET - A graphical presentation of ground-water flow lines and lines of equal pressure head.

GEOLOGIC FORMATION - A body of rock that can be distinquished on the basis of characteristic lithologic features such as chemical composition, structures, textures, or fossil content.

GROUND-WATER - Subsurface water within the zone of saturation.

GROUND-WATER BASIN - (a) A subsurface structure having the character of a basin with respect to the collection, retention, and outflow of water, (b) An aquifer, or system of aquifers, whether or not basin-shaped, that has reasonably well defined hydrologic boundaries and, more or less, definite areas of recharge and discharge.

GROUND-WATER FLOW DIVIDE - An imaginary plane (or curved surface) distinguished by the limiting flow lines of adjacent flow systems. Conceptually there is no flow across this plane between the flow systems.

GROUND-WATER FLOW REGIME - The sum total of all ground water (water within the saturated zone) and surrounding geologic media (e.g., sediment and rocks). The top of the ground-water regime is the water table while the bottom would be the base of significant ground-water circulation. Temporarily perched waters within the vadose zone would generally not qualify as part of the ground-water regime.

GROUND-WATER FLOW SYSTEM (GROUND-WATER SYSTEM) - A body of circulating ground water having a water-table upper boundary and ground-water flow divide boundaries along all other sides. These boundaries encompass distinct recharge and discharge areas unique to the flow system.

GROUND-WATER SYSTEM - See GROUND-WATER FLOW SYSTEM.

HYDRAULIC CONDUCTIVITY - The capacity of earth materials to transmit water.

HYDRAULIC GRADIENT - The change in STATIC HEAD per-unit-of-distance in a given direction.

HYDRAULIC HEAD GRADIENT - See HYDRAULIC GRADIENT.

PIEZOMETRIC SURFACE - See POTENTIOMETRIC SURFACE.

POTABLE WATER - Water that is safe and palatable for human use; concentrations of pathogenic organisms and dissolved toxic constituents have been reduced to safe levels, and it has been treated so as to be tolerably low in objectionable taste, odor, color, or turbidity.

POTENTIOMETRIC SURFACE (PIEZOMETRIC SURFACE) - An imaginary surface representing the STATIC HEAD of ground water and defined by the level to which water will rise in a well. The WATER TABLE is a particular potentiometric surface.

RECHARGE AREA - A recharge area is an area of land beneath which there is a net annual transfer of water through the vadose zone into the ground-water regime. The net recharge is manifested by an decrease in hydraulic heads with depth (i.e., downward ground-water flow from the water table).

SATURATED ZONE - A subsurface zone in which all the voids are filled with water under pressure greater than that of the atmosphere. This zone is separated from the overlying zone of aeration (unsaturated zone) by the WATER TABLE.

STATIC HEAD (HYDRAULIC HEAD) - The height above a datum plane of the surface of a column of water (or liquid) that can be supported by the static pressure at a given point.

STRESS (PUMPING STRESS) - Drawdown of water level and change in HYDRAULIC GRADIENT induced by pumping ground water.

SURFACE-WATER DIVIDE - The line of separation, or ridge, summit, or narrow tract of high ground, marking the boundary between two adjacent drainage basins, or dividing the surface waters that flow naturally in one direction from those that flow in the opposite direction.

TOTAL DISSOLVED SOLIDS (TDS) - The quantity of dissolved material in a sample of water determined either from the residue on evaporation by drying at 180°C, or, for waters containing more than 1,000 parts per million, from the sum of determined constituents.

UNCONFINED CONDITIONS - Exists when the upper limit of the aquifer is defined by the water table itself. At the water table, water in the aquifer pores is at atomospheric pressure.

UNSATURATED ZONE - See VADOSE ZONE.

VADOSE ZONE (ZONE OF AERATION) - A subsurface zone containing water under pressure less than that of the atmosphere, including water held by capillarity, and containing air or gases generally under atmospheric pressure.

WATER TABLE - The surface of a body of unconfined ground water at which the pressure is equal to that of the atmosphere.

WATER-TABLE GRADIENT - The change in elevation of the water table per unit of horizontal distance.

APPENDIX B

ALTERNATIVE OPTIONS CONSIDERED FOR DEFINING CLASSIFICATION KEY-TERMS AND CONCEPTS

TABLE OF CONTENTS

		Page
1.0	INTRODUCTION	B-3
2.0	CLASSIFICATION REVIEW AREA	B-4
3.0	CLASS I KEY TERMS AND CONCEPTS	B-5
3.1	Irreplaceable Source of Drinking Water	B-5
3.1.1	Substantial Population	B-5
3.1.2	Comparable Quality	B-5
3.1.3	Economic Infeasibility	B-6
3.2	Ecologically Vital Ground Water	B-7
3.3	Highly Vulnerable Ground Water	B-8
3.3.1	Alternative Approaches to Utilize Ground-Water Vulnerability Concept	B-8
3.3.2	Selection of a Methodology to Operationally Define Ground-Water Vulnerability	B-9
4.0	CLASS II KEY TERMS AND CONCEPTS	B-14
4.1	Current Source of Drinking Water	B-14
4.2	Potential Source of Drinking Water	B-15
4.3	Ground Water with Beneficial Uses Other Than Drinking	B-17
5.0	CLASS III KEY TERMS	B-18
5.1	Methods Reasonably Employed in Public Water Treatment Systems	B-18

1.0 INTRODUCTION

One phase of the process for preparing the Guidelines for Ground-Water Classification involved defining key terms and concepts related to the classification scheme. The Office of Ground-Water Protection and guidelines work group developed these definitions through an intensive analysis of alternative options. As described previously, each approach was examined with respect to its:

- stringency
- consistency with other programs, and the overall intent of the strategy
- flexibility for accommodating state and region-specific characteristics or concerns
- arbitrariness
- potential implementational difficulties or complexities

This Appendix documents those options which were considered during the development process, but not specifically highlighted for public consideration in these Draft Guidelines. The alternatives discussed are not necessarily poor approaches to the key issues and concepts. In fact, many are currently used very effectively by other Federal, State, and local programs. These options, however, were deemed less suitable for a classification system with nationwide, broad-spectrum application. Comments on these alternatives, especially in the case of the "vulnerability," "substantial population," and "economically irreplaceable" terms will, of course, be considered by the Agency in preparing the Final Classification Guidelines.

2.0 CLASSIFICATION REVIEW AREA

Prior to the development of the Classification Review Area concept, the Agency reviewed the methods used by states in designating classified segments for ground-water systems. These include the classification of aquifers, or portions of aquifers as defined by geology, water quality, and surface-water relationships. In addition, cones of influence of individual wells are mapped and classified by some states.

It was decided that these techniques are not appropriate for the EPA process, as they would involve in-advance classification of large areas, in some cases, hundreds of square miles in extent. The Strategy clearly establishes that classification at this scale is within the role of the states. A more limited scope of review which centers on the proposed activity or facility was found to be most consistent with EPA policy.

One option which was also considered included a range in variable radii for the Classification Review Area, using combinations of hydrogeologic characteristics such as ground-water velocity, or types of geology (e.g., karst or glacial till) specific to different regions of the country. The disadvantage of using a geology-based variable radius is the inconsistency of its use. Given that this is a method of approximation only, designation of too small a Classification Review Area could provide inadequate protection to interconnected ground-water resources.

Also considered was the use of activity-specific radii--for example, a different radius for landfills than for pesticide application or underground tank installation. This alternative was critiqued for several reasons. Most importantly, the Agency believed that use of activity-related criteria to define the Classification Review Area could result in a different classification being applied to the same ground water for different types of activities. The classification process is designed to avoid such variability whenever possible.

3.0 CLASS I KEY TERMS AND CONCEPTS

3.1 Irreplaceable Source of Drinking Water

3.1.1 Substantial Population (Option A)

Option A for "substantial population" takes into account a quantitative or semi-quantitative assessment of both public water systems and concentrations of private wells. This approach also takes into account the added burden of providing alternative drinking water to users not served by a centralized water supply.

This definition for substantial population provides two important advantages:

- It considers both central city and suburban/ rural settings (public water systems as well as private well users) and, therefore, makes ground water in both settings potential Class I waters.

- It is based on terms and thresholds defined by the Census Bureau, is compatible with publicly available census data, and incorporates terms that have been used to describe population settings by other Federal programs.

Another option for a "quantifiable" Option A which involved defining "substantial population" in relative terms, considering all populations served by public water systems within a state. This option would define a substantial population as one that is served by a public water system that is larger than, for example, at least 95 percent of the systems that are served by ground water in the state. Such a definition would ensure that, at a minimum, the largest system or systems in each state would qualify as serving a substantial population. One concern was that this might produce inconsistencies between states. Some possible conflict with the policy of giving "special" protection to areas with greatest communal risk (inherent in the Strategy) was also noted. It should be remembered that Option B for defining "substantial population" is more qualitative in nature.

3.1.2 Comparable Quality

The Agency considered a definition of "comparable quality" consistent with the Class III definition of "treatable," or having Total Dissolved Solids equal to or less than 10,000 mg/l, but was concerned over the possibility that alternatives might be considered acceptable replacements

although they deviate considerably from the quality of the current source or from the quality of water typically used for drinking in this Region.

3.1.3 Economic Infeasibility

Several alternative options considered for defining economic infeasibility under the "quantitative test" of Option A were assessed. One involved using the criteria developed by EPA'S Office of Drinking Water for evaluating excessive economic burden. This set of approaches would designate an alternative source as economically infeasible if:

- water bills to a typical user (a user who consumes about 100,000 gallons-per-year) will increase by more than $100 per year
- water bills to a typical user will increase to more than $300 per year
- the system investment (measured as undepreciated replacement costs) will increase by more than 100 percent.

Such options do not account for the community's ability to pay, a consideration of significant importance. Moreover, the dollar values set by the criteria are dated and have not been adjusted to account for inflation.

Another option considered for defining economic infeasibility would designate a source as infeasible if the cost to a typical user exceeds the amount paid by the upper five percent of all public water-system users in the state. This option accounts for ability and willingness to pay to some extent. Judgments are based, however, on data describing water costs (rather than household income) statewide. The measure of ability or willingness to pay is, therefore, indirect. This measure is also less accurate than the selected approach because statewide water rates do not always reflect the true cost of the water. Subsidies from state or local governments and economies of scale may cause rates paid by users to be lower than actual costs.

A third approach considered was an evaluation of economic feasibility on the basis of a comprehensive cost and benefit analysis. This option would require a much more data-intensive and complex analysis than any of the other options considered. More important, the Agency noted that a cost/ benefit analysis would necessarily give explicit consideration to the type of activity motivating the classi-

fication decision, contrary to the intent of the Ground-Water Protection Strategy. It should be remembered that Option B for determining "economic irreplaceability" is more qualitative in nature, but could utilize some of these specific measures as appropriate.

3.2 Ecologically Vital Ground Water

Several alternative options were considered, but not highlighted for public comment, within the definition of an ecologically vital area. These included:

- Designating all discharge areas as ecologically vital ("all discharge areas" option)

- Designating ground-water discharge areas as ecologically vital if they contain an endangered or threatened species, or a management area designated for ecological protection by a Federal, State or local agency ("any protected ecosystem in a discharge area" option)

- Using critical habitats instead of all habitats of endangered species ("critical habitats" option).

The "all discharge areas" option was attractive, in that it would be relatively uncomplicated to implement and would serve to define both key terms, sensitive ecological system, and unique habitat. The Agency, however, perceived that it would result in a very large number of Class I designations, which is not in keeping with the intent of the Ground-Water Protection Strategy. More important, not all discharge areas are associated with truly unique habitats.

The " protected ecosystem in a discharge area" option was judge be an exceedingly comprehensive approach, accommodating currently existing ecological protection programs at all levels of government. However, extensive research would be required to identify the universe of such protected areas, and many inconsistencies exist from program to program and from state to state.

To clarify the "Critical Habitats" option, the reader should be aware that Critical Habitat areas are designated for some endangered or threatened species, and range from less than one square mile to thousands of square miles. Specific locational information is available in the Federal Register and Code of Federal Regulations for each of these areas. Use of Critical Habitats alone was considered unworkable for several reasons. Pursuant to the Endangered Species Act of 1973, equivalent protection must be afforded

to all habitats, not just Critical Habitats. Many truly endangered species lack Critical Habitat designations. Although, at the present time, Critical Habitats are assigned on a routine basis when species become endangered, this was not the case at the inception of the program. Under extreme circumstances, Critical Habitats are intentionally not delineated to avoid publicizing an especially sensitive species. Limiting unique habitats to only the designated Critical Habitats would leave the habitats of many endangered and threatened species without Class I protection.

3.3 Highly Vulnerable Ground Water

With respect to ground-water vulnerability to contamination, options for both basic utilization and operational standpoints were examined. The Agency is requesting comment most specifically on the latter, although the choice of operational definition will have an impact on the overall concept use.

3.3.1 Alternative Approaches to Utilize the Ground-Water Vulnerability Concept

Two alternative approaches were considered for utilizing the ground-water vulnerability concept. Both were based on the concept that vulnerability is dependent upon the nature of the activity. This concept has validity in two respects. First, different kinds of activities will involve wastes of contrasting hazard. For example, hazardous wastes disposed of within a RCRA landfill present a significantly greater health risk upon direct contact than some mining wastes. Second, different kinds of activities have contrasting design and operating features. Consider the comparison of land treatment versus underground injection (via a deep well) of secondarily treated municipal waste waters. Some activities take place within the ground water medium and others take place well above the ground-water table. Thus, an approach employing this concept would provide a greater activity-specific picture of the potential for contamination to occur.

The first alternative considered would have incorporated an activity-dependent vulnerability concept, requiring the development of specialized operational methodologies for defining vulnerability for different activities. The Agency found two major disadvantages for this approach. First, under an activity-dependent vulnerability concept, the same ground water would likely be placed into different classes where different activities take place or are proposed in the same vicinity. Ground water could be vulnerable to one activity and not the other. It might lead to confusion in

the regulated community, and the public at large, to find that the class of ground water changes with each activity. Secondly, the effort and time to develop specialized operational methodologies for each activity would be substantial.

The second alternative considered involved removing vulnerability as a class-determining factor. Each EPA program would, at its option, establish activity-specific operational definitions for vulnerability as might be needed for implementing management strategies. The principal advantage is that the class of ground water would consistently reflect the current and potential use of the resource. Specific operational definitions would then not need to be developed and tested as part of the OGWP classification program. One major disadvantage was raised, in addition. Ground-water vulnerability to contamination was established in the Ground-Water Protection Strategy as an essential component to the Class I concept. If EPA had decided to consider removing vulnerability as a class-determining factor, then this very important concept would be lost.

3.3.2 Selection of a Methodology to Operationally Define Ground-Water Vulnerability

Five operational methodologies were considered to determine ground-water vulnerability (see Table B-1).

3.3.2.1 Qualitative Methodology

A descriptive/qualitative method establishes the vulnerability of hydrogeologic settings, based on concepts of terrain lithology or hydrogeologic functions, as expressed in a few well chosen, technical words. Examples of highly vulnerable settings might include areas of karst terrain or ground-water recharge areas. Examples of low vulnerability may be discharge areas or confined aquifers. The general procedures to implement such a method would be to either match a candidate, real setting to a "standard setting," or to provide a map showing their location. While no quantitative criteria would necessarily be set, this type of method, when implemented, will result in the establishment of "precedent criteria" whenever a specific site is accepted or rejected.

3.3.2.2 Single Factor Methodology

The single factor method would employ a single quantitative criterion to all hydrogeologic settings. For example, areas with a depth to water of less than 150 feet could be considered highly vulnerable to contamination. The

TABLE B-1
SUMMARY OF OPERATIONAL METHODS FOR DEFINING THE KEY TERM
"HIGHLY VULNERABLE" GROUND WATER

METHODS	EXAMPLES OF "HIGHLY VULNERABLE"	COMMENTS
1. Qualitative description of highly vulnerable hydrogeologic settings	Highly vulnerable settings: a. unconfined aquifers overlain by sandy, highly permeable soils, or b. karst terrain, or c. ground-water recharge areas	Simple to use; requires judgement to match real settings to qualitative descriptions and a need for lengthy process to inventory descriptions of hydrogeologic settings judged to be highly vulnerable.
2. Single independent factor and criteria.	Vadose zone thickness less than 150 feet <u>or</u> hydraulic conductivity $>1 \times 10^{-4}$	Simple to use; difficult to establish single criterion which is realistically applicable across the country.
3. Multiple independent	Vadose zone <150 feet, hydraulic conductivity $>1.0 \times 10^{-4}$ cm/sec, <u>and</u> recharge >5 inches per year	Improvement over single factor; in use by States; assumes each factor equal weight; assumes failure to meet any factor criterion will result in a determination of highly vulnerable; interrelationships between factors is ignored.
4. Numerical rating (weighted and non-weighted). For example, DRASTIC, a rating scheme developed by the National Water Well Association (Aller et al, 1985); other examples: . The hazard-ranking system for CERCLA (40 CFR 300, Appendix A); and . Legrand's standardized system for evaluating waste-disposal site (Legrand, 1980).	DRASTIC index greater than 150 over CRA	A more sophisticated method allowing for factor weighting and a single score or index. Weighted factors are added. States often moved in this direction after considering multiple factor approach; provides for professional judgment in selecting specific ratings; sometimes critized for being too "simplistic" for site-specific geotechnical assessment
5. Integrative criterion. Time-of-travel for a selected distance or time to reach an exposure point.	Average time-of-travel greater than 1/2 foot per day over CRA	Allows for factor weighting and a single score. Considers the interrelationships between factors. Very data intensive. Yields a single score. Not suited to mapping large areas.

fatal flaw to this method is the selection of a single quantitative factor to represent highly vulnerable conditions that can be applied across the country and its various hydrogeologic settings.

3.3.2.3 Multiple Factor Methology

The method of listing multiple independent-criteria is commonly applied in state programs for the location of hazardous-waste facilities and other facilities used for the disposal of noxious wastes. The principal drawback is the lack of consistency in these criteria among states. This method also has the disadvantage of not being able to weigh each factor according to their relative importance for contaminating ground-water. In addition, it sets a criterion that must be met for each factor. The approach is inflexible, in that a poor rating for one factor cannot be balanced against a superior rating of another factor to achieve an average acceptable rating. This balancing is important because ground-water transport and leaching potential are not additive processes, but are multiplicative.

3.3.2.4 Numerical Rating Methodology

The numerical rating methodology is an extension of the multiple independent factor criteria listing method. In addition to establishing multiple factors, the range for each factor is subdivided and assigned relative numerical ratings. An example concerns the depth-to-water factor in DRASTIC (Aller, et al, 1985) shown in Table B-2. The numerical factor ratings can be multiplied by weight in order to reflect the relative importance of factors. Finally, the factor ratings, or weighted factor ratings, are added to give a final score. The selection of factors follows the same reasoning as discussed for the multiple factor method. Under this type of method, only a criterion for the final score is established. As long as the final score criterion is met, there are no limits assigned to any factors.

Hybrids of a numerical rating method and multiple factor method, or more sophisticated types of standards, are also possible. For example, minimum criterion can be established for critical factors. In addition, factor ratings may be multiplied or divided by other factor ratings to better approximate interrelationships between those factors.

The principal advantages of a numerical rating method include those presented for the multiple factor method, plus factor weighting. These systems are relatively easy to implement, depending upon the difficulty of measuring the

TABLE B-2
RANGES AND RATINGS FOR DEPTH TO WATER
AS USED IN THE NUMERICAL RATING SYSTEM DRASTIC
(ALLER, ET AL, 1985)

Depth to Water (feet)	
Range	Rating
0 - 5	10
5 - 15	9
15 - 30	7
30 - 50	5
50 - 75	3
75 - 100	2
100+	1
Weight: 5	

factors selected. Factor weighting allows for the more important factors to be distinguished. This method also allows for compensation between factors, a low score in one factor may be offset by a high score in another factor.

The disadvantages are essentially the same as those of a multiple factor method. The factor weights, when used, will be somewhat subjective. The typical approach to assigning weights is to poll the "experts" and establish a consensus value. Weights assigned in one region may not work very well in other regions. The selection of a cut-off value for highly vulnerable will also have a limited technical basis.

3.3.2.5 Integrative Methodology

Integrative methodologies are often considered the most sophisticated, since they can represent the interaction and relative importance of the various hydrogeologic factors. The Office of Solid Waste is investigating a time-of-travel criterion as part of hazardous-waste land disposal siting requirements. The high-level radioactive waste (HLW) program within the Department of Energy has established a time-to-exposure criterion. The disadvantage of the integrative methods (for localized vulnerability assessments) is the need for accurate, site-specific data, usually requiring a detailed hydrogeological investigation. This presents conflicts with lower-risk activities where high cost investigations are typically not performed. In addition, the integrative methods are less suited to mapping purposes should states be interested in building upon EPA's system.

As a final note, Option B for determining vulnerability opens up the use of any or all of these approaches, depending on site and decision specificity. It is considered a "qualitative" option since the Agency would not provide specific recommendations on preferred methods, cutoffs, etc.

4.0 CLASS II KEY TERMS AND CONCEPTS

4.1 Current Source of Drinking Water

Several alternative options were considered within the definition of current source of drinking water. These were based upon:

- Occurrence of multiple wells in the Classification Review Area ("multiple well" option)
- Exceedance of a specified ground-water production level in the Classification Review Area ("exceeding a production level" option)
- Application of intensive management practices, or evidence of regional stress in the Classification Review Area ("intensive management or stress" option).

The multiple well option is an expansion of the "one-well" option that is highlighted for public comment. The determination of a current source of drinking water would be based upon the presence of two or more wells and would result in a more restrictive current-source subclass and increase the size of the potential-source subclass. This option would have created a bias against the more sparsely populated rural areas. The philosophy of the Agency is that, if a source is being used as drinking water by even one family, it should be classified and protected as a current source of drinking water.

The "exceeding-a-production level" option looks at the volume of drinking water being pumped, rather than a set number of wells. The intent of the option was to screen out little-used aquifers from the current source of drinking-water designation. This option was not highlighted for public comment for the same reasons as the multiple-well option.

The "intensive management or stress" option would focus on areas which are controlled through ground-water management agencies, or are exhibiting pumping stress (e.g., persistently falling water levels). This approach by itself could overlook a large number of other sources of drinking water that are not managed for ground-water withdrawal, or are not under stress.

4.2 Potential Source of Drinking Water

Several other options were considered for the definition of "potential source of drinking water." These included:

- Stricter water-quality criteria
- Non-quantitative yield criterion
- Specific water-quality data needs
- Socioeconomic considerations.

The "Stricter Water-Quality Criteria" option would have adopted the Federal primary drinking-water-quality standards, in addition to the selected TDS cutoff. This was viewed as an attractive approach because it addresses levels of specific toxic contaminants. However, it was deemed to be overly restrictive since many ground waters that do not meet primary drinking water standards are treatable. Also, it is hard to "prove" they meet the MCLs.

The "Non-Quantitative Yield Requirements" option would have set no minimum yield to qualify as a potential source. The Agency decided, however, that areas do exist where yields are insignificant, however rare, and, therefore, must be considered in order that the classification system be complete.

Since ground-water quality data are not consistently available for all areas or regions, the issue of data needs for classification was carefully examined. One option studied was to require a ground-water quality test for classification. This approach would result in the most accurate quality assessment of the potential for the ground water to serve as drinking water, but was considered to be unnecessarily burdensome for most activities.

The "Socioeconomic Considerations" option would base the determination of potential drinking water on socioeconomic criteria. Some water is potentially drinkable, but may never be used because it is too costly to retrieve, not available because of institutional constraints, or is in an area in which development is unlikely. This approach was rejected because it was judged difficult to implement and not highly workable, since economic and institutional trends are often difficult to predict. Also, the test is too complex for the baseline of protection in Class II.

TABLE B-3
BENEFICIAL USES OF GROUND WATER
OTHER THAN FOR DRINKING WATER

A. MUNICIPAL	. fire protection . district heating . landscaping . blending
B. AGRICULTURE	. irrigation . livestock . frost protection . blending
C. INDUSTRY	. heating/cooling . process water . blending
D. MINING AND ENERGY DEVELOPMENT	. mineral . geothermal . hydrocarbon
E. ENERGY PRODUCTION	. power plants . heat pumps
F. ECOLOGICAL (NON-CLASS I)	. baseflow . heat pumps
G. STORAGE/WASTE DISPOSAL	. disposal of waste and treated waste water effluent . surplus fresh water management
H. RECREATION	. swimming pools (indirect) . golf courses . ice skating (indirect)
I. PASSIVE USES	. physical support for earth structures . impedance of subsidence and salt-water intrusion

4.3 Ground Water with Beneficial Uses Other Than Drinking

Within the context of "other beneficial use" (OBU), several options were considered but not adopted. These included:

- Providing a separate subclass within Class II for OBU
- Consideration of specific OBUs v. all OBUs as a group
- Giving more protection to ground water with dual uses.

The idea of creating a third subclass under Class II for ground waters with other beneficial uses (Table B-3) was not adopted for several reasons. First, the existing current and potential source of drinking-water subclasses appears to provide sufficient protection for the majority of OBUs. Second, most OBU ground waters would have a dual role as a current or potential source of drinking water, and would be afforded the protection given to drinking water as the highest and best use. Third, it would be difficult to assess the protection that should be afforded for OBU ground waters as a general subclass, because quality, yield, and other requirements are so varied among the many different uses and between regions.

Because EPA does not intend to use different management practices according to the various other beneficial uses of ground water, the Agency judged the consideration of specific OBUs to be unnecessary. In addition, the selection, definition, and determination of resource value of OBUs would be difficult national scale, since resource values and uses vary cons ly within a region. Some states are reviewing specific OB subclasses for agricultural or other purposes. This is an ideal approach for tailoring ground-water protection at the state level, though it was deemed impractical to adopt some number of subclasses for OBUs on a nationwide basis.

The Agency considered providing a higher level of protection to drinking water, which is also being used for selected OBUs. This approach was considered to be less feasible on a national scale since resource values and uses vary widely.

APPENDIX C

SAMPLE APPLICATIONS OF THE CLASSIFICATION PROCEDURES

SAMPLE APPLICATIONS OF THE CLASSIFICATION PROCEDURES

The following case studies are presented to illustrate the central classification concepts and use of the various classification procedures. Individual case studies are presented in a systematic fashion in accordance with the Classification Procedural Chart (Figure 4-1) and associated worksheet (Table 4-1) - instructions or questions are posed followed by the corresponding information with subsequent directives, or a final class determination. The general format for the case studies begins with a presentation of the preliminary information and concludes with the completion of the Classification Worksheet.

Each case study has been modeled after real activities and physical settings. Data sources have been generalized to avoid identification of the specific site under examination. The particular activity under consideration has also been omitted since classification is essentially independent of the activity type. Place names and localities have been disguised, but my be recognizable to a familiar reader. Costs and other figures used in these case studies are hypothetical. It should also be noted that the final classification decision presented in each case study does not represent the Agency's determination for the real activity from which the case study has been developed since some factors were changed for the purposes of this review. A summary of case studies and related issues addressed in each case is presented in Table C-1.

TABLE C-1
MATRIX OF CASE STUDIES AND RELATED ISSUES

Case Number	Ecologically Vital	Irreplaceability	Substantial Population	Vulnerability	Current Source	Potential Source	Treatability	Interconnection	Subdivided Classification Review Area	Expansion of Classification Review Area	Ground-Water Class Determination
1					X						IIA - Current Source
2						X		X	X		IIB - Potential Source
3						X					IIB - Potential Source
4					X					X	IIA - Current Source
5								X	X		IIIB - Low Interconnection
6							X	X	X		IIIA - Moderate Interconnection with Adjacent Ground Water Units/High Interconnection with Surface Water
7		X	X	X							I - Irreplaceable
8						X		X	X		IIB - Potential Source
9	X			X							I - Ecologically Vital
10			X	X	X						IIA - Current Source
11	X			X						X	I - Ecologically Vital

CASE STUDY 1

Introduction

The following case study is an example of a Class IIA-Current Source of Drinking Water. The standard Classification Review Area, defined by a two-mile radius from the proposed facility, is used in this example. Although a substantial population is involved, the Classification Review Area is not highly vulnerable to ground-water contamination.

Preliminary Information with Respect to the Classification Review Area

General

A permit application is being submitted for a site located in the Eastern United States, east of the City of Hilton Heights. Land use in the area is primarily rural farmland interspersed with chemical industries. The Classification Review Area is shown in Figure C1-1.

Maps provided in this case study were developed from U.S. Geological Survey quadrangle sheets. Text information was collected from ground-water availability studies conducted by the county, U.S. Geological Survey reports, and from U.S. Census Bureau statistics.

Geology/Hydrogeology

The stratigraphic sequence of geologic units regionally present is, in descending order (Figure C1-2):

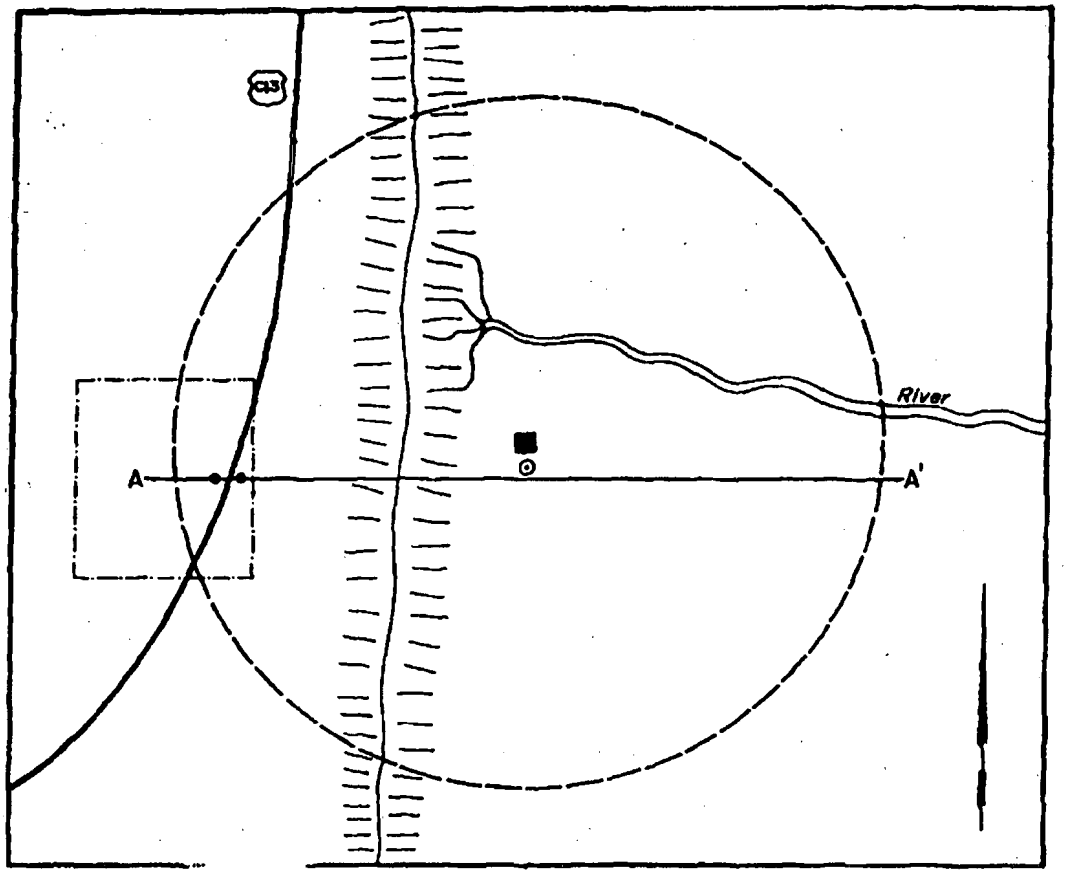
- Umber Formation - silty sand
- Hunter Formation - clay
- Toth Formation - sandstone
- Crystalline igneous and metamorphic bedrock.

The major aquifers in the area are the Umber and Toth Formations. The Hunter Formation is known to be an unfractured, laterally continuous aquitard.

Well/Reservoir Survey

Two large capacity water-supply wells, screened in the Umber aquifer and registered with the state, are located in the Classification Review Area. These wells provide public water supplies for the City of Hilton Heights, which, according to U.S. Census Bureau statistics, had a population of 3,700 persons in 1980.

FIGURE C1-1
BASE MAP ENCOMPASSING THE CLASSIFICATION REVIEW AREA

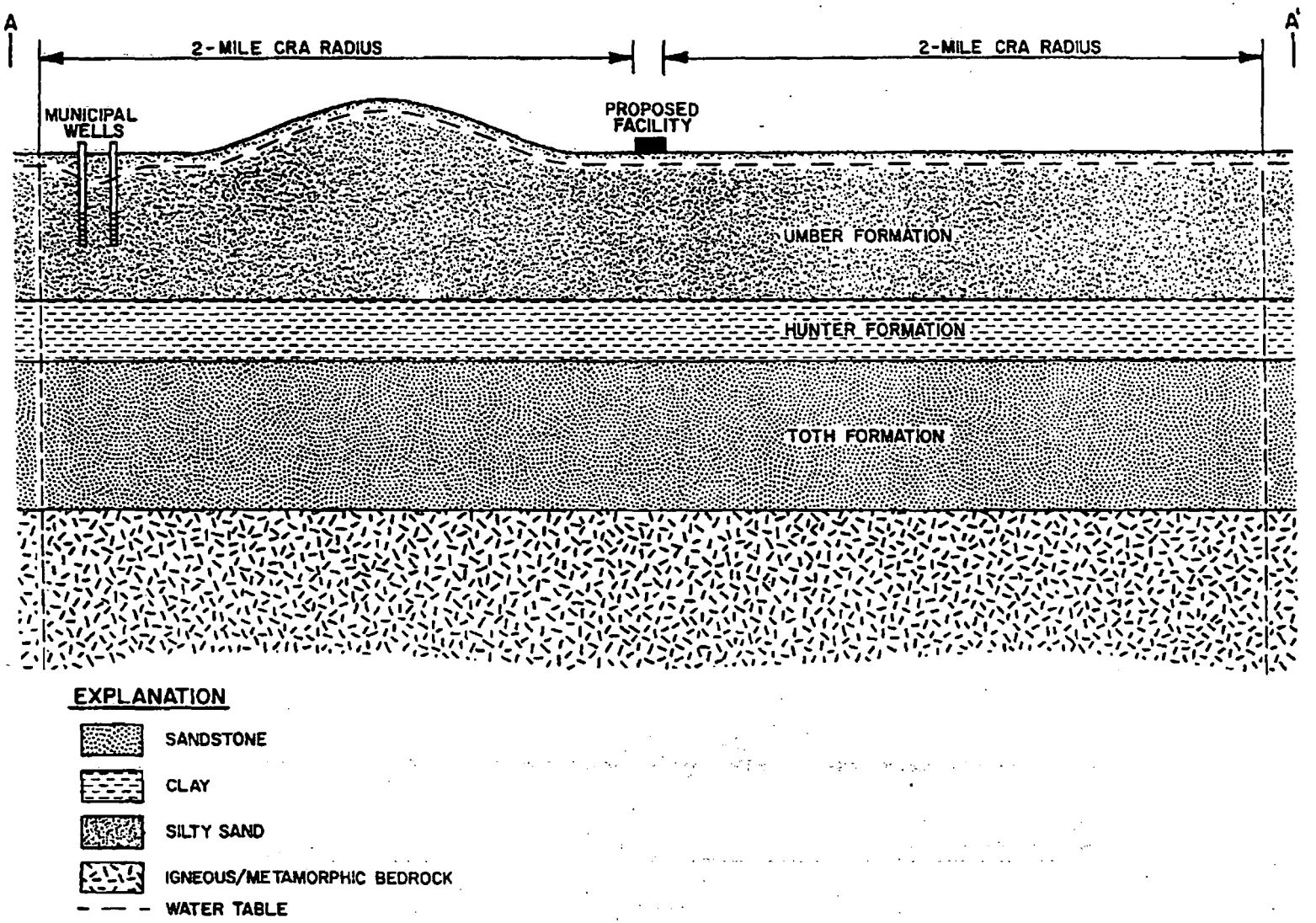


EXPLANATI

0 1 2 MILES

- PROF... ...ILITY
- CLASSIFICATION REVIEW AREA BOUNDARY
- INDUSTRIAL SUPPLY WELL
- MUNICIPAL SUPPLY WELL
- CITY LIMITS
- ROADWAY
- RIDGE

FIGURE C1-2
GENERALIZED CROSS-SECTION OF THE HYDROGEOLOGY WITHIN THE CLASSIFICATION REVIEW AREA



Additionally, if the proposed activity is permitted, a new well will be constructed at the site. This well will be screened in the deeper Toth aquifer.

No water-supply reservoirs are present in the Classification Review Area.

Demography

The City of Hilton Heights is located west of the proposed facility and has a population of 3,700. All residents are served by ground-water supplies, therefore the well field is considered to serve a substantial population under Option A. As no irreplaceability analysis was performed, the ground waters are assumed to be irreplaceable. Under Option B, the population is considered substantial by recognized experts given the demographics of the region.

Ecologically Vital Areas

U.S. Fish and Wildlife Service records indicate the Classification Review Area does not encompass any Federal lands designated for ecological protection or ecologically vital areas.

Vulnerability

Given that the irreplaceability of the ground waters is assumed, it is necessary to perform a vulnerability analysis for the area. Under Option A for determining vulnerability, DRASTIC is utilized with the following results averaged over the review area:

UMBER FORMATION	Rating	Weight	Number
. Depth to water - 15-30 ft	7	5	35
. Net recharge - approximately 20 in/yr	9	4	36
. Aquifer media - silty sand	6	3	18
. Soil media - loam	5	2	10
. Topography - 2-6%	9	1	9
. Impact of vadose zone media - sand with silt and clay	5	5	25
. Hydraulic conductivity - 100-300 gpd/ft^2	2	3	6
		DRASTIC Index (TOTAL)	139

This area is not considered highly vulnerable to ground-water contamination under Option A since the DRASTIC Index is less than 150.

Under Option B for determining vulnerability, two expert hydrogeologists in the area were consulted. The hydrogeologic setting of loamy soils overlying silty sand aquifers are considered "vulnerable" but not "highly vulnerable" by these experts.

Referring to the Procedural Chart shown in Figure 4-1 and associated worksheet in Table 4-1, the ground water is classified using the following steps:

Step	Question/Direction	Response/Comment
1	Establish Classification Review Area (CRA) and collect preliminary information. Optional - Demonstrate subdivision(s) of the CRA.	The CRA is defined by a two-mile radius from the proposed facility. No CRA subdivision has been performed.
2	Locate any ecologically vital areas in the CRA. Does the CRA or appropriate subdivision overlap an ecologically vital area? . Yes, go to next step . No, go to Step 4	No ecologically vital areas are present in the CRA.
4	Determine location of well(s) within the CRA or appropriate subdivision. Does the CRA or appropriate subdivision contain well(s) used for drinking water? . Yes, go to next Step . No, go to Step 8	Yes, two large-capacity water-supply wells are located within the CRA.
5	Inventory population served by well(s). Does the well(s) serve a substantial population? . Yes, go to next step . No, then the ground water is CLASS IIA-CURRENT SOURCE OF DRINKING WATER	Yes, under Option A, the population served exceeds the 2500-person threshold. Under Option B, the population is considered substantial by recognized experts given the demographics of the region.

Step	Question/Direction	Response/Comment
6	Unless proven otherwise, the drinking water source is assumed to be irreplaceable. Optional - perform irreplaceability analysis. Is the source of drinking water irreplaceable? . Yes, go to next step . No, then the ground water is CLASS IIA-CURRENT SOURCE OF DRINKING WATER	Yes, irreplaceability is assumed.
7	Perform vulnerability analysis. Is the CRA or appropriate subdivision a highly vulnerable hydrogeologic setting? . Yes, then the ground water is CLASS I-IRREPLACEABLE SOURCE OF DRINKING WATER . No, then the ground water is CLASS IIA-CU[illegible] SOURCE OF D[illegible]G WATER	No, under Option A, a DRASTIC index of less than 150 does not constitute a highly vulnerable hydrogeologic setting. Under Option B, the area is not deemed highly vulnerable by hydrogeologic experts.

FINAL CLASS DETERMINATION: CLASS IIA - CURRENT SOURCE OF DRINKING WATER

CASE STUDY 2

Introduction

This case study is a permutation of Case Study 1 leading to a Class IIB - Potential Source of Drinking Water classification. Although the preliminary information remains the same, the Classification Review Area has been subdivided to identify those ground-water units not highly interconnected with the ground-water unit directly beneath the facility. In this manner, we have attempted to illustrate how subdividing the Classification Review Area can alter the final ground-water classification. Subdivision of the Classification Review Area into ground-water units results in a class determination of potential source of drinking water rather than a current source.

Preliminary Information with Respect to the Classification Review Area

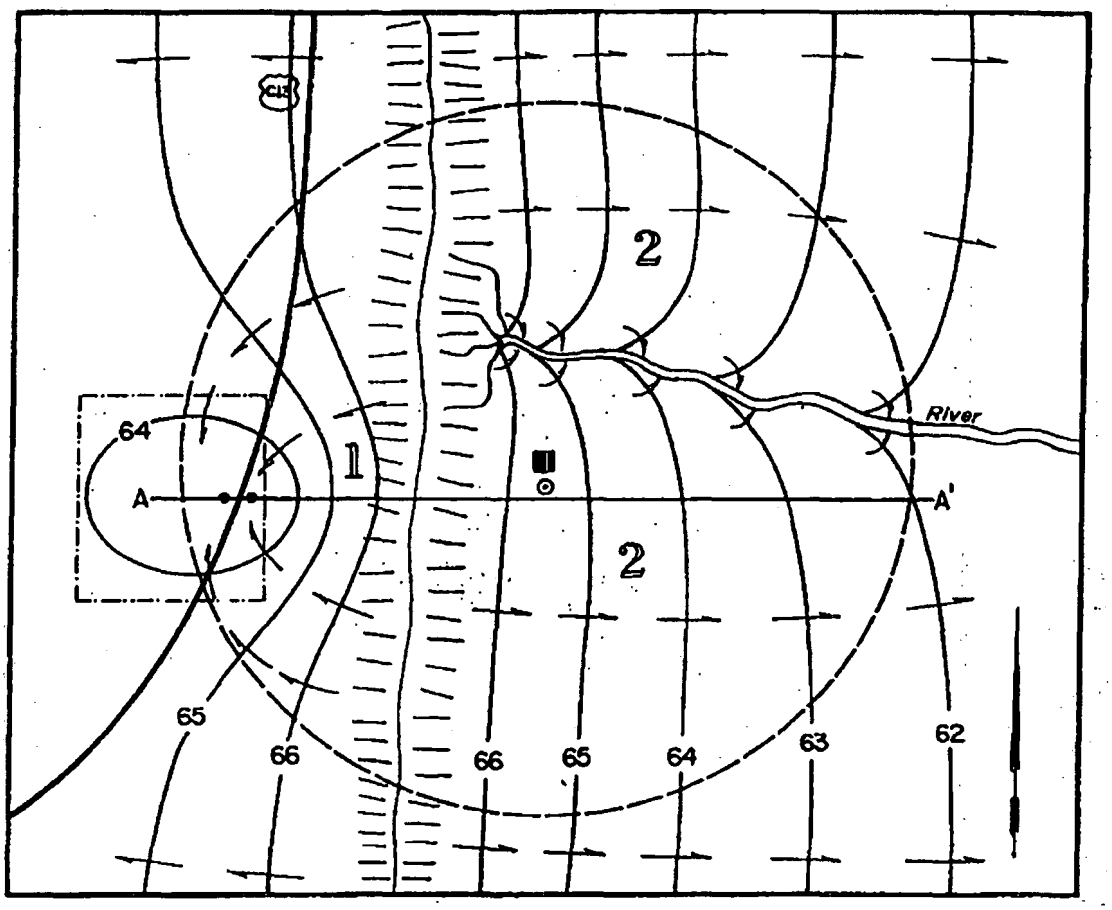
General

Material presented in Case Study 1 is not repeated. Figure C2-1 is a map of the water-table surface developed from U.S. Geological Survey and State Geological Survey well data and water-level measurements made specifically for this study.

Classification Review Area Subdivision (Interconnection)

Three ground-water units can be identified within the Classification Review Area (Figures C2-2 and C2-3). The topographic divide serves as a ground-water flow divide creating ground-water units 1 and 2 (Figure C2-2). Two large capacity water-supply wells, located in ground-water unit 1, provide public water supplies for the City of Hilton Heights. Under pumping conditions, the water pumped by the high-yield wells is derived from ground-water unit 1, resulting in displacement of the ground-water flow divide (Figure C2-2). The river, recharged by ground-water unit 2, does not serve as a ground-water flow divide. Regional investigations conducted by county hydrogeologists have shown that ground-water flow beneath the river occurs in the lowermost Umber Formation. The Hunter Formation, an unfractured, laterally continuous aquitard, restricts vertical flow between the Umber and Toth aquifers. Thus, a third ground-water unit can be identified and is confined to ground-water movement in the Toth aquifer.

FIGURE C2-1
MAP OF THE WATER TABLE



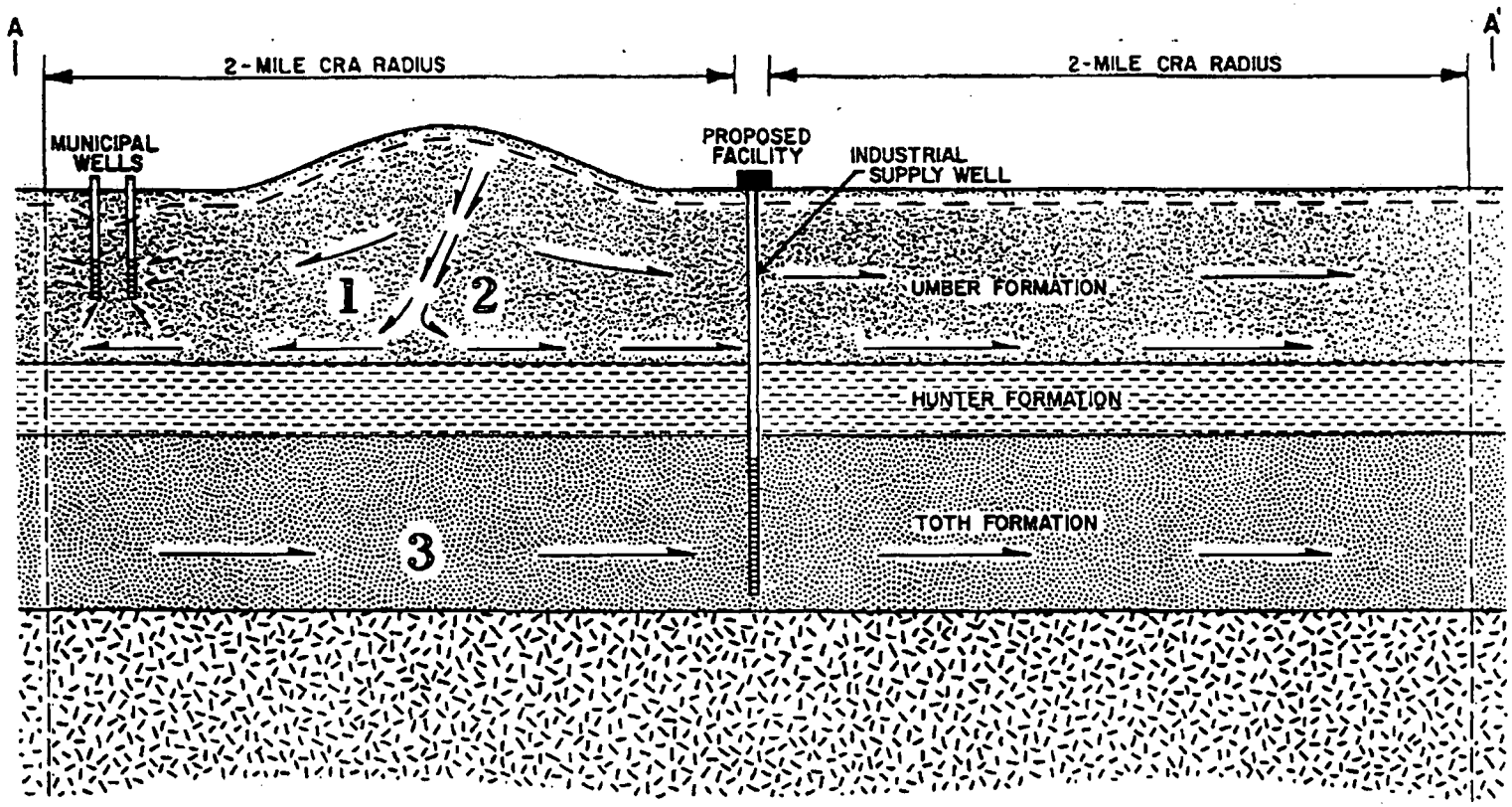
EXPLANATION

- PROPOSED FACILITY
- CLASSIFICATION REVIEW AREA BOUNDARY
- INDUSTRIAL SUPPLY WELL
- MUNICIPAL SUPPLY WELL
- CITY LIMITS
- ROADWAY
- RIDGE

0 1 2 MILES

- 2 GROUND-WATER UNIT NUMBER
- 63 WATER TABLE CONTOUR, IN FEET
- GROUND-WATER FLOW DIRECTION

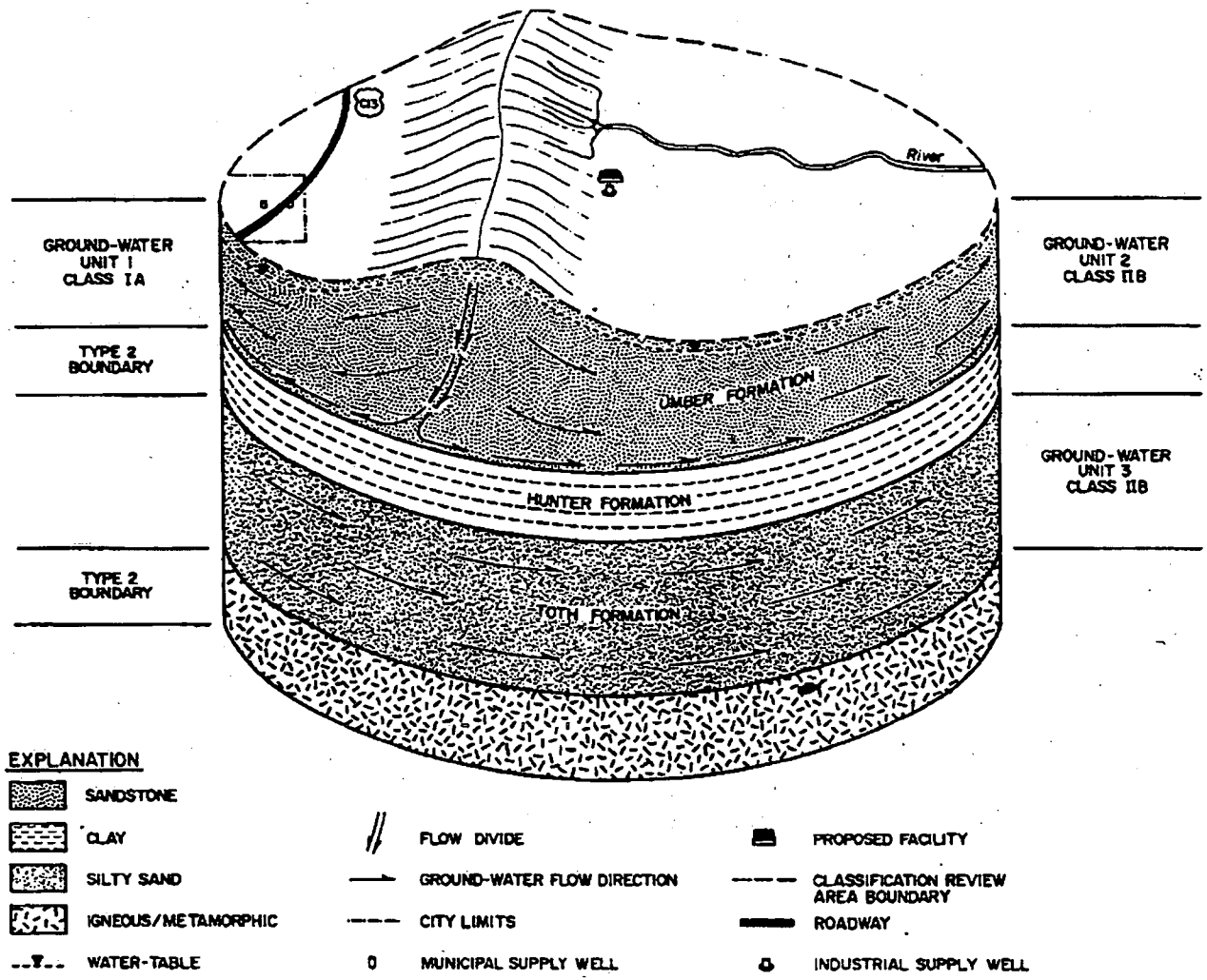
FIGURE C2-2
GENERALIZED CROSS-SECTION OF THE HYDROGEOLOGY WITHIN THE CLASSIFICATION REVIEW AREA



EXPLANATION

- SANDSTONE
- CLAY
- SILTY SAND
- IGNEOUS/METAMORPHIC BEDROCK
- WATER TABLE
- GROUND-WATER FLOW DIRECTION
- 2 GROUND-WATER UNIT NUMBER

FIGURE C2-3
THREE-DIMENSIONAL ILLUSTRATION OF THE HYDROLOGY AND GROUND-WATER UNITS WITHIN THE CLASSIFICATION REVIEW AREA



An intermediate degree of interconnection is demonstrated where a Type 1 boundary separates adjacent ground-water units and a Type 2 boundary with a low degree of interconnection is demonstrated due to the presence of an aquitard. Thus, it is possible to subdivide the Classification Review Area in order to restrict ground-water classification to the ground-water unit which is potentially affected by the presence of the proposed facility.

Potential contaminants entering the ground water from the facility would be transported in ground-water unit No. 2 and, ultimately, discharge to the river. The ground water classification decision is thus restricted to ground-water unit No. 2.

The following classification demonstration is limited to ground-water unit No. 2 located beneath the proposed facility. Classification of other ground-water units is not necessary.

Referring to the Procedural Chart shown in Figure 4-1 and associated worksheet in Table 4-1, the ground-water is classified using the following steps:

Step	Question/Direction	Response/Comment
1	Establish Classification Review Area (CRA) and collect preliminary information. Optional - Demonstrate subdivision(s) of the CRA.	The CRA is defined by a two-mile radius from the proposed facility. The CRA has been subdivided into three ground-water units. The ground-water classification decision is restricted to ground-water unit No. 2 located beneath the proposed facility.
2	Locate any ecologically vital areas in the CRA. Does the CRA or appropriate subdivision overlap an ecologically vital area? . Yes, go to next step . No, go to Step 4	No ecologically vital areas are present in the CRA.
4	Determine location of well(s) within the CRA or appropriate subdivision. Does the CRA or appropriate subdivision contain well(s) used for drinking water? . Yes, go to next Step . No, go to Step 8	No drinking-water wells are within ground-water unit No. 2.

Step	Question/Direction	Response/Comment
8A	Determine location of reservoirs within the CRA or appropriate subdivision. Does the CRA or appropriate subdivision contain reservoirs used for drinking water? . Yes, go to next step . No, go to Step 9	No reservoirs are present within the subdivided CRA.
9	Determine yield from ground-water medium (total depth across CRA or appropriate subdivision). Can it yield 150 gallons-per-day to a well? . Yes, go to next step . No, then the ground water is CLASS IIIA-NOT A SOURCE OF DRINKING WATER (INSUFFICIENT YIELD)	Yes, the ground-water medium is presumed to meet the sufficient yield criterion.
10	Determine water-quality characteristics within the CRA or appropriate subdivision. Is the water quality greater than 10,000 mg/l total dissolved solids (TDS)? (Note: If water quality is unknown then this question must be answered no.) . Yes, go to Step 12 . No, go to next step	No, the water-quality is unknown.

Step	Question/Direction	Response/Comment
11	Are the ground waters so contaminated as to be untreatable? (Note: If water quality is unknown then this question must be answered no.) . Yes, go to next step . No, then the ground water is CLASS IIB-POTENTIAL SOURCE OF DRINKING WATER	No, the water-quality is unknown.

FINAL CLASS DETERMINATION: CLASS IIB - POTENTIAL SOURCE OF DRINKING WATER

CASE STUDY 3

Introduction

This case study is an example of a Class IIB Potential Source of Drinking Water. The standard Classification Review Area, defined by a two-mile radius from the proposed facility, is used in this example. No drinking water wells are present within the Classification Review Area. Also absent are any ecologically vital areas.

Preliminary Information with Respect to the Classification Review Area

General

A permit application is being submitted for a site in the Armadillo Desert in the Basin and Range physiographic province. The standard Classification Review Area is shown in Figure C3-1. The U.S. Geological Survey characterizes the regional landscape as broad, open, relatively flat-floored valleys, separated by rugged mountain ranges. Valley-fill deposits are sands, gavels, and cobbles of local origin, transported to the site by alluvial and colluvial processes. Figure C3-2 is a generalized cross-section of the hydrogeology in the Classification Review Area determined from a limited number of borings.

The climate of the Armadillo Desert is characterized as arid. Average annual evapotranspiration exceeds average-annual precipitation by an order of magnitude; hence, the area is normally water deficient.

Well/Reservoir Survey

No ground water wells or drinking water reservoirs are present in the Classification Review Area (Figure C3-1). If the permit is approved for the facility to begin operation, bottled drinking water will be delivered to the site for employee use.

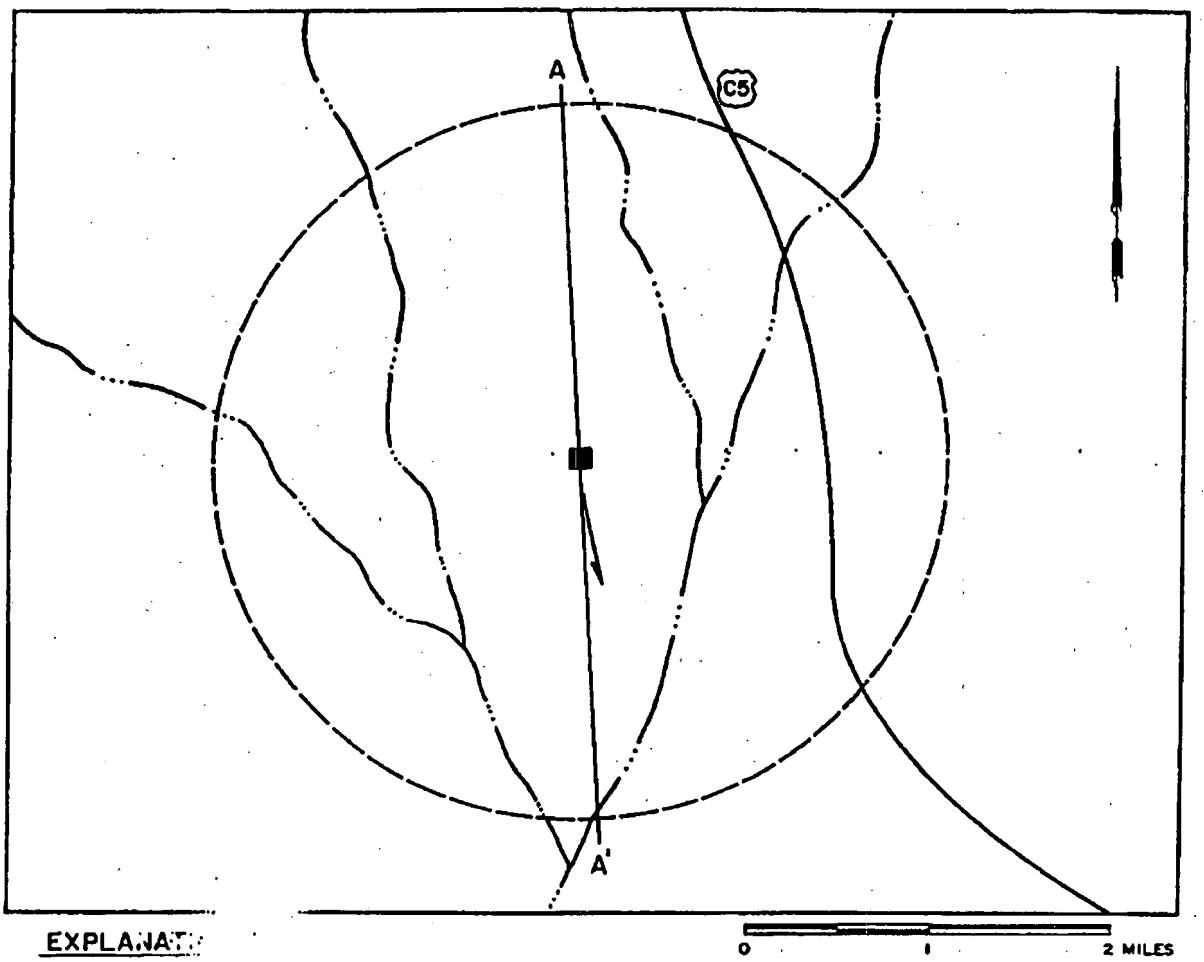
Demography

The nearest town is ten miles north of the proposed site and has an approximate population of 5,000. There are no known rural dwellings within a two-mile radius of the proposed site.

Ecologically Vital Areas

No ground-water discharge areas, or Federal lands designated for ecological protection, are present in the two-mile Classification Review Area.

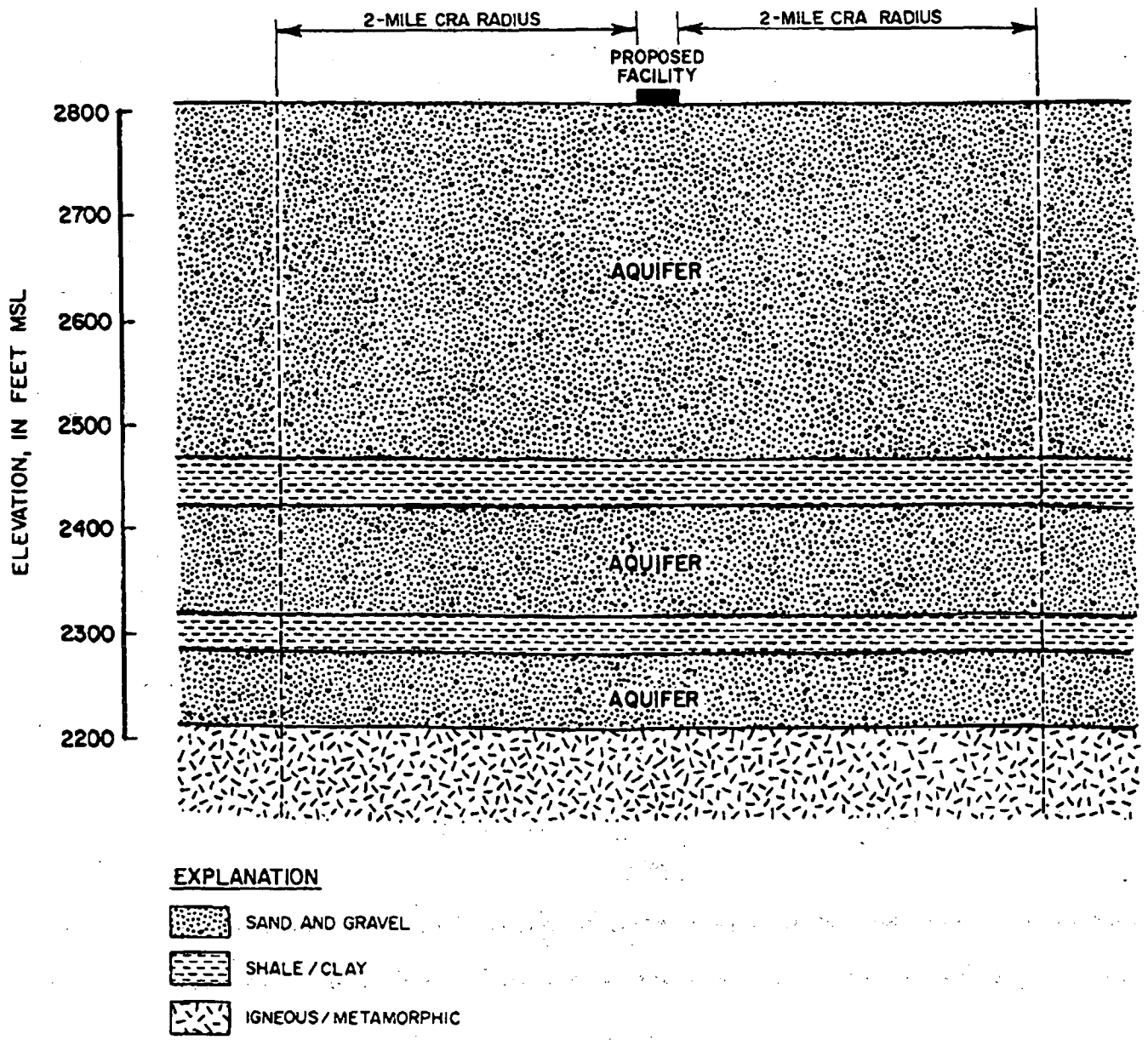
FIGURE C3-1
BASE MAP ENCOMPASSING THE CLASSIFICATION REVIEW AREA



EXPLANATION

- PROPOSED FACILITY
- CLASSIFICATION REVIEW AREA BOUNDARY
- INTERMITTENT STREAM
- GROUND-WATER FLOW DIRECTION
- ROADWAY

FIGURE C3-2
GENERALIZED CROSS SECTION OF THE HYDROGEOLOGY WITHIN THE CLASSIFICATION REVIEW AREA



Referring to the procedural chart shown in Figure 4-1 and the associated worksheet in Table 4-1, the ground water is classified using the following steps:

Step	Question/Direction	Response/Comment
1	Establish Classification Review Area (CRA) and collect preliminary information. Optional - Demonstrate subdivision(s) of the CRA.	The CRA is defined by a two-mile radius from the proposed facility. No CRA subdivision has been performed.
2	Locate any ecologically vital areas in the CRA. Does the CRA or appropriate subdivision overlap an ecologically vital area? . Yes, go to next step . No, go to Step 4	No ecologically vital areas are present in the CRA.
4	Determine location of well(s) within the CRA or appropriate subdivision. Does the CRA or appropriate subdivision contain well(s) used for drinking water? . Yes, go to next Step . No, go to Step 8	No drinking water wells are present in the CRA.
8A	Determine location of reservoirs within the CRA or appropriate subdivision. Does the CRA or appropriate subdivision contain reservoirs used for drinking water? . Yes, go to next step . No, go to Step 9	No, there are no reservoirs present within the CRA.

Step	Question/Direction	Response/Comment
9	Determine yield from ground water medium (total depth across CRA or appropriate subdivision). Can it yield 150 gallons-per-day to a well? . Yes, go to next step . No, then the ground water is CLASS IIIA-NOT A SOURCE OF DRINKING WATER (INSUFFICIENT YIELD)	Yes, in the absence of data, sufficient yield is assumed.
10	Determine water-quality characteristics within the CRA or appropriate subdivision. Is the water quality greater than 10,000 mg/l total dissolved solids (TDS)? (Note: If water quality is unknown then this question must be answered no.) . Yes, go to Step 12 . No, go to next step	No, water-quality characteristics within the CRA are unknown.
11	Are the ground waters so contaminated as to be untreatable? (Note: If water quality is unknown then this question must be answered no.) . Yes, go to next step . No, then the ground water is CLASS IIB-POTENTIAL SOURCE OF DRINKING WATER	No, water-quality characteristics within the CRA are unknown.

FINAL CLASS DETERMINATION: CLASS IIB - POTENTIAL SOURCE OF DRINKING WATER

CASE STUDY 4

Introduction

This case study was developed from Case Study 3 in order to demonstrate an expanded Classification Review Area for an alluvial setting. The classification decision with a two-mile Classification Review Area was Class IIB Potential Source of Drinking Water. No sources of drinking water were found in the two-mile Classification Review Area (Figure C4-1). An expanded review area as demonstrated in this case study may lead to a different classification decision.

Preliminary Information with Respect to the Classification Review Area

Expanded Classification Review Area

This setting is found in the alluvial basin ground-water region (after Heath, 1984) and based on the above information matches the conditions for an expanded Classification Review Area. These conditions are:

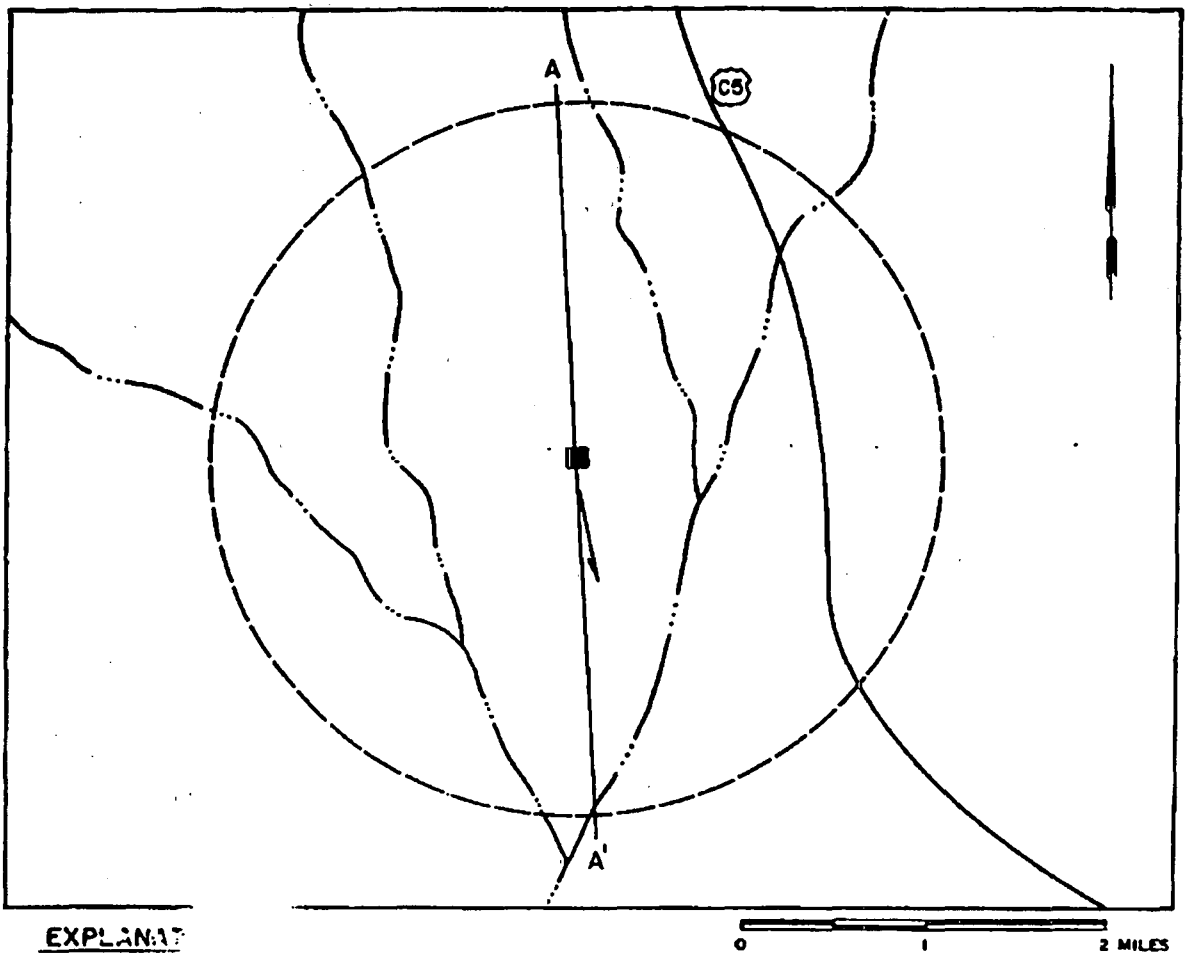
- An unconfined aquifer as the dominant aquifer
- Losing streams as the predominant source of ground-water discharge
- Transmissivities and flow velocities that are moderate to high (>250 m^2/d and >60 m/yr, respectively)
- Relatively low annual rainfall (less than 20 inches-per-year)

The expanded review area is based on a five-mile radius from the activity boundary. A five-mile radius was selected because calculation of ground-water velocities near the proposed facility was not possible due to a lack of information on ground-water gradients. Where velocity is known, the expanded review area radius is the distance water will flow in 50 years. Figure C4-2 shows the expanded review area.

General

A permit application is being submitted for a site in the Armadillo Desert in the Basin and Range physiographic province. The U.S. Geological Survey characterizes the regional landscape as broad, open, relatively flat-floored valleys, separated by rugged mountain ranges. Valley-fill

FIGURE C4-1
BASE MAP ENCOMPASSING THE TWO-MILE CLASSIFICATION REVIEW AREA



EXPLANATION

PROPOSED FACILITY

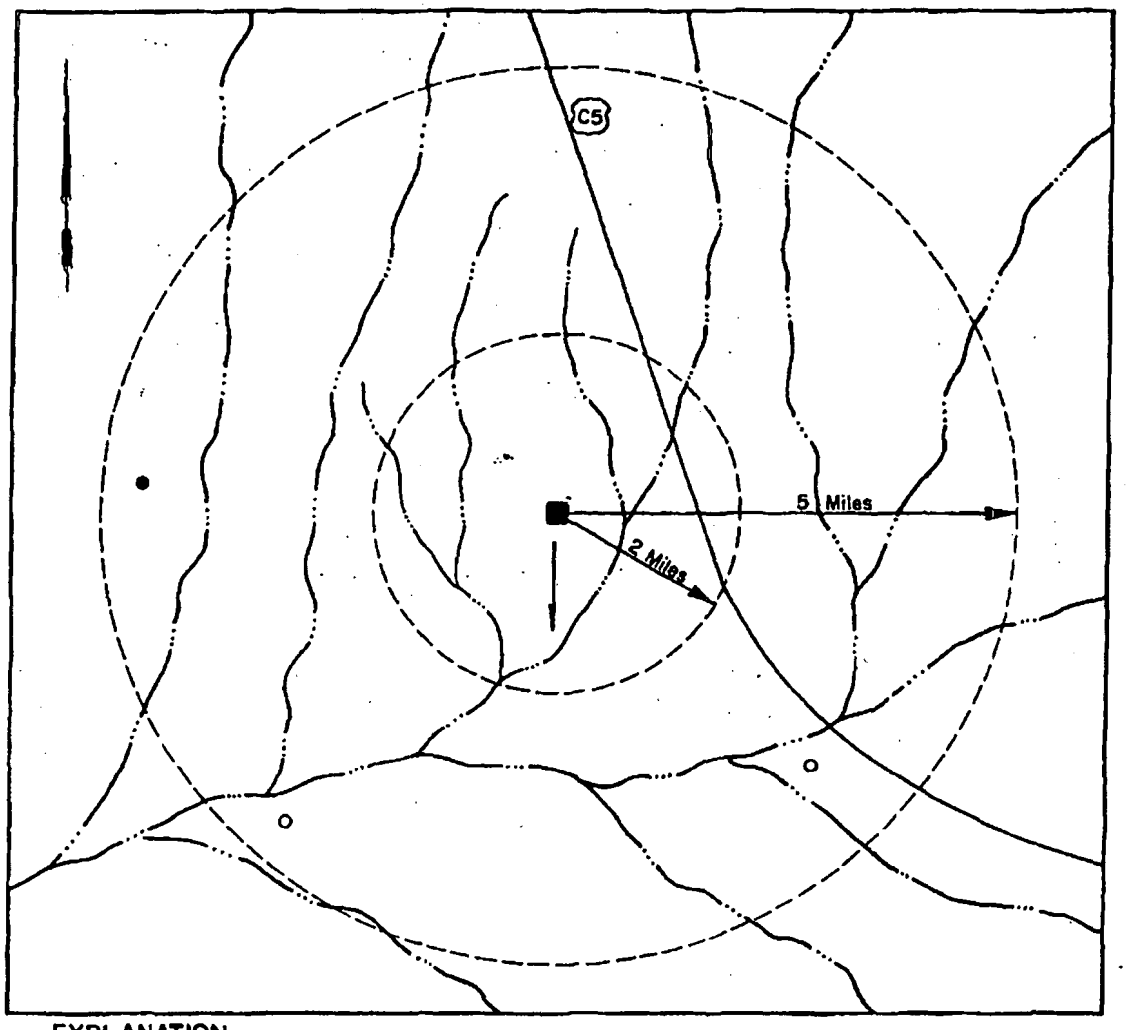
CLASSIFICATION REVIEW AREA BOUNDARY

INTERMITTENT STREAM

GROUND-WATER FLOW DIRECTION

ROADWAY

FIGURE C4-2
BASE MAP ENCOMPASSING THE EXPANDED CLASSIFICATION REVIEW AREA



EXPLANATION

- PROPOSED FACILITY
- CLASSIFICATION REVIEW AREA BOUNDARY
- INTERMITTENT STREAM
- GROUND-WATER FLOW DIRECTION
- ROADWAY
- RESIDENTIAL WELL
- IRRIGATION WELL

0 1 2 4 MILES

deposits are sands, gravels, and cobbles of local origin, transported to the site by alluvial and colluvial processes. A generalized cross-section of the hydrogeology within the five-mile Classsification Review Area was assembled based on a review of literature and well logs available for the region (see Figure C4-3). The uppermost aquifer is unconfined and has a transmissivity greater than 300 m^2/d.

The climate of the Armadillo Desert is characterized as arid. Average annual evapotranspiration exceeds average annual precipitation by an order of magnitude; hence, the area is normally water deficient. Ground-water recharge occurs primarily at the higher elevations as snow melt charged streams lose water into the ground.

Well/Reservoir Survey

No ground-water wells or drinking water reservoirs are present in the two-mile Classification Review Area. However, within the expanded Classification Review Area, there are two wells used for irrigation and one well used for water supply to a residence. If the permit is approved for the facility to begin operation, bottled drinking water will be delivered to the site for employee use.

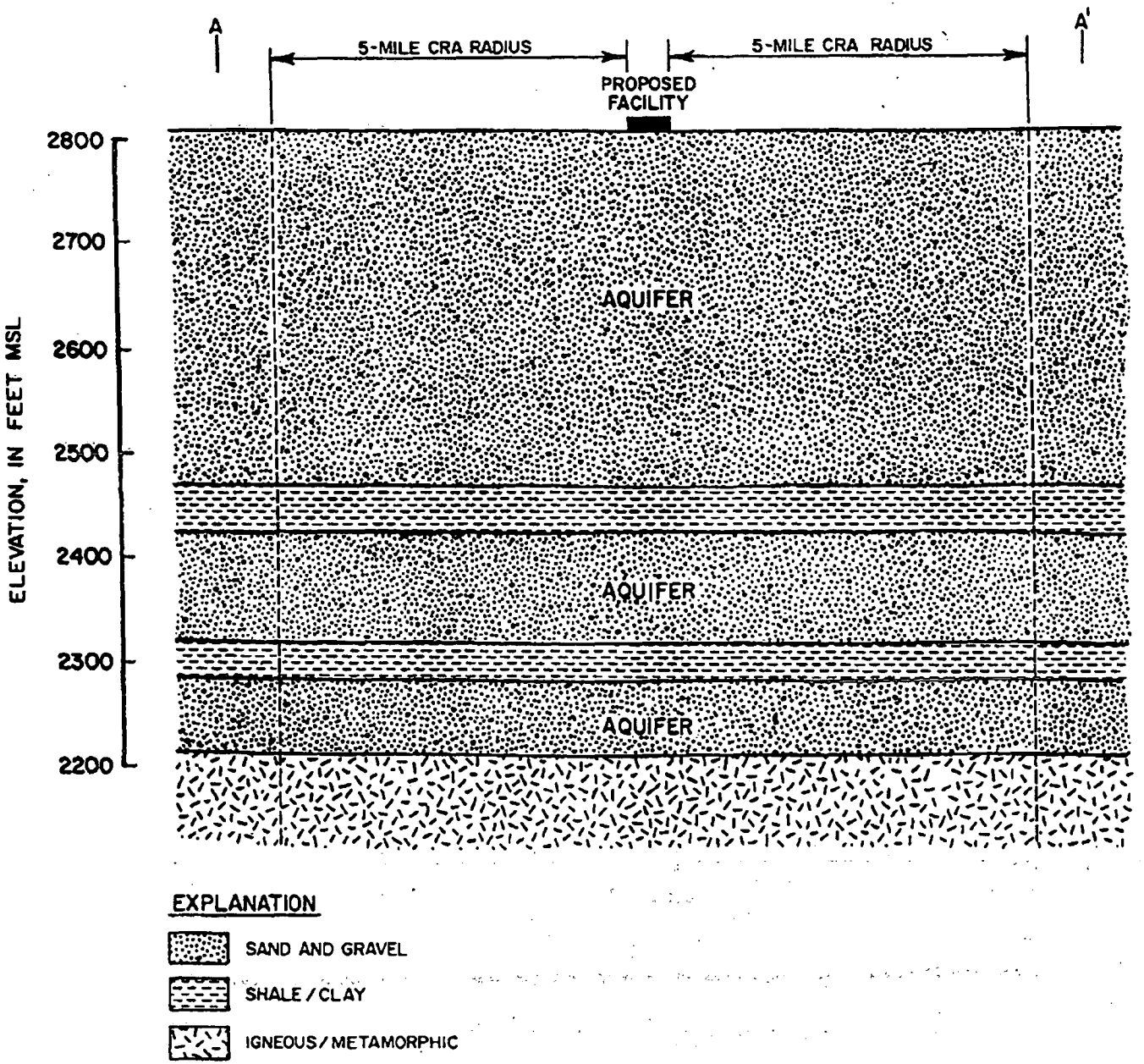
Demography

The nearest town is ten miles north of the proposed site and has an approximate population of 5,000. There are no known rural dwellings within a two-mile radius of the proposed site. There is one dwelling within the expanded review area.

Ecologically Vital Areas

No ground-water discharge areas, or Federal lands designated for ecological protection, are present in either the two-mile or expanded Classification Review Area.

FIGURE C4-3
GENERALIZED CROSS-SECTION OF THE HYDROGEOLOGY WITHIN THE EXPANDED CLASSIFICATION REVIEW AREA



Expanded Classification Review Area Decision

Referring to the Procedural Chart shown in Figure 4-1 and associated worksheet in Table 4-1, the ground water is classified using the following steps:

Step	Question/Direction	Response/Comment
1	Establish Classification Review Area (CRA) and collect preliminary information. Optional - Demonstrate subdivision(s) of the CRA.	The CRA has been expanded to a five-mile radius from the activity boundary because of an alluvial hydrogeological setting and a lack of information on ground-water velocities. No CRA subdivision has been performed.
2	Locate any ecologically vital areas in the CRA. Does the CRA or appropriate subdivision overlap an ecologically vital area? . Yes, go to next step . No, go to Step 4	No ecologically vital areas are present in the CRA.
4	Determine location of well(s) within the CRA or appropriate subdivision. Does the CRA or appropriate subdivision contain well(s) used for drinking water? . Yes, go to next Step . No, go to Step 8	Yes, one drinking-water well is present in the expanded CRA.
5	Inventory population served by well(s). Does the well(s) serve a substantial population? . Yes, go to next step . No, then the ground water is CLASS IIA-CURRENT SOURCE OF DRINKING WATER	No, the well does not serve a substantial population as determined by Option A.

FINAL CLASS DETERMINATION: CLASS IIA-CURRENT SOURCE OF DRINKING WATER

CASE STUDY 5

Introduction

Case Study 5 is an example of a Class IIIB - Low Interconnection ground water. This case is based on a permit application for underground injection of liquid wastes. The standard Classification Review Area, defined by a two-mile radius from the proposed facility, is used in this example. Subdivision of the Classification Review Area is exemplified below.

Preliminary Information with Respect to the Classification Review Area

General

A permit application is being submitted for underground injection of liquid wastes into the Emery Formation. Planning, zoning, and tax maps indicate land use in the area is primarily for farming and cattle production. The Classification Review Area is shown in Figure C5-1.

Geology/Hydrogeology

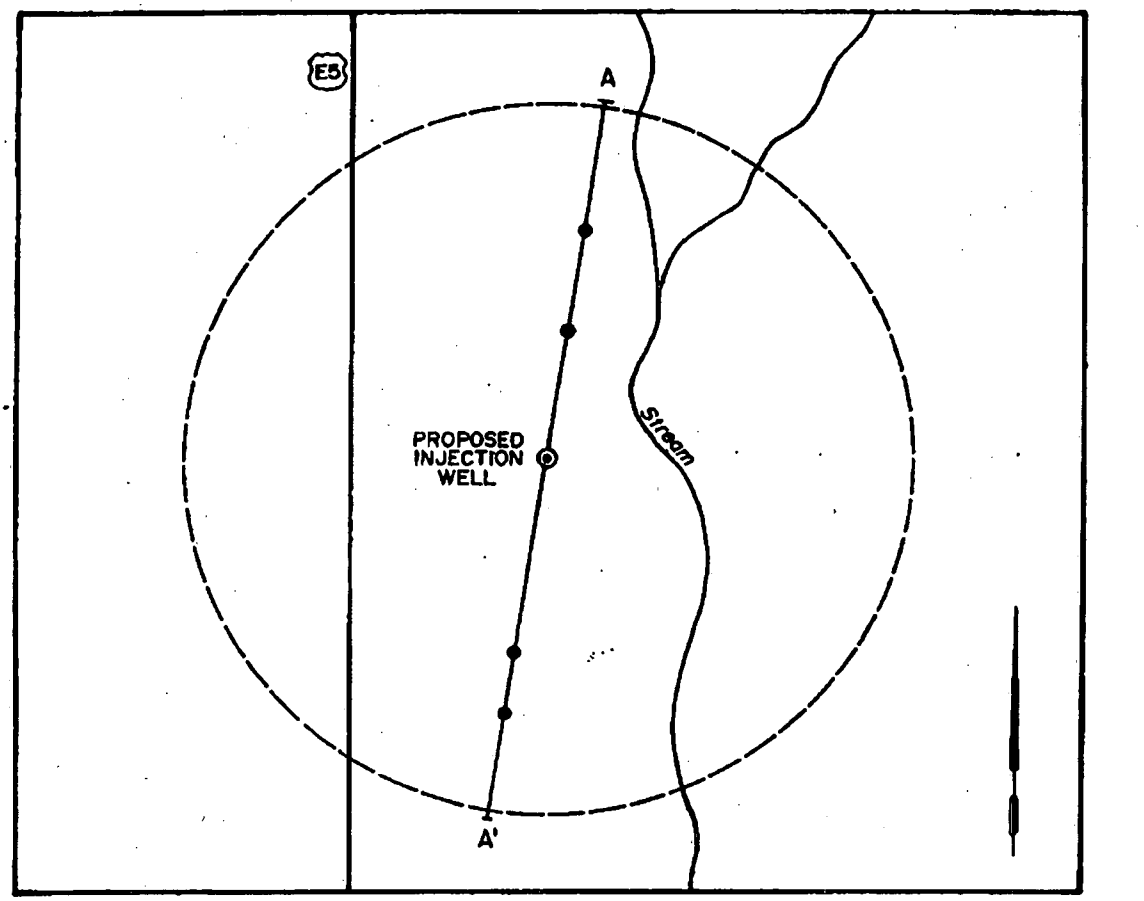
U.S. Geological Survey reports indicate the target formation for subsurface disposal is the lower ground-water unit (Emery sandstone) located at a depth of approximately 4,000 feet (Figure C5-2). Below this formation are basement rocks of quartzite, schist, and granite. The upper ground-water units are composed of flat-lying, alternating layers of dolomite, limestone, and sandstone.

The stratigraphic sequence shown in Figure C5-2 was developed [illegible] previous well logs taken during oil and gas exploratio[illegible] The stratigraphy encountered correlates with the stratigraphy in other parts of the basin and reflects the regional geology.

Water-quality samples were also taken during drilling. It was determined that ground water in the Emery Sandstone has a total dissolved solids content ranging from 12,000-15,000 mg/l.

Potable water for area residents, as well as for livestock, is produced from the uppermost sandstone aquifer, the Wagner Formation.

FIGURE C5-1
BASE MAP ENCOMPASSING THE CLASSIFICATION REVIEW AREA



EXPLANATION

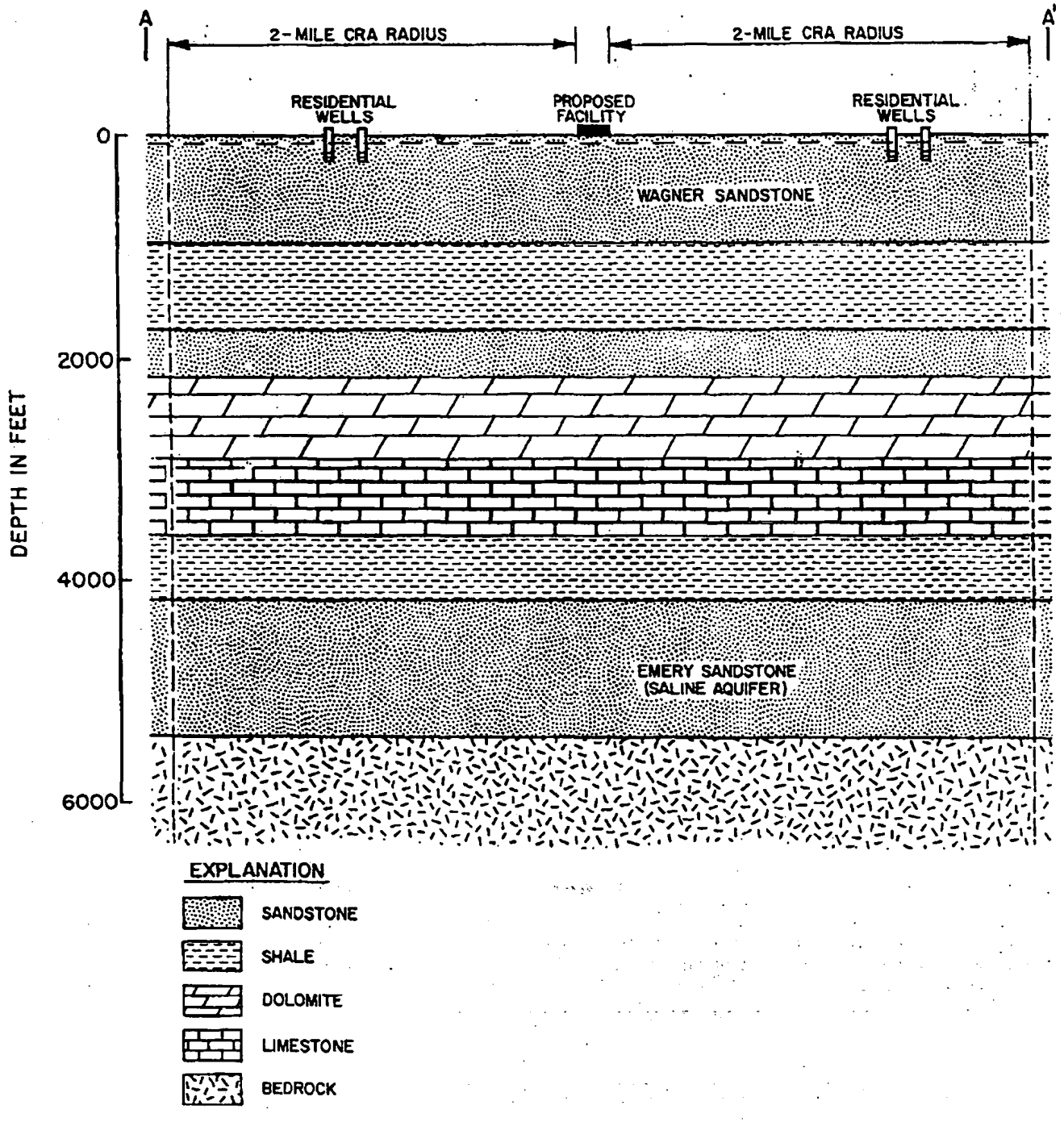
0 1 2 MILES

CLASSIFICATION REVIEW AREA BOUNDARY

RESIDENTIAL WELL

ROADWAY

FIGURE C5-2
GENERALIZED CROSS-SECTION OF THE HYDROGEOLOGY WITHIN THE CLASSIFICATION REVIEW AREA



Classification Review Area Subdivision (Interconnection)

Three ground-water units can be identified within the Classification Review Area and are numbered as shown in Figure C5-3. Ground waters in each ground-water unit are separated from each other by unfractured, laterally extensive shale units. A low degree of interconnection is demonstrated due to the presence of these Type 2 boundaries. The integrity of these boundaries has not been compromised by improperly constructed or abanondoned wells, or other apertures. Injection and pressure tests performed indicate that pressures required to meet the design flow rate fall well below the Emery Formation's pressure-induced fracturing limits.

Normally ground-water classification would be restricted to the ground-water unit which is potentially affected by the presence of the proposed facility. The proposed facility, in this case, is a liquid waste injection well. Under a worst-case scenario, potential contaminants entering the ground water from the facility would be tranported in all ground-water units underlying the facility rather than just the Emery Formation. Therefore, classification of each ground-water unit is necessary.

Well/Reservoir Survey

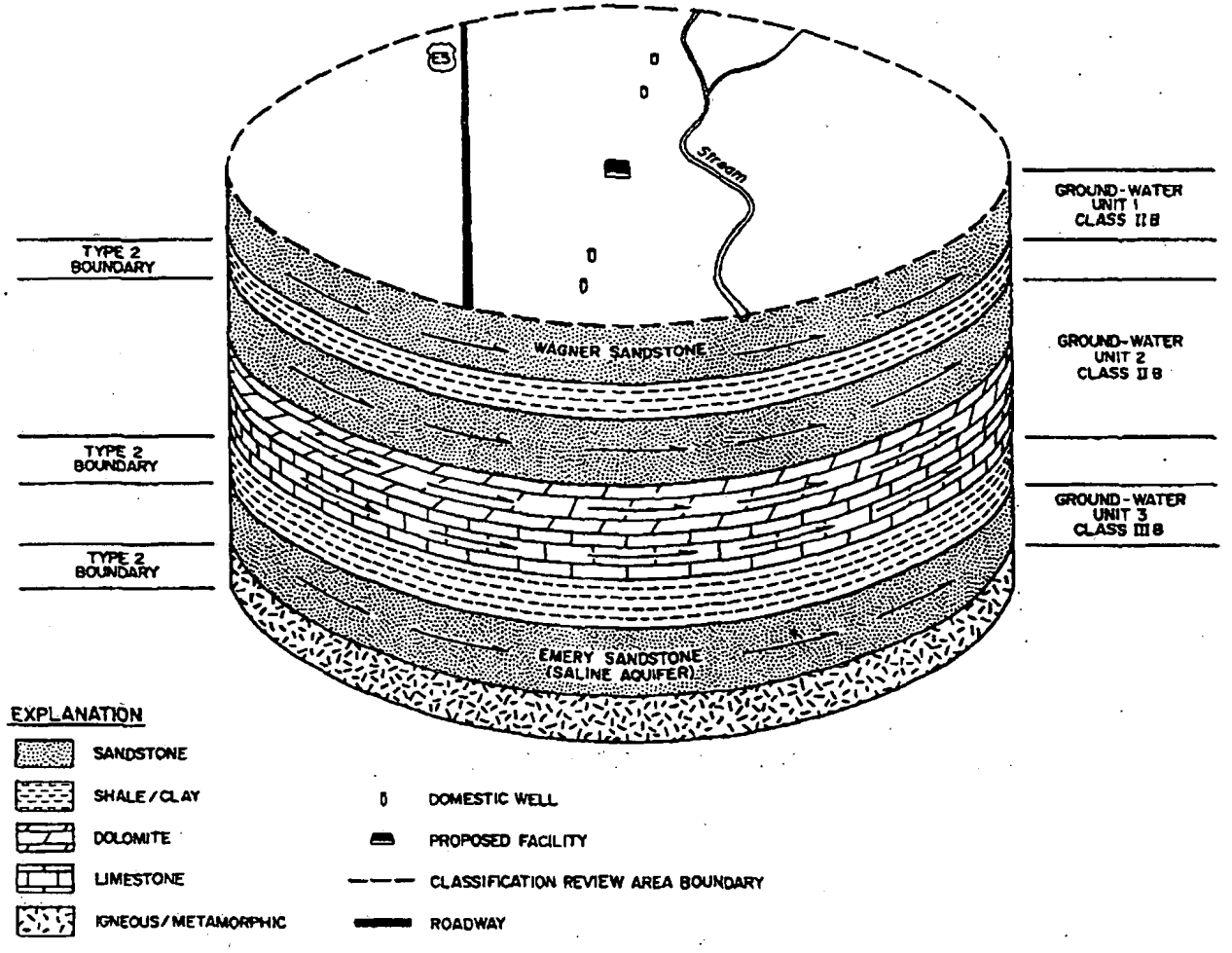
Figure C5-1 shows the location of four domestic wells identified in the Classification Review Area. These wells are screened within 200 feet of the ground surface in the uppermost sandstone aquifer.

No water-supply reservoirs are present in the Classification Review Area.

Ecologically Vital Areas

The only discharge point in the Classification Review Area is from the upper sandstone aquifer to a local stream. However, the U.S. Fish and Wildlife Service confirmed that this stream does not provide habitat for an endangered species. Additionally, no Federally-protected lands exist in the area. Thus, the ground water is not considered to be ecologically vital.

FIGURE C5-3
THREE-DIMENSIONAL ILLUSTRATION OF THE HYDROLOGY AND GROUND-WATER UNITS WITHIN THE CLASSIFICATION REVIEW AREA



Referring to the Procedural Guide shown in Figure 4-1 and assoicated worksheet in Table 4-1, ground-water Unit No. 3 is classified using the following steps:

Step	Question/Direction	Response/Comment
1	Establish Classification Review Area (CRA) and collect preliminary information. Optional - Demonstrate subdivision(s) of the CRA.	The CRA is defined by a two-mile radius from the proposed facility and has been subdivided because of the presence of low permeability flow barriers beneath the ground-water units.
2	Locate any ecologically vital areas in the CRA. Does the CRA or appropriate subdivision overlap an ecologically vital area? . Yes, go to next step . No, go to Step 4	No ecologically vital areas are present in the CRA.
4	Determine location of well(s) within the CRA or appropriate subdivision. Does the CRA or appropriate subdivision contain well(s) used for drinking water? . Yes, go to next Step . No, go to Step 8	No drinking water wells are within ground-water unit No. 3.
8A	Determine location of reservoirs within the CRA or appropriate subdivision. Does the CRA or appropriate subdivision contain reservoirs used for drinking water? . Yes, go to next step . No, go to Step 9	No reservoirs are present within the CRA.

Step	Question/Direction	Response/Comment
9	Determine yield from ground water medium (total depth across CRA or appropriate subdivision). Can it yield 150 gallons-per-day to a well? . Yes, go to next step . No, then the ground water is CLASS IIIA-NOT A SOURCE OF DRINKING WATER (INSUFFICIENT YIELD)	Yes, the uppermost sandstone aquifer exceeds the sufficient yield criteria.
10	Determine water-quality characteristics within the CRA or appropriate subdivision. Is the water quality greater than 10,000 mg/l total dissolved solids (TDS)? (Note: If water quality is unknown then this question must be answered no.) . Yes, go to Step 12 . No, go to next step	Yes, ground-water unit No. 3 contains water with TDS averaging 12,000 to 15,000 mg/l and exceeds the Class III TDS threshold.
12	Perform interconnectedness analysis. Is there a low degree of interconnection between the ground water being classified and adjacent ground units or surface waters within the initial CRA? . Yes, then the ground water is CLASS IIIB-NOT A SOURCE OF DRINKING WATER (LOW INTERCONNECTION)	Yes, verticle movement to adjacent upper or lower units is restricted by geologic units of low permeability.

Step	Question/Direction	Response/Comment
	. No, then the ground water is CLASS IIIA-NOT A SOURCE OF DRINKING WATER (INTERMEDIATE-TO-HIGH INTERCONNECTION)	

FINAL CLASS DETERMINATION: CLASS IIIB - NOT A SOURCE OF DRINKING WATER (LOW INTERCONNECTION)

Classification of Ground-Water Unit No. 2 is accomplished using the Procedural Guide shown in Figure 4-1 and associated worksheet in Table 4-1.

Step	Question/Direction	Response/Comment
1	Establish Classification Review Area (CRA) and collect preliminary information. Optional - Demonstrate subdivision(s) of the CRA.	The CRA is defined by a two-mile radius from the proposed facility and has been subdivided because of the presence of low permeability flow barriers between the ground-water units.
2	Locate any ecologically vital areas in the CRA. Does the CRA or appropriate subdivision overlap an ecologically vital area? . Yes, go to next step . No, go to Step 4	No ecologically vital areas are present in the CRA.
4	Determine location of well(s) within the CRA or appropriate subdivision. Does the CRA or appropriate subdivision contain well(s) used for drinking water? . Yes, go to next Step . No, go to Step 8	No drinking water wells are wihtin ground-water Unit No. 2.
8A	Determine location of reservoirs within the CRA or appropriate subdivision. Does the CRA or appropriate subdivision contain reservoirs used for drinking water? . Yes, go to next step . No, go to Step 9	No water-supply reservoirs are within the CRA.

Step	Question/Direction	Response/Comment
9	Determine yield from ground water medium (total depth across CRA or appropriate subdivision). Can it yield 150 gallons-per-day to a well? . Yes, go to next step . No, then the ground water is CLASS IIIA-NOT A SOURCE OF DRINKING WATER (INSUFFICIENT YIELD)	The uppermost sandstone aquifer exceeds the sufficient yield criteria.
10	Determine water-quality characteristics within the CRA or appropriate subdivision. Is the water quality greater than 10,000 mg/l total dissolved solids (TDS)? (Note: If water quality is unknown then this question must be answered no.) . Yes, go to Step 12 . No, go to next step	Water quality is unknown for ground-water unit No. 2.
11	Are the ground waters so contaminated as to be untreatable? (Note: If water quality is unknown then this question must be answered no.) . Yes, go to next step . No, then the ground water is CLASS IIB-POTENTIAL SOURCE OF DRINKING WATER	Water quality is unknown for ground-water unit No. 2.

FINAL CLASS DETERMINATION: CLASS IIB - POTENTIAL SOURCE OF DRINKING WATER

Finally, classification of Ground-Water Unit No. 1 is accomplished using the following steps from the Procedural Guide shown in Figure 4-1 and associated worksheet in Table 4-1:

Step	Question/Direction	Response/Comment
1	Establish Classification Review Area (CRA) and collect preliminary information. Optional - Demonstrate subdivision(s) of the CRA.	The CRA is defined by a two-mile radius from the proposed facility and has been subdivided because of low permeability flow barriers between the ground-water units.
2	Locate any ecologically vital areas in the CRA. Does the CRA or appropriate subdivision overlap an ecologically vital area? . Yes, go to next step . No, go to Step 4	No ecologically vital areas are present in the CRA.
4	Determine location of well(s) within the CRA or appropriate subdivision. Does the CRA or appropriate subdivision contain well(s) used for drinking water? . Yes, go to next Step . No, go to Step 8	Four domestic wells are present within ground-water unit No. 1.
5	Inventory population served by well(s). Does the well(s) serve a substantial population? . Yes, go to next step . No, then the ground water is CLASS IIA-CURRENT SOURCE OF DRINKING WATER	The wells do not serve a substantial population as determined under Option A.

FINAL CLASS DETERMINATION: CLASS IIA - CURRENT SOURCE OF DRINKING WATER

CASE STUDY 6

Introduction

The following case study deals with the issues of treatability and interconnection. It is an example of a Class IIIA - High Interconnection between surface and ground waters. In addition, based on the ground-water discharge scheme of this flow system, and the intermediate degree of connection between ground waters on opposite sides of a river, the Classification Review Area has been subdivided.

Preliminary Information with Respect to the Classification Review Area

General

A permit application is being submitted for a site approximately 1000 feet west of the Pearl River (Figure C6-1). This site is located within city limits.

Geology/Hydrogeology

Based on U.S. Geological Survey reports, the site geology consists of 15 to 30 feet of flood plain silts and very fine sands immediately beneath the proposed facility (Figure C6-2). The water table is located in this unit. Underlying the silty unit are 4 to 11 feet of more permeable fluvial sand. Thick lacustrine clays below the fluvial sediments form the lower flow boundary of the site. Ground water discharges to the Pearl River.

Classification Review Area Subdivision (Interconnection)

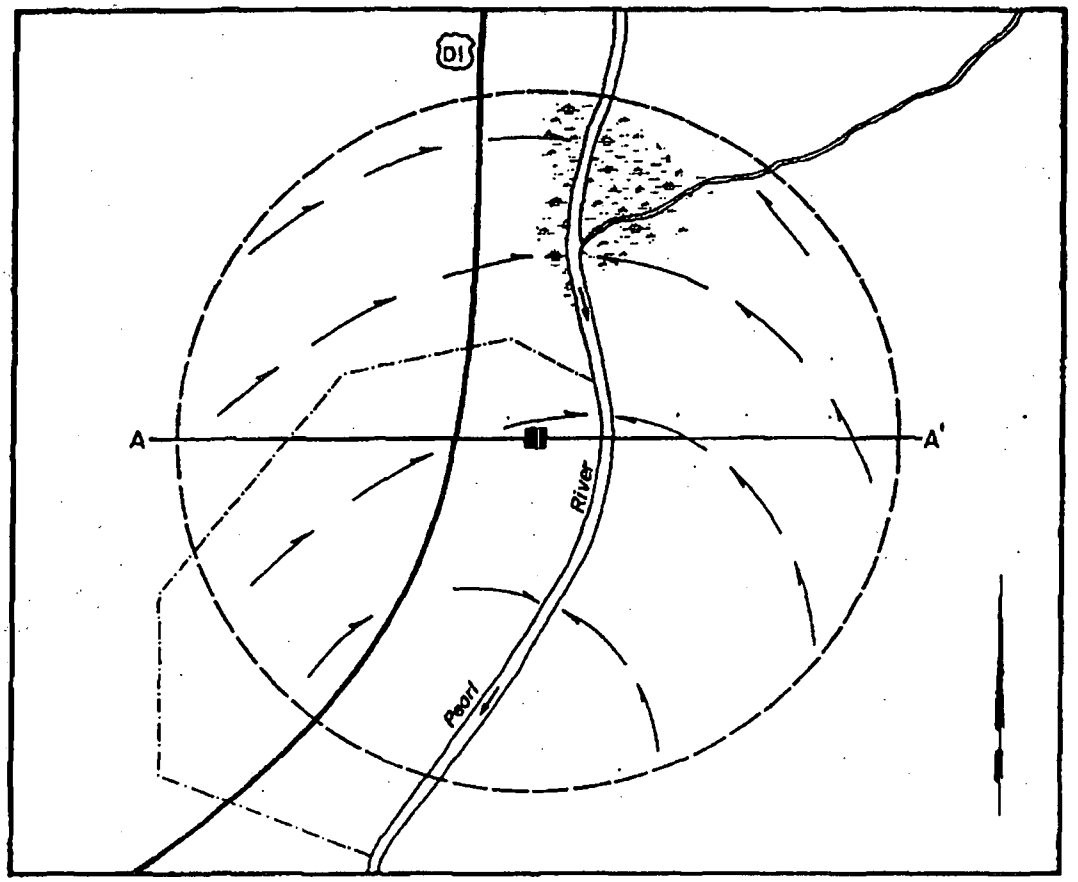
It is known that the Pearl River serves as a ground-water flow divide, therefore, division of the Classification Review Area into two separate ground-water units (each of which discharges to the river) is possible (Figure C6-3). An intermediate degree of interconnection is demonstrated where the adjacent ground waters are in separate ground-water units due to the presence of a flow boundary. The position of the river as a flow boundary is not expected to change to any significant degree from current or planned ground-water withdrawals.

Well/Reservoir Survey

No water-supply reservoirs or drinking-water wells are present in the Classification Review Area. Local residents' drinking-water supply is piped-in from a source outside the Classification Review Area.

The above information was verified by the County Public Health Agency.

FIGURE C6-1
BASE MAP ENCOMPASSING THE CLASSIFICATION REVIEW AREA

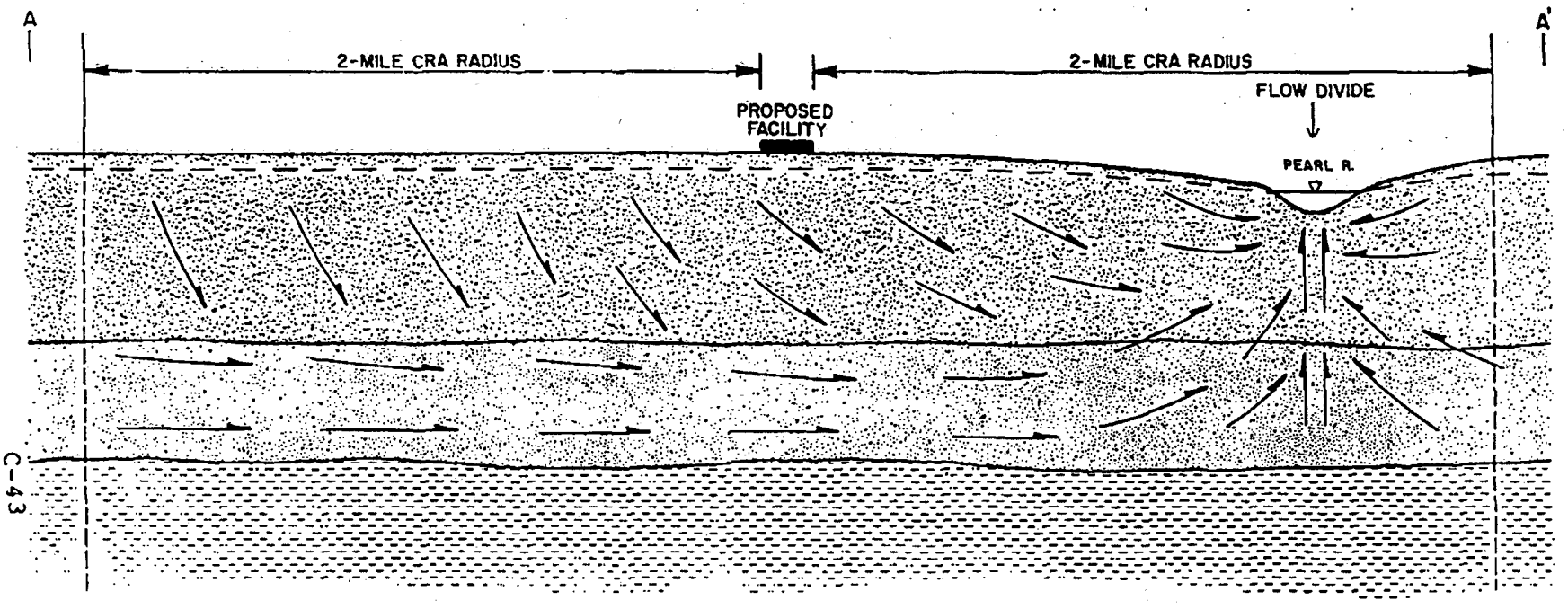


EXPLANATION

- PROPOSED FACILITY
- CLASSIFICATION REVIEW AREA BOUNDARY
- WETLANDS
- CITY LIMITS
- DIRECTION OF GROUND-WATER FLOW
- ROADWAY

0 1 2 MILES

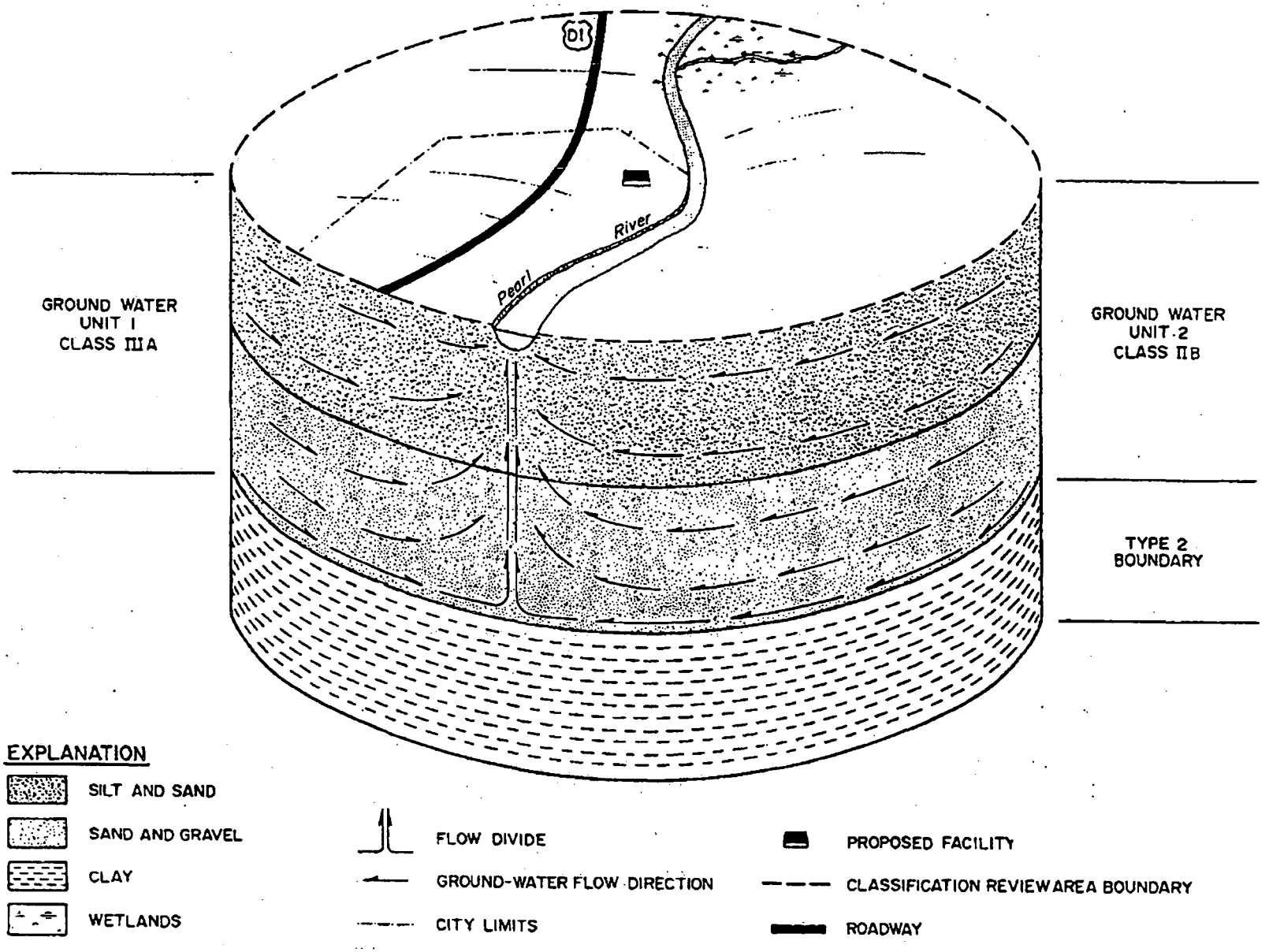
FIGURE C6-2
GENERALIZED CROSS SECTION OF THE HYDROGEOLOGY WITHIN THE CLASSIFICATION REVIEW AREA



EXPLANATION

- SILT AND SAND
- SAND AND GRAVEL
- CLAY
- WATER TABLE
- GROUND-WATER FLOW DIRECTION

FIGURE C6-3
THREE-DIMENSIONAL ILLUSTRATION OF THE HYDROGEOLOGY AND GROUND-WATER UNITS WITHIN THE CLASSIFICATION REVIEW AREA



Demography

The population is centered on the west side of the Pearl River. Based on U.S. Census Bureau statistics, approximately 100,000 persons reside there. The remainder of the Classification Review Area is sparsely populated.

Ecologically Vital Areas

The Classification Review Area does not encompass any Federal lands designated for ecological protection or ecologically vital areas. Ground-water discharge areas have been identified as the Pearl River and associated tributaries. The U.S. Fish and Wildlife Service confirmed that these areas do not provide unique habitats for any endangered species.

Treatability

Over the years, the city has maintained numerous industrial activities which have resulted in gross, widespread contamination of the ground water. Based on an extensive network of monitoring wells, it has been determined that the ground water has been polluted by various organic and inorganic constituents. Table C-3 lists various contaminants present in the ground water and treatment efficiencies typically reported in EPA treatability and effluent guideline manuals. The amount of contaminant cited represents an average of water-quality samples obtained from monitoring wells located on the west side of the Pearl River. Should these waters be used as a source of drinking water they would require treatment using technologies such as air stripping, lime precipitation, sand filtration, and reverse osmosis. Table C-3 also presents contaminant concentrations after application of these technologies. Drinking water standards for some constituents were not met, therefore, the ground water is deemed untreatable, by reasonably available technologies.

The following classification demonstration is applicable only to the ground-water unit located beneath the proposed facility - the western portion of the Classification Review Area relative to the Pearl River. Classification of the ground-water unit east of the river is not necessary.

TABLE C-5

APPROXIMATE REMOVAL OF CONTAMINANTS FROM AN INFLUENT TREATED USING AIR STRIPPING, LIME PRECIPITATION, SAND FILTRATION, AND REVERSE OSMOSIS

Constituent	Initial Concentration (mg/l)	TREATMENT EFFICIENCIES[a] Air Stripping	Precipitation Clarification	Sand Filtration	Reverse Osmosis	Effluent Conc. With Reverse Osmosis (mg/l)	D.W.[b] Met?	Effluent Conc. W/O Reverse Osmosis (mg/l)	D.W.[b] Met?
Trichloroethylene	150	98%	57%	43%	99%	0.007	Yes	0.74	No
Tetrachloroethylene	25	98%	85%	0%	60%	0.03	No	0.08	No
1,1,1-Trichloroethane	50	99%	73%	97%	60%	0.002	NA	0.004	NA
Carbon Tetrachloride	300	98%	99%	93%	79%	0.001	Yes	0.004	Yes
Benzene	300	80%	99%	41%	75%	0.09	No	0.35	No
Toluene	50	95%	50%	67%	12%	0.36	No	0.41	No
Chloroform	250	60%	99%	50%	79%	0.11	No	0.50	No
Ca	1,500	0%	58%	13%	95%	27.4	NA	548	NA[c]
Mg	500	0%	83%	6%	95%	4.0	NA	79.9	NA[c]
K	75	0%	22%	0%	95%	2.9	NA	58.3	NA
Na	100	0%	22%	0%	95%	3.9	NA	78.0	NA
Fe	20	0%	96%	32%	47%	0.29	NA[d]	0.54	NA[d]
Ni	5	0%	75%	19%	47%	0.54	NA[e]	1.0	NA[e]
Cu	150	0%	93%	42%	84%	0.97	NA[f]	6.1	NA[e]
Zn	500	0%	93%	55%	98%	0.32	NA[f]	15.8	NA[e]
Cd	25	0%	89%	67%	89%	0.10	No	0.91	No
TDS	4,000 mg/l TDS					41 mg/l TDS[g]	Yes	790 mg/l TDS[g]	No

[a] Reported are the median efficiencies for contaminant removal from various water and wastewater treatment operations. Many of the removals are incidental in processes designed for removal of other contaminants.

[b] Drinking water criteria are available for the following constituents:

Trichloroethylene (0.075 mg/l Long-Term Health Advisory)
Tetrachloroethylene (0.02 mg/l Long-Term Health Advisory)
Carbon Tetrachloride (0.02 mg/l 10-day Health Advisory)
Benzene (0.7 mg/l Long-Term Health Advisory)
Toluene (0.34 mg/l Long-Term Advisory)
Chloroform (0.1 mg/l MCL)
Cadmium (0.01 mg/l MCL)

[c] Without reverse osmosis, this water has excessive hardness (as measured by the presence of calcium and magnesium ions). Further softening treatment processes would be required in order to distribute water which will not cause excessive scaling and degradation of the distribution systems.

[d] The iron content of the treated water is sufficiently low that it is not expected to impart undesirable flavor, nor to cause staining of receiving basins or laundry.

[e] These concentrations exceed the U.S. EPA Ambient Water Quality Criteria developed in 1980.

[f] These concentrations are less than the U.S. EPA Ambient Water Quality Criteria developed in 1980.

[g] Public water supply systems typically provide drinking waters with less than 500 mg/l TDS, although this is not a mandated level.

Referring to the Procedural Chart shown in Figure 4-1 and associated worksheet in Table 4-1, the ground water is classified using the following steps:

Step	Question/Direction	Response/Comment
1	Establish Classification Review Area (CRA) and collect preliminary information. Optional - Demonstrate subdivision(s) of the CRA.	The CRA is defined by a two-mile radius from the proposed facility and has been subdivided into two ground-water units. The ground-water classification decision is restricted to the western ground-water unit.
2	Locate any ecologically vital areas in the CRA. Does the CRA or appropriate subdivision overlap an ecologically vital area? . Yes, go to next step . No, go to Step 4	No ecologically vital areas are present in the CRA.
4	Determine location of well(s) within the CRA or appropriate subdivision. Does the CRA or appropriate subdivision contain well(s) used for drinking water? . Yes, go to next Step . No, go to Step 8	No, the ground-water unit being classified does not contain any drinking-water wells.
8A	Determine location of reservoirs within the CRA or appropriate subdivision. Does the CRA or appropriate subdivision contain reservoirs used for drinking water? . Yes, go to next step . No, go to Step 9	No water-supply reservoirs are present in the CRA.

Step	Question/Direction	Response/Comment
9	Determine yield from ground-water medium (total depth across CRA or appropriate subdivision). Can it yield 150 gallons-per-day to a well? . Yes, go to next step . No, then the ground water is CLASS IIIA-NOT A SOURCE OF DRINKING WATER (INSUFFICIENT YIELD)	Yes, the ground-water medium is presumed to meet the sufficient yield criterion.
10	Determine water-quality characteristics within the CRA or appropriate subdivision. Is the water quality greater than 10,000 mg/l total dissolved solids (TDS)? (Note: If water quality is unknown then this question must be answered no.) . Yes, go to Step 12 . No, go to next step	No, the ground-water unit being classified has less than 10,000 mg/l TDS.
11	Are the ground waters so contaminated as to be untreatable? (Note: If water quality is unknown then this question must be answered no.) . Yes, go to next step . No, then the ground water is CLASS IIB-POTENTIAL SOURCE OF DRINKING WATER	Yes, the ground-water unit being classified is deemed untreatable by reasonably available technologies.

Step	Question/Direction	Response/Comment
12	Perform interconnectedness analysis. Is there a low degree of interconnection between the ground water being classified and adjacent ground units or surface waters within the initial CRA? . Yes, then the ground water is CLASS IIIB-NOT A SOURCE OF DRINKING WATER (LOW INTERCONNECTION) . No, then the ground water is CLASS IIIA-NOT A SOURCE OF DRINKING WATER (INTERMEDIATE-TO-HIGH INTERCONNECTION)	No, a high degree of interconnection exists between the ground water and surface waters. An intermediate degree of interconnection exists between ground waters on opposite sides of the river.

FINAL CLASS DETERMINATION: CLASS IIIA - NOT A SOURCE OF DRINKING WATER (INTERMEDIATE TO HIGH INTERCONNECTION)

CASE STUDY 7

Introduction

A Class I irreplaceable drinking-water source is represented in this Case Study. The standard Classification Review Area, defined by a two-mile radius from the proposed facility, is used in this example. Relevant issues for irreplaceability include substantial population and vulnerability.

Preliminary Information with Respect to the Classification Review Area

General

A permit application is being submitted for a site along the White River in the midwest (Figure C7-1). Land use in the vicinity is light to heavy industrial with a residential area to the north.

Geology/Hydrogeology

The U.S. Geological Survey and county hydrogeologists characterize the principal aquifer of the well field (Figure C7-2) as a fractured sandstone formation which is overlain by a sandy glacial till and alluvium. Ground-water movement through the water-table aquifer occurs primarily through fractures and is toward the White River where the ground water discharges (Figure C7-3).

Well/Reservoir Survey

A municipal well field exists north of the proposed facility. It contains 19 large-capacity wells pumping a total of 8 million gallons-per-day (mgd). These wells are screened in the fractured sandstone formation to an approximate depth of 300 feet.

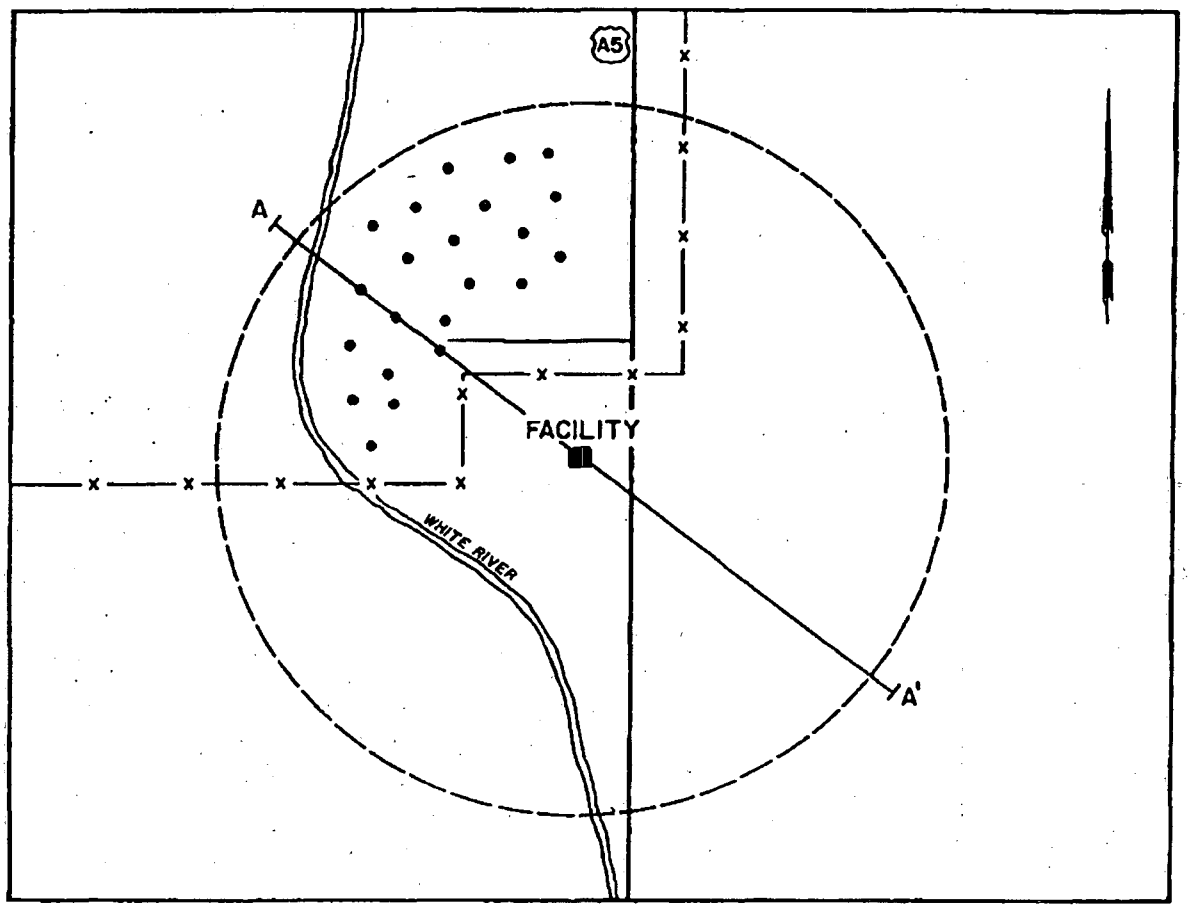
Residential wells are also present in the Classification Review Area although their exact locations have not been determined. It is known, however, that they are also screened in the sandstone, as well as the alluvium.

No water-supply reservoirs are present in the Classification Review Area.

Demography

The population within the Classification Review Area is estimated at 125,000, 60 percent of which are provided drinking water from the well field. This site population constitutes a substantial population under irreplaceability Option A.

FIGURE C7-1
BASE MAP ENCOMPASSING THE CLASSIFICATION REVIEW AREA



EXPLANATION

- PROPOSED FACILITY
- CLASSIFICATION REVIEW AREA BOUNDARY
- MUNICIPAL WELL
- CITY LIMITS
- ROADWAY

0 1 2 MILES

FIGURE C7-2
GENERALIZED CROSS SECTION OF THE HYDROGEOLOGY WITHIN THE CLASSIFICATION REVIEW AREA

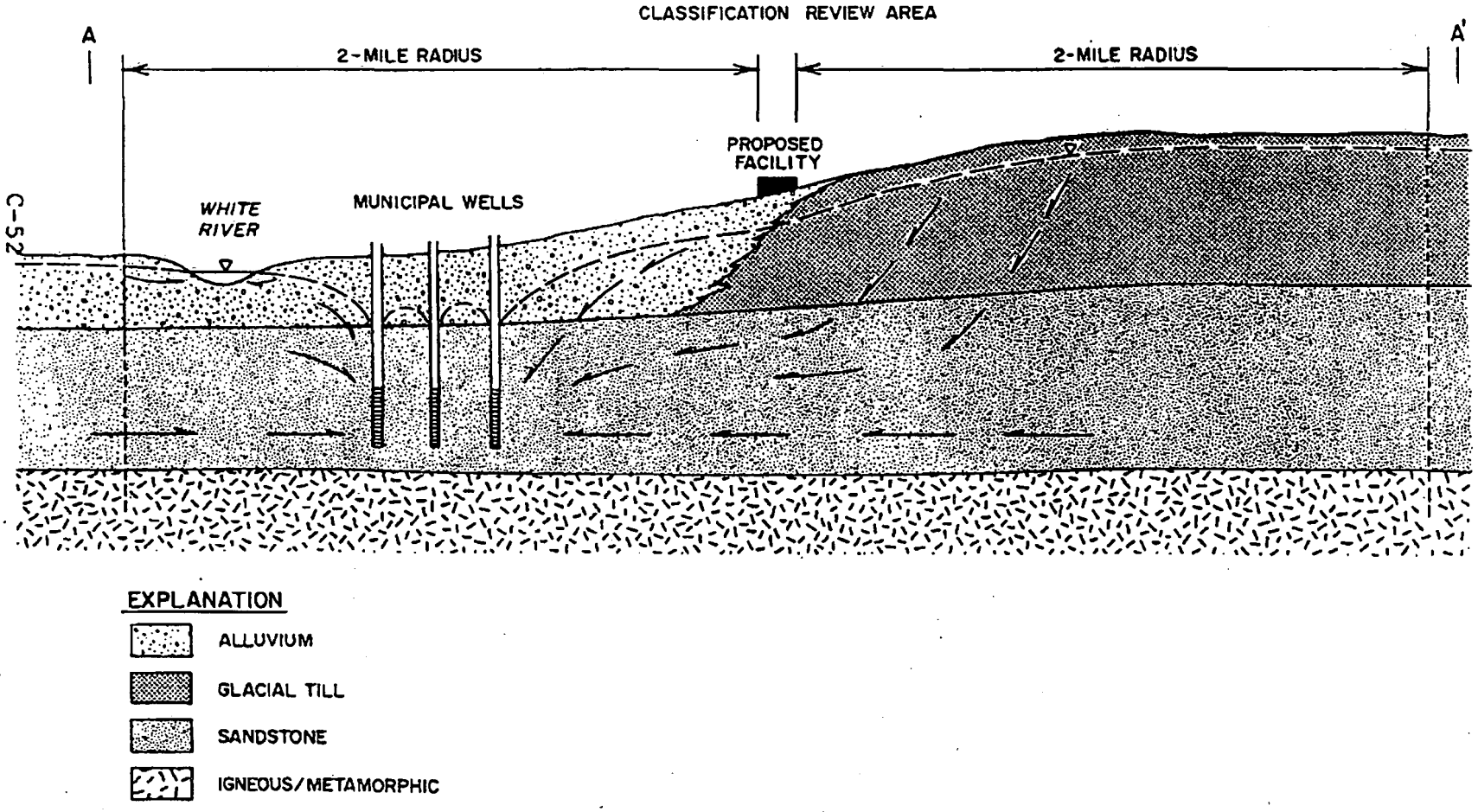
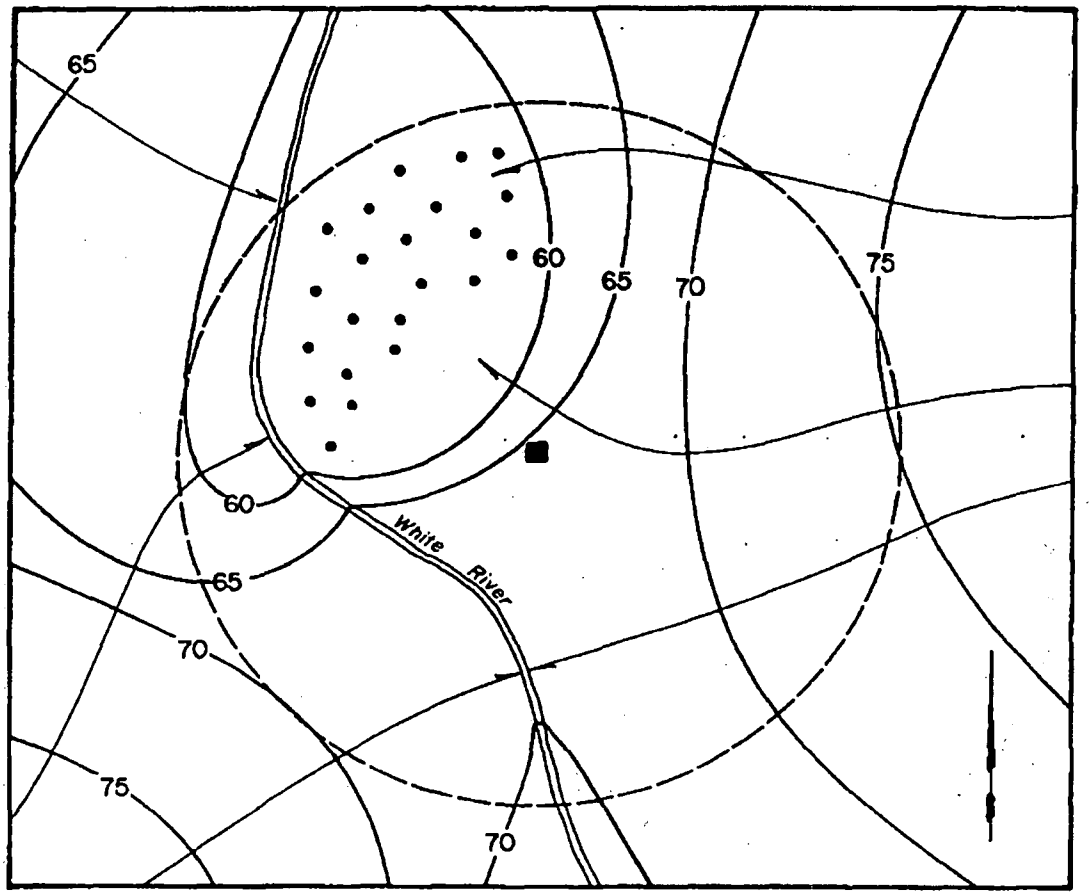


FIGURE C7-3
MAP OF THE WATER TABLE SURFACE



EXPLANATION

0 1 2 MILES

■ PROPOSED FACILITY

— — — CLASSIFICATION REVIEW AREA BOUNDARY

● MUNICIPAL WELL

—70— PIEZOMETRIC HEAD

DIRECTION OF GROUNDWATER FLOW

Ecologically Vital Areas

Ground water discharges to the White River. It has been confirmed by the U.S. Fish and Wildlife Service that this area does not provide habitat for any endangered species. Thus, the ground water is not considered to be ecologically vital.

Vulnerability

Under Option A for determining vulnerability, one approach, presented here, is to map out each hydrogeologic setting in the Classification Review Area that may have differing DRASTIC indices. An area weighted average index can then be computed. Figure C7-4 shows the mapped DRASTIC map units.

	Rating	Weight	Number
Map Unit A - Glacial Till			
. Depth to water - 5-10 feet	9	5	45
. Net recharge - 6-9 inches/year	8	4	32
. Aquifer media - fractured sandstone	8	3	24
. Soil media - clay loam	3	2	6
. Topography - 6-12 percent	5	1	5
. Impact of vadose zone media - sand and gravel with significant silt and clay	4	5	20
. Hydraulic conductivity - estimated 500 gpd/ft^2	4	3	12
DRASTIC Index (TOTAL)			144

	Rating	Weight	Number
Map Unit B - Alluvium			
. Depth to water - 5-10 feet	9	5	45
. Net recharge - 6-9 inches/year	8	4	32
. Aquifer media - fractured sandstone	8	3	24
. Soil media - sandy loam	6	2	12
. Topography - 2-6 percent	9	1	9
. Impact of vadose zone media - sand and gravel with significant silt and clay	7	5	35
. Hydraulic conductivity - estimated 500 gpd/ft^2	4	3	12
DRASTIC Index (TOTAL)			169

Area Weighted DRASTIC

Map Unit	DRASTIC Index	Proportion of Classification Review Area	Area Weighted Index
A	144	40%	57.6
B	169	60%	101.4
Classification Review Area Weighted Index			159

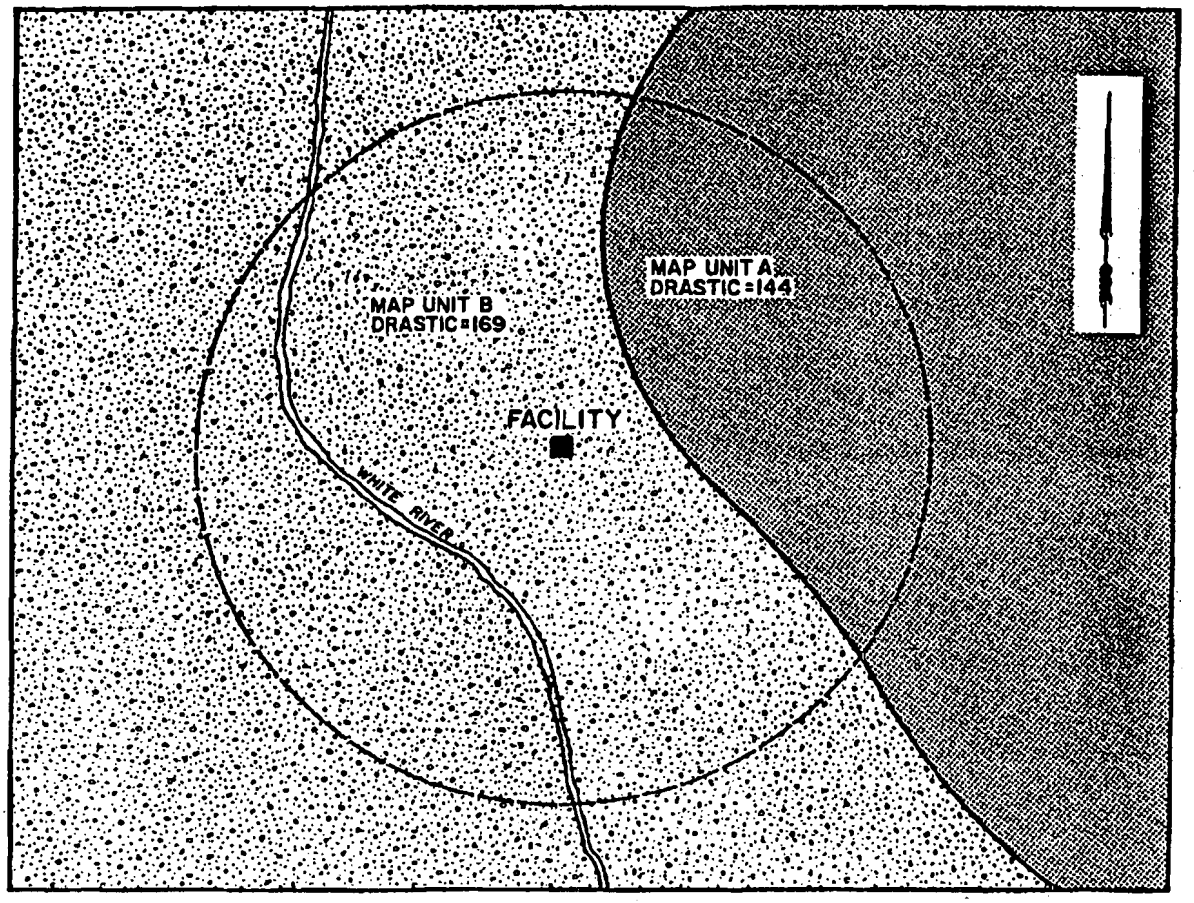
The facility is sited over Map Unit B and is designated as a highly vulnerable hydrogeologic setting. If the facility had overlain Map Unit A then the decision would still be for highly vulnerable because the area weighted DRASTIC index exceeds the criterion and more than 50 percent of the CRA is highly vulnerable. Thus, the entire Classification Review Area is designated as highly vulnerable to ground-water contamination under Option A for assessing vulnerability.

Under Option B for determining vulnerability, an expert hydrogeologist in the area was consulted. The hydrogeologic setting of fractured sandstone overlain by sandy glacial till and alluvium is considered highly vulnerable by this expert.

Irreplaceability

An analysis of available alternative sources of water was not conducted. Thus, by default, the drinking-water supply is assumed irreplaceable under both Options A and B.

FIGURE C7-4
MAPPED DRASTIC UNITS OF THE CLASSIFICATION REVIEW AREA



EXPLANATION

- PROPOSED FACILITY
- CLASSIFICATION REVIEW AREA BOUNDARY
- ALLUVIUM
- TILL

Referring to the procedural chart shown in Figure 4-1 and the associated worksheet in Table 4-1, the ground water is classified using the following steps:

Step	Question/Direction	Response/Comment
1	Establish Classification Review Area (CRA) and collect preliminary information. Optional - Demonstrate subdivision(s) of the CRA.	The CRA is defined by a two-mile radius from the proposed facility. No CRA subdivision has been performed.
2	Locate any ecologically vital areas in the CRA. Does the CRA or appropriate subdivision overlap an ecologically vital area? . Yes, go to next step . No, go to Step 4	No ecologically vital areas are present in the CRA.
4	Determine location of well(s) within the CRA or appropriate subdivision. Does the CRA or appropriate subdivision contain well(s) used for drinking water? . Yes, go to next Step . No, go to Step 8	Yes, a municipal well field exists north of the proposed facility, residential wells are also present in the CRA.
5	Inventory population served by well(s). Does the well(s) serve a substantial population? . Yes, go to next step . No, then the ground water is CLASS IIA-CURRENT SOURCE OF DRINKING WATER	Yes, the municipal well field serves 75,000 persons.

Step	Question/Direction	Response/Comment
6	Unless proven otherwise, the drinking water source is assumed to be irreplaceable. Optional - perform irreplaceability analysis. Is the source of drinking water irreplaceable? . Yes, go to next step . No, then the ground water is CLASS IIA-CURRENT SOURCE OF DRINKING WATER	Yes, the drinking water is assumed irreplaceable under Options A and B. (Irreplaceability analysis not performed).
7	Perform vulnerability analysis. Is the CRA or appropriate subdivision a highly vulnerable hydrogeologic setting? . Yes, then the ground water is CLASS I - IRREPLACEABLE SOURCE OF DRINKING WATER . No, then the ground water is CLASS IIA-CURRENT SOURCE OF DRINKING WATER	Yes, the CRA is a highly vulnerable hydrogeologic setting under both Options A and B.

FINAL CLASS DETERMINATION: CLASS I - IRREPLACEABLE SOURCE OF DRINKING WATER

CASE STUDY 8

Introduction

Case Study 8 relates to an ecologically vital habitat. However, the Classification Review Area is subdivided such that the ultimate ground-water class determination beneath the facility is Class IIB - Potential Source of Drinking Water.

Preliminary Information with Respect to the Classification Review Area

General

A permit application is being submitted for a site located along the Logan River (Figure C8-1). The area is generally undeveloped, with the exception of the city located in the northwestern portion of the Classification Review Area.

Geology/Hydrogeology

U.S. Geological Survey reports indicate the Valley Sand aquifer is protected by the Green Formation, a predominantly clayey sediment unit which is known to be an unfractured, laterally continuous aquitard. The upper Caldor Formation aquifer (Figure C8-2) discharges to rivers in the region, and leaks downward into the aquitard. Beneath the proposed site, ground water from the Caldor aquifer moves away from the site and discharges into the Logan River.

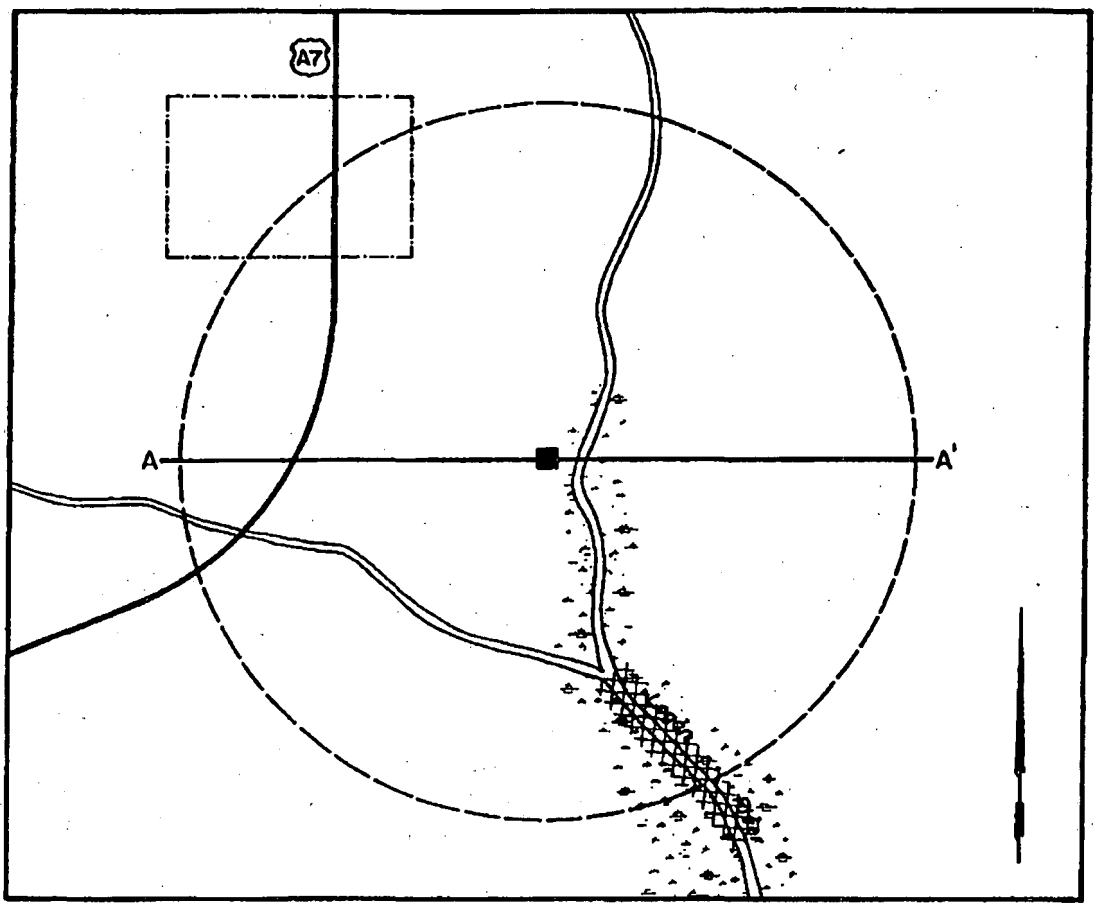
Classification Review Area Subdivision (Interconnection)

It is known from existing studies that the river and its tributaries serve as ground-water divides in the area, thus, creating three ground-water units which discharge to the river bodies. Each system has been numbered as shown in Figure C8-3. That portion of the Classification Review Area containing the proposed facility (ground-water unit No. 1) does not discharge to the segment of the river designated as an endangered species critical habitat. As such, this ground water unit is not highly interconnected to the waters of the critical habitat.

Well/Reservoir Survey

Based on state and local planning board records, no municipal/residential wells or water-supply reservoirs are present in the Classification Review Area.

FIGURE C8-1
BASE MAP ENCOMPASSING THE CLASSIFICATION REVIEW AREA

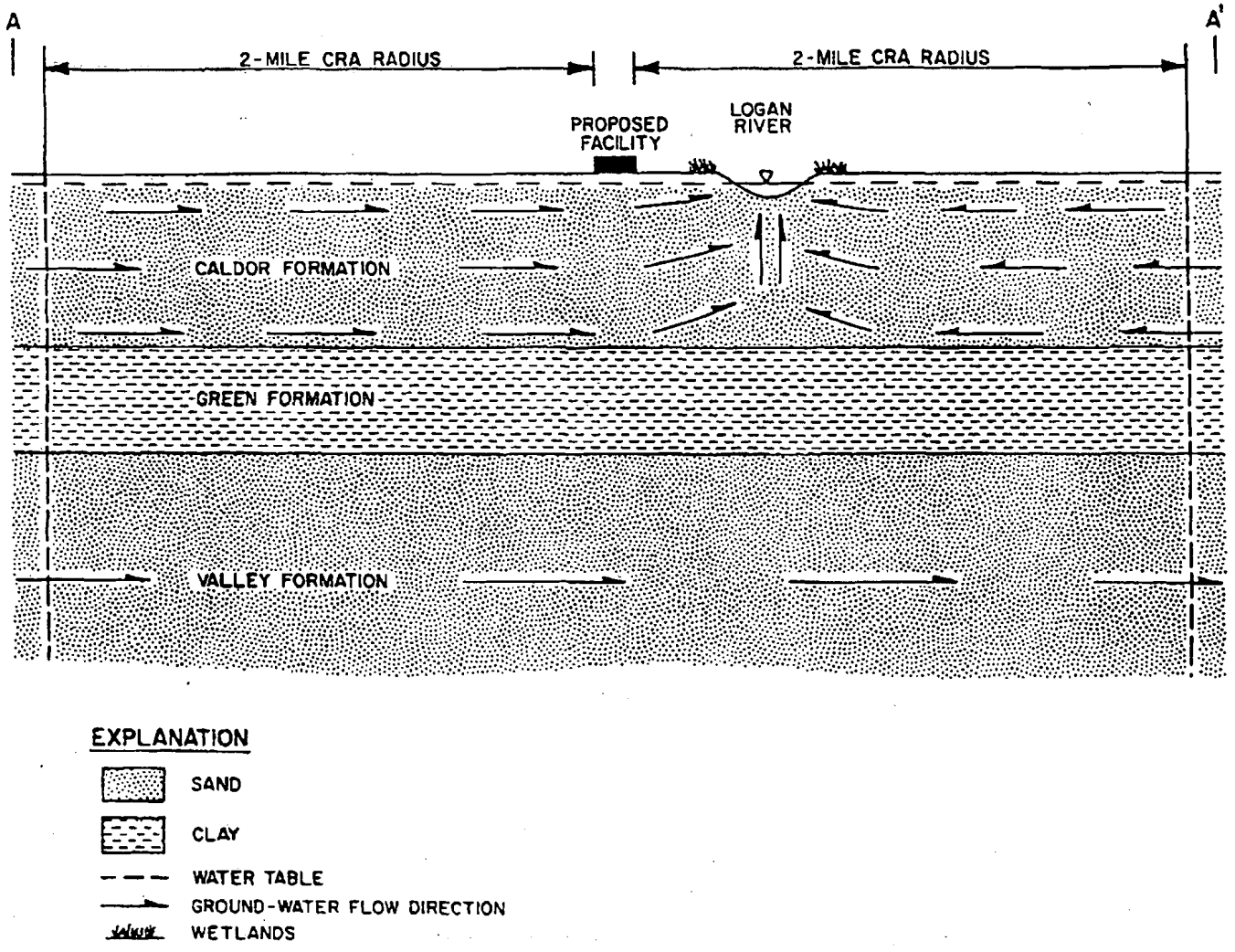


0 1 2 MILES

EXPLANATION

- PROPOSED FACILITY
- CLASSIFICATION REVIEW AREA BOUNDARY
- WETLANDS
- ECOLOGICALLY VITAL AREA
- CITY LIMITS
- ROADWAY

FIGURE C8-2
GENERALIZED CROSS-SECTION OF THE HYDROGEOLOGY WITHIN THE CLASSIFICATION REVIEW AREA



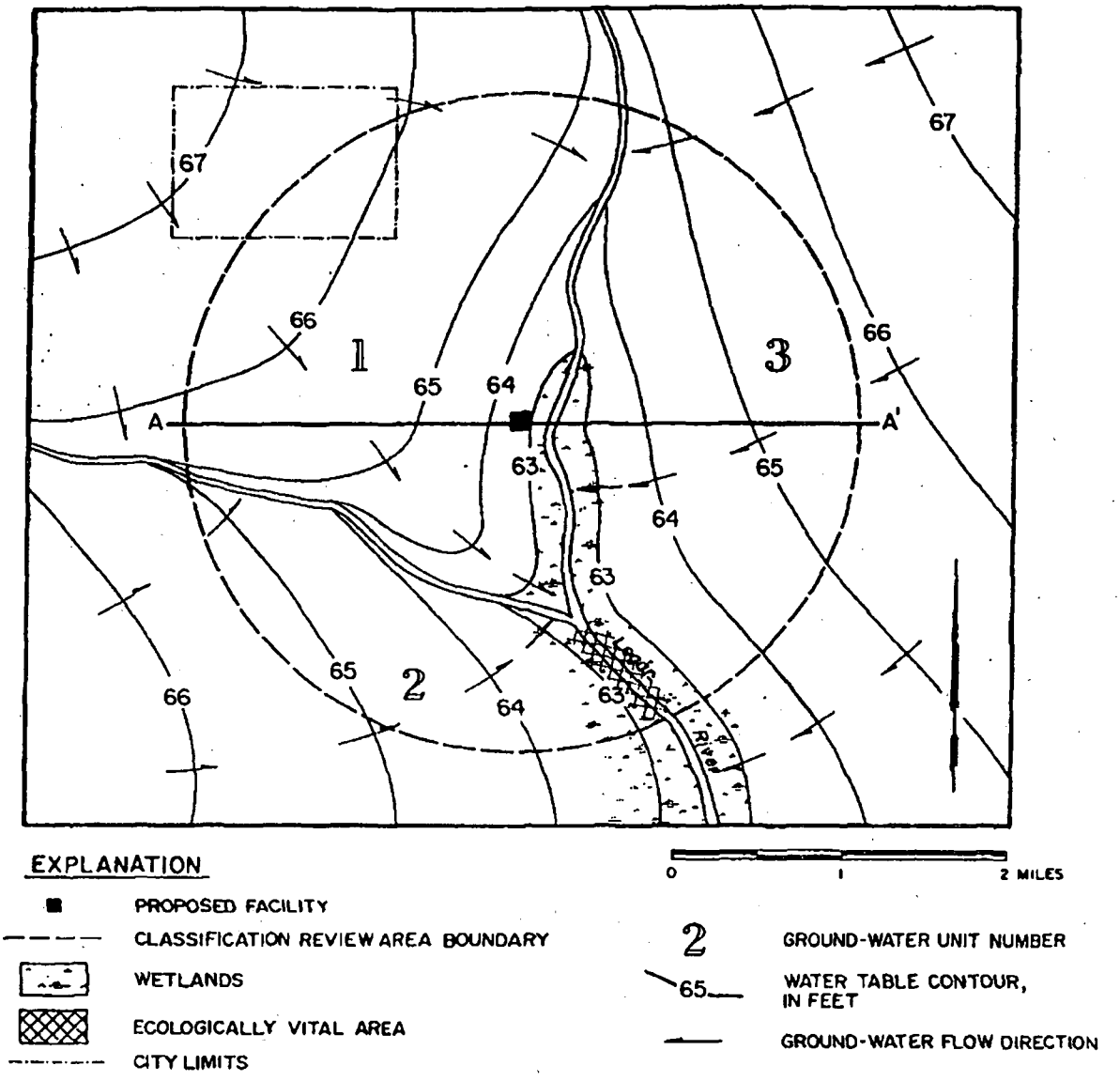
Demography

Based on U.S. Census Bureau information, approximately 20,000 persons live in the northwestern section of the Classification Review Area. The remaining area is undeveloped to date.

Ecologically Vital Area

National Fish and Wildlife Federation records indicate that the southernmost portion of the Logan River, within the Classification Review Area, is designated as a critical habitat for an endangered fish species. The location of this habitat also serves as a ground-water discharge area for ground-water units 2 and 3 (Figure C8-3). It should be noted, however, that the proposed facility is located such that any potential pollutants leaching into the ground water would enter ground-water unit No. 1 and eventually discharge to the Logan River.

FIGURE C8-3
MAP OF THE WATER TABLE AND GROUND-WATER UNITS
WITHIN THE CLASSIFICATION REVIEW AREA



Referring to the Procedural Chart shown in Figure 4-1 and associated worksheet in Table 4-1, the ground water is classified using the following steps:

Step	Question/Direction	Response/Comment
1	Establish Classification Review Area (CRA) and collect preliminary information. Optional - Demonstrate subdivision(s) of the CRA.	The CRA is defined by a two-mile radius from the proposed facility and has been subdivided into three ground-water units due to the presence of a ground-water divide.
2	Locate any ecologically vital areas in the CRA. Does the CRA or appropriate subdivision overlap an ecologically vital area? . Yes, go to next step . No, go to Step 4	While there is an eco-vital habitat within the CRA, the ground-water unit being classified does not discharge into it.
4	Determine location of well(s) within the CRA or appropriate subdivision. Does the CRA or appropriate subdivision contain well(s) used for drinking water? . Yes, go to next Step . No, go to Step 8	No water-supply wells are present within the CRA.
8A	Determine location of reservoirs within the CRA or appropriate subdivision. Does the CRA or appropriate subdivision contain reservoirs used for drinking water? . Yes, go to next step . No, go to Step 9	No water-supply reservoirs present in the CRA.

Step	Question/Direction	Response/Comment
9	Determine yield from ground water medium (total depth across CRA or appropriate subdivision). Can it yield 150 gallons-per-day to a well? . Yes, go to next step . No, then the ground water is CLASS IIIA-NOT A SOURCE OF DRINKING WATER (INSUFFICIENT YIELD)	Yes, the ground water medium is presumed to meet the sufficient yield criterion.
10	Determine water-quality characteristics within the CRA or appropriate subdivision. Is the water quality greater than 10,000 mg/l total dissolved solids (TDS)? (Note: If water quality is unknown then this question must be answered no.) . Yes, go to Step 12 . No, go to next step	No, water quality is unknown.
11	Are the ground waters so contaminated as to be untreatable? (Note: If water quality is unknown then this question must be answered no.) . Yes, go to next step . No, then the ground water is CLASS IIB-POTENTIAL SOURCE OF DRINKING WATER	No, water quality is unknown.

FINAL CLASS DETERMINATION: CLASS IIB - POTENTIAL SOURCE OF DRINKING WATER

CASE STUDY 9

Introduction

The following case study is a permutation of Case Study 8 leading to a Class I - Ecologically Vital Classification. Although the preliminary information remains the same, the location of the endangered species habitat has changed (see Figure C9-1). Relevant issues addressed in this case include ecologically vital areas and vulnerability.

Ecologically Vital Areas

The State Endangered Species Coordinator reports that the banks of the Logan River provide wetland habitat for an endangered species. This area serves as a ground-water discharge area for the Caldor Formation. (Figure C9-2).

Vulnerability

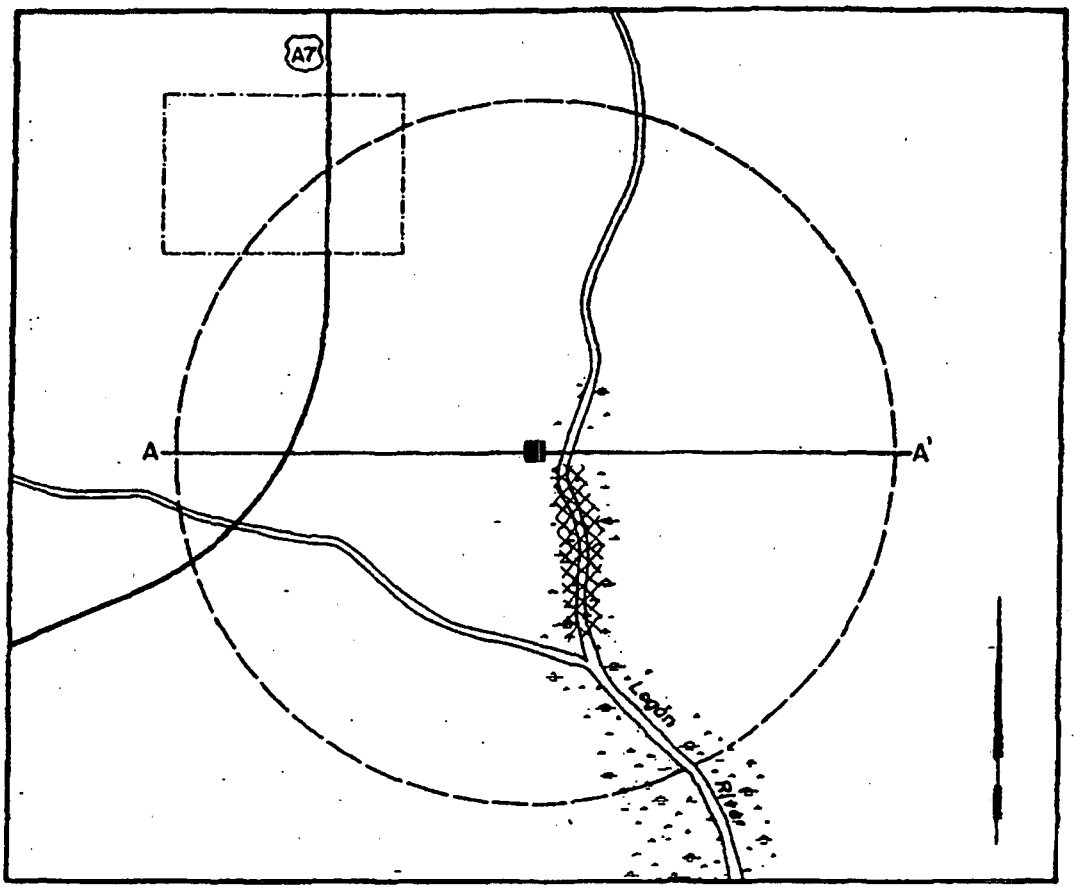
A vulnerability analysis is the next step in the ground-water classification process upon determining that an endangered species habitat is present within the Classification Review Area and the habitat can be shown to be a discharge area for the proposed activity. This is necessary in order to establish whether the area is highly vulnerable to ground-water contamination. (See Section 4.4 and Appendix D for procedural information.)

Under Option A for determining vulnerability, DRASTIC is utilized with the following results:

CALDOR FORMATION	Rating	Weight	Number
. Depth to water - 5 to 10 feet	9	5	45
. Net recharge - approximately 10-15 in/year	9	4	36
. Aquifer media - sand with silt, clay, and lignite	7	3	21
. Soil media - sandy loam	6	2	12
. Topography - less than 2%	10	1	10
. Impact of vadose zone media - interbedded sand with silt, clay and lignite	6	5	30
. Hydraulic conductivity - highly permeable (approximately .16 ft/sec)	10	3	30
		DRASTIC Index (TOTAL)	164

A DRASTIC score of 150 or more constitutes a highly vulnerable hydrogeologic setting under Option A.

FIGURE C9-1
BASE MAP ENCOMPASSING THE CLASSIFICATION REVIEW AREA

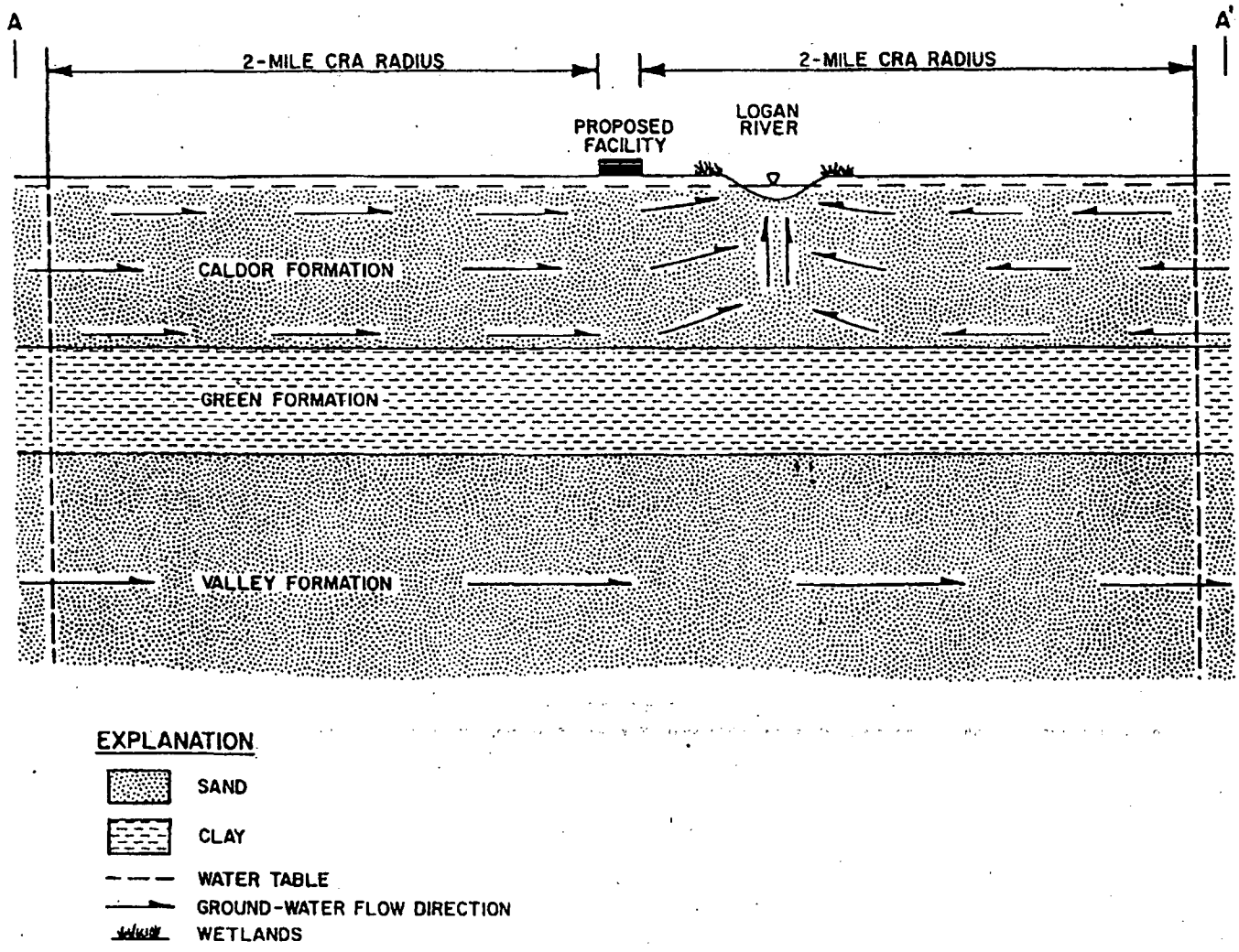


EXPLANATION

0 1 2 MILES

- PROPOSED FACILITY
- CLASSIFICATION REVIEW AREA BOUNDARY
- WETLANDS
- ECOLOGICALLY VITAL AREA
- CITY LIMITS
- ROADWAY

FIGURE C9-2
GENERALIZED CROSS-SECTION OF THE HYDROGEOLOGY WITHIN THE CLASSIFICATION REVIEW AREA



Under Option B for determining vulnerability, two expert hydrogeologists were consulted. These experts disagree on whether the hydrogeologic conditions present constitute a "highly vulnerable" setting as they have differing professional opions regarding the hydrologic properties of the aquifer media. This situation under Option B was resolved by making the conservative assumption that the setting is highly vulnerable.

Referring to the Procedural Chart shown in Figure 4-1 and associated worksheet in Table 4-1, the ground water is classified using the following steps:

Step	Question/Direction	Response/Comment
1	Establish Classification Review Area (CRA) and collect preliminary information. Optional - Demonstrate subdivision(s) of the CRA.	The CRA is defined by a two-mile radius from the proposed facility and has been subdivided into various shallow flow systems due to the presence of a ground-water divide.
2	Locate any ecologically vital areas in the CRA. Does the CRA or appropriate subdivision overlap an ecologically vital area? . Yes, go to next step . No, go to Step 4	Yes, an ecologically vital area is present in the CRA.
3	Perform vulnerability analysis. Is the CRA or appropriate subdivision a highly vulnerable hydrogeologic setting? . Yes, then the ground water is CLASS I - ECOLOGICALLY VITAL . No, go to next step	Yes, under Option A, a DRASTIC score of 150 or more constitutes a highly vulnerable setting. Under Option B, differing expert professional opinions exist, therefore, it is conservatively assumed that the hydrogeologic setting is highly vulnerable.

FINAL CLASS DETERMINATION: CLASS I - ECOLOGICALLY VITAL

CASE STUDY 10

Introduction

Case Study 10 is another example of a CLASS IIA replaceable drinking-water source. An analysis determined that the ground-water supply was replaceable.

Preliminary Information with Respect to the Classification Review Area

General

A permit application is being submitted for a site which would overlie a highly transmissive aquifer, serving as the major water-supply aquifer for the area. A two-mile Classification Review Area (shown in Figure 10-1) was employed.

Geology/Hydrogeology

Based on U.S. Geological Survey field work, the aquifer is divided into two, approximately 50-foot thick, highly interconnected zones (Figure C10-2). The upper zone consists of dense, sandy limestones and soft, fine-grained, quartz sandstones. The lower zone is made of hard, medium-grained, quartz sandstones and sandy limestones which exhibit extensive dissolution features. Underlying the aquifer is a limestone formation of low permeability.

Well/Reservoir Survey

The Classification Review Area contains a well field comprised of large-capacity wells that produce 8 million gallons-per-day for 75,000 area residents (Figure C10-1). The wells are screened in the lower sandy limestone formation where dissolution features have greatly enhanced aquifer permeability.

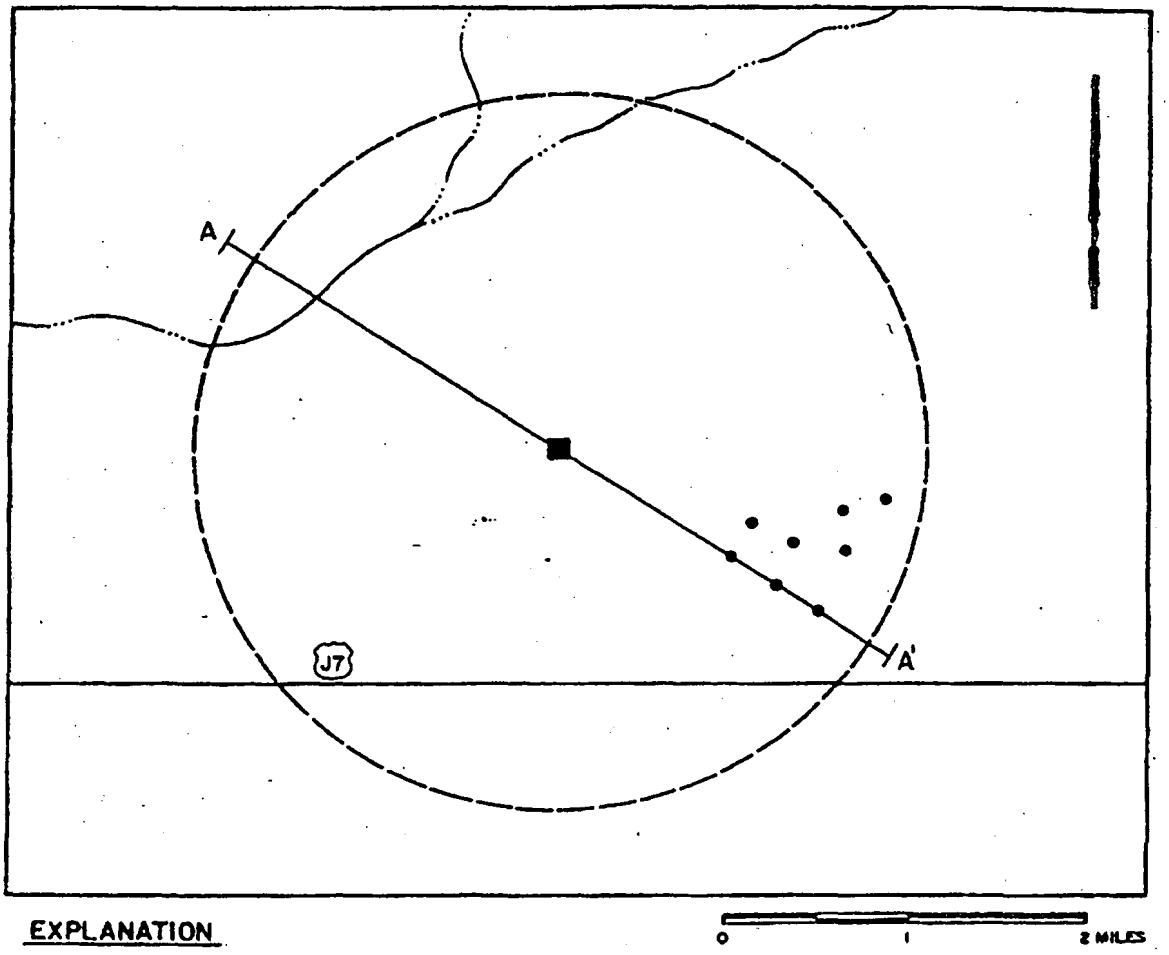
No water-supply reservoirs are present.

The above information was verified by the county public health agency.

Demography

The Classification Review Area is well populated. Based on U.S. Census Bureau information, an estimated 75,000 persons live within the two-mile-wide radius. All persons, as well as industries, utilize ground-water resources for their drinking water supply. This site population constitutes a substantial population under irreplaceability Option A.

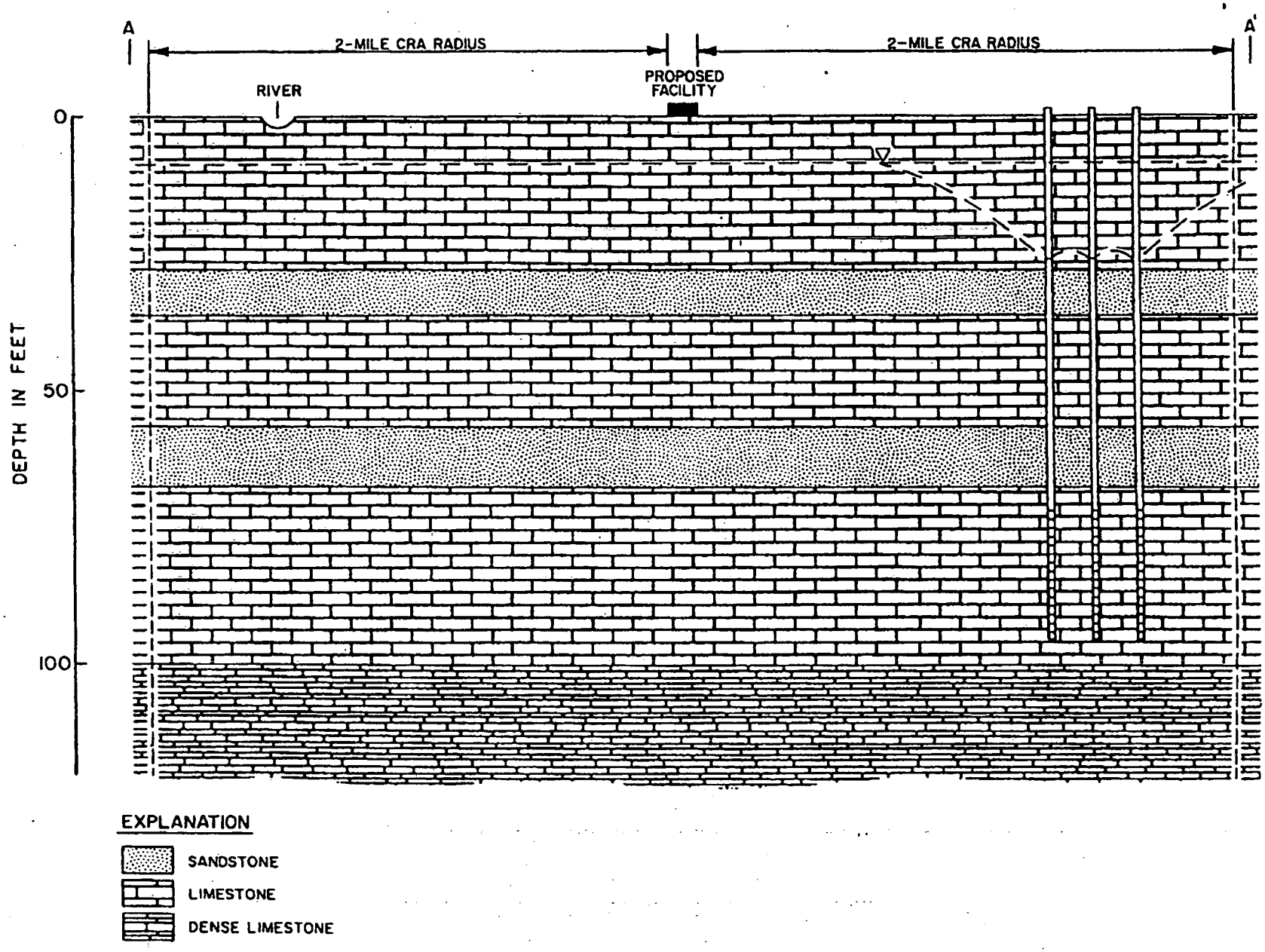
FIGURE C10-1
BASE MAP ENCOMPASSING THE CLASSIFICATION REVIEW AREA



EXPLANATION

- PROPOSED FACILITY
- CLASSIFICATION REVIEW AREA BOUNDARY
- MUNICIPAL WELL
- STREAM
- INTERMITTENT CREEK
- ROADWAY

FIGURE C10-2
GENERALIZED CROSS SECTION OF THE HYDROGEOLOGY WITHIN THE CLASSIFICATION REVIEW AREA



Ecologically Vital Areas

No ecologically vital areas are present within the Classification Review Area. The State Endangered Species Coordinator confirmed that the Classification Review Area does not contain any ecologically vital areas or provide a habitat to any endangered species.

Irreplaceability Analysis

The well/reservoir survey in the Classification Review Area indicates a municipal well field producing 8 mgd and serving 75,000 area residents and it is determined that the substantial population criterion is met under both Options A and B. Subsequently, a Class I, irreplaceability analysis is performed. In determining irreplaceability, the following factors are addressed:

- Uncommon pipeline distance
- Comparable quality
- Comparable quantity
- Institutional constraints
- Economic infeasibility

The notion of uncommon pipeline distance creates a manageable boundary within which alternative water supplies can be identified. According to Table 4-3, a distance of 100 miles would be appropriate in this case. Use of surface-water resources in the area is precluded due to tidal influences requiring desalination. However, a review of local geological reports, indicates the continuity of lower sandy limestones tapped by the existing municipal well field. To the south, urbanization and agriculture is limited indicating that production of the required volume of water may be possible. An alternative well field could be located four miles south of the facility and five miles from the existing water plant.

Local geological reports include extensive data on ground-water quality, particularly for the lower sandy limestone unit. Throughout the region, this unit is used as a water-supply aquifer, and background water quality parameters have limited variation. Elevated total dissolved solids levels have been observed 15 miles to the southeast. However, as far as five miles south, the TDS levels average less than 100 mg/l, only 25 mg/l higher than the existing municipal wells to the north. As a result, water quality is anticipated to be of comparable quality to the existing source, and treatment in addition to that received by the existing source will not be required.

Although water-quality data is well characterized, the quantity of water that can be produced or the aquifer's sustainable yield is not specically known in the proposed area. However, data from a local USGS observation well indicates fairly constant water levels in the proposed area. The data also indicates the sandy limestone formation to be slightly thicker near the USGS observation well than in the vicinity of the municipal well field. Additionally, the composition of the sandy limestone formation in each area is similar. In this region, aquifer transmissivities correlate closely with thickness, indicating fairly homogeneous permeability of materials. Although a pump test was not conducted, productivity would appear to be between 7 and 12 mgd, and should be adequate to replace the existing source.

Planning and zoning maps and tax maps indicate that lands in the proposed area are privately owned and are zoned for agriculture. Also, no other supply wells are recorded within a 3-mile radius of the proposed alternative supply. As a result, it is likely that an adequate property could be acquired to establish the new well field. The easement required for the 5-mile pipeline should also not represent a constraint as a power utility easement already exists between the two points.

The final step in evaluating the alternative supply is to determine if the additional cost of water-supply development and delivery would be economically infeasible to the community. The additional cost to be borne would include:

- Land aquisition
- Well-field development
- Pipeline construction

According to the local economic development agency, the average cost of agricultural land in the area is $2500/acre, resulting in a cost of $50,000 for a 20-acre property suitable for a well field. In order to develop 8 mgd, four 100-foot deep, 16-inch wells are required, including high capacity pumps and testing. This system would cost about $500,000 according to cost information provided by the municipality from construction of the existing system. The 10-year old cost data was escalated using appropriate construction cost indices. Operation and maintenance costs for the well field were also provided and average $200,000/year, mainly for power and well maintenance. Construction costs for a five-mile, 30-inch diameter pipeline was estimated from previous sewerage transmission lines constructed in the area. A local engineering firm constructed the line and indicated the cost at approximately $30/foot or about $750,000. As the power utility is providing the easement for no charge, this is the total capital cost. Operation and

maintenance of the line is estimated at an annual cost of $100,000. Other cost components such as the water plant, distribution lines and treatment facility will not require replacement.

In order to compute the total annual cost of the new water-supply components, capital costs are annualized as indicated in Section 4.3 or in Appendix E.

Total Capital Cost ($1,300,000) x
Annualization Factor (.1) =
Annualized Capital Cost ($130,000)

The annualized capital cost of $130,000 is added to the $300,000 in operation and maintenance costs resulting in an average annual cost of $430,000 as the incremental increase in water-supply cost. This figure expressed on a per household basis results in $15 per household (e.g., 75,000 people/2.7 people/household = 28,000). Using Option A for assessing irreplaceability, the figure of $15 is compared to the average annual household income for the state. Average household income for the state is $20,000 according to the 1980 census figures. As $15 is less than 1 percent of that figure ($200), the ground water is considered replaceable and not Class I under Option A.

Under Option B, expert socioeconomists in the area were consulted. These experts agree that the cost of replacing the ground water does not exceed the community's ability to pay. Thus, under Option B, as under Option A, the ground water would be considered replaceable and not Class I.

Referring to the Procedural Guide shown in Figure 4-1 and associated worksheet in Table 4-1, the ground water is classified using the following steps:

Step	Question/Direction	Response/Comment
1	Establish Classification Review Area (CRA) and collect preliminary information. Optional - Demonstrate subdivision(s) of the CRA.	The CRA is defined by a two-mile radius from the proposed facility. No CRA subdivision has been performed.
2	Locate any ecologically vital areas in the CRA. Does the CRA or appropriate subdivision overlap an ecologically vital area? . Yes, go to next step . No, go to Step 4	No ecologically vital areas are present in the CRA.
4	Determine location of well(s) within the CRA or appropriate subdivision. Does the CRA or appropriate subdivision contain well(s) used for drinking water? . Yes, go to next Step . No, go to Step 8	Yes, a well field comprised of large-capacity wells that provide 8 mgd for 75,000 area residents is present in the CRA.
5	Inventory population served by well(s). Does the well(s) serve a substantial population? . Yes, go to next step . No, then the ground water is CLASS IIA-CURRENT SOURCE OF DRINKING WATER	Yes, drinking-water wells within the CRA serve a population of 75,000. Under Option A, the population served exceeds the 2500-person threshold. Under Option B, the population served is considered substantial given the demographics of the region.

Step	Question/Direction	Response/Comment
6	Unless proven otherwise, the drinking water source is assumed to be irreplaceable. Optional - perform irreplaceability analysis. Is the source of drinking water irreplaceable? . Yes, go to next step . No, then the ground water is CLASS IIA-CURRENT SOURCE OF DRINKING WATER	No, under Option A, the ground water is considered replaceable. Under Option B, the ground water is considered replaceable.

FINAL CLASS DETERMINATION: CLASS IIA-CURRENT SOURCE OF DRINKING WATER

CASE STUDY 11

Introduction

This case study details the problems associated with karst hydrogeology and the need for an expanded Classification Review Area. The hypothetical facility setting is first examined using the standard two-mile Classification Review Area and second using an expanded review area to demonstrate the disparity of results and limitations of a two-mile radius to this particular setting.

Preliminary Information with Respect to the Classification Review Area

General

A permit application is being submitted for a site located in Central Kentucky near the Little Blue River. Planning and zoning maps indicate land use in the area is primarily rural farmland. Several population centers exist at distances greater than two miles which are served solely by ground water.

Regional Physiography/Geology

The area under consideration is within the Central Kentucky Karst terrain which is characterized by sinkholes, infrequent streams and an integrated system of subsurface drainage conduits within a carbonate bedrock complex. Directly west of the facility, streams drain an upland area, flowing eastward to the sinkhole plain. At the plain, the streams intersect sinkholes and surface water is diverted to the underground network of solution conduits within the karst bedrock. This zone where surface water is re-routed to the subsurface represents the termination of the eastwardly extent of the more resistant sandstone formation overlying limestone and dolomites. Without the resistant sandstone, surface water has reworked the carbonate bedrock into a network of vertical and horizontal solution cavities and conduits that drain the sinkhole plain eastward to the Little Blue River (Figure C11-1).

Hydrogeology

The hydraulic characteristics of a karst aquifer are far different from the Darcian principles of flow through a granular media. Instead, ground-water circulation occurs through a system of conduits having a variety of shapes and capacities. The spatial position and relationship of these

conduits and the temporal hydraulic heads within the voids determine the geometry of ground-water flow paths. Regional investigations including dye tracer tests, field mapping, exploratory drilling, spelunking, and geochemical reconnaissance sampling have been performed by county hydrogeologists. The flow system is characterized as dynamic and undergoes major changes depending upon the magnitude of a precipitation recharge event. Extending our view eastward past the two-mile Classification Review Area radius to the Little Blue River during two distinct precipitation/recharge events will help in understanding the intricacies of karst groundwater circulation (Figure C11-1).

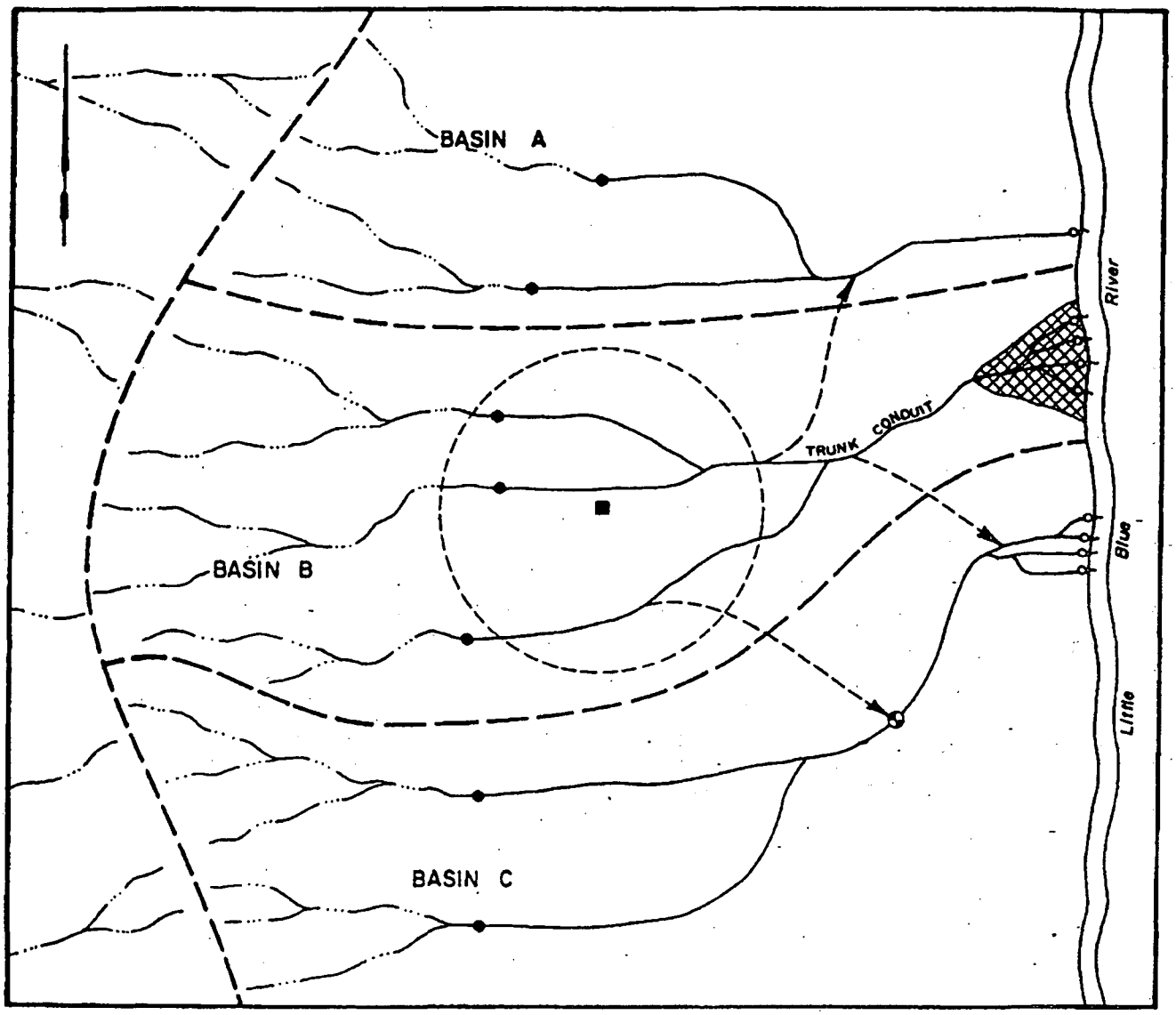
During periods of low flow (little or no precipitation), surface-water recharges the carbonate aquifer at the sinkhole plain and travels through a series of solution cavities to the ground-water Basin B trunk conduit (Figure C11-2 and Figure C11-3). Under these conditions, each ground-water basin hydraulically operates as a separate entity. The general direction of flow in Basin B (although tortuous) is directly toward the Little Blue River.

During peak rainfall events, recharge to the aquifer via sinkholes and swallets causes ground-water levels within the Basin B trunk conduit to increase to the point where upper cavity transverse conduits are intersected and ground-water migrates into the trunk conduits of Basins A and C. This process is termed "ground-water piracy". The consequence of this process can be severe. In the example setting, a substantial population within Basin C is served by ground water from the trunk conduit. During high intensity recharge events, ground water from Basin B which could potentially contain contaminants from the proposed facility will travel to all three ground-water basins. In effect, disposal activities in one distinct basin could potentially affect both the substantial population and the ecologically vital area.

Well Survey

Within the two-mile Classification Review Area radius, several domestic wells exist on the sinkhole plain as well as domestic spring houses along the sandstone upland region. Within the expanded review area there is a small city that relies on ground water taken from a cave stream.

FIGURE C11-1
FEATURES OF THE EXAMPLE KARST SETTING



EXPLANATION

0 1 2 4 MILES

- PROPOSED FACILITY
- CLASSIFICATION REVIEW AREA BOUNDARY
- 3000 POPULATION WELL CENTER
- ECOLOGICALLY VITAL AREA
- SPRING/SEEP
- FLOW ROUTE
- HIGH-LEVEL OUTFLOW ROUTE
- GROUND-WATER BASIN BOUNDARY
- SWALLET OF SINKING STREAM

FIGURE C11-2
GENERALIZED CROSS-SECTION OF A KARST HYDROGEOLOGIC SETTING

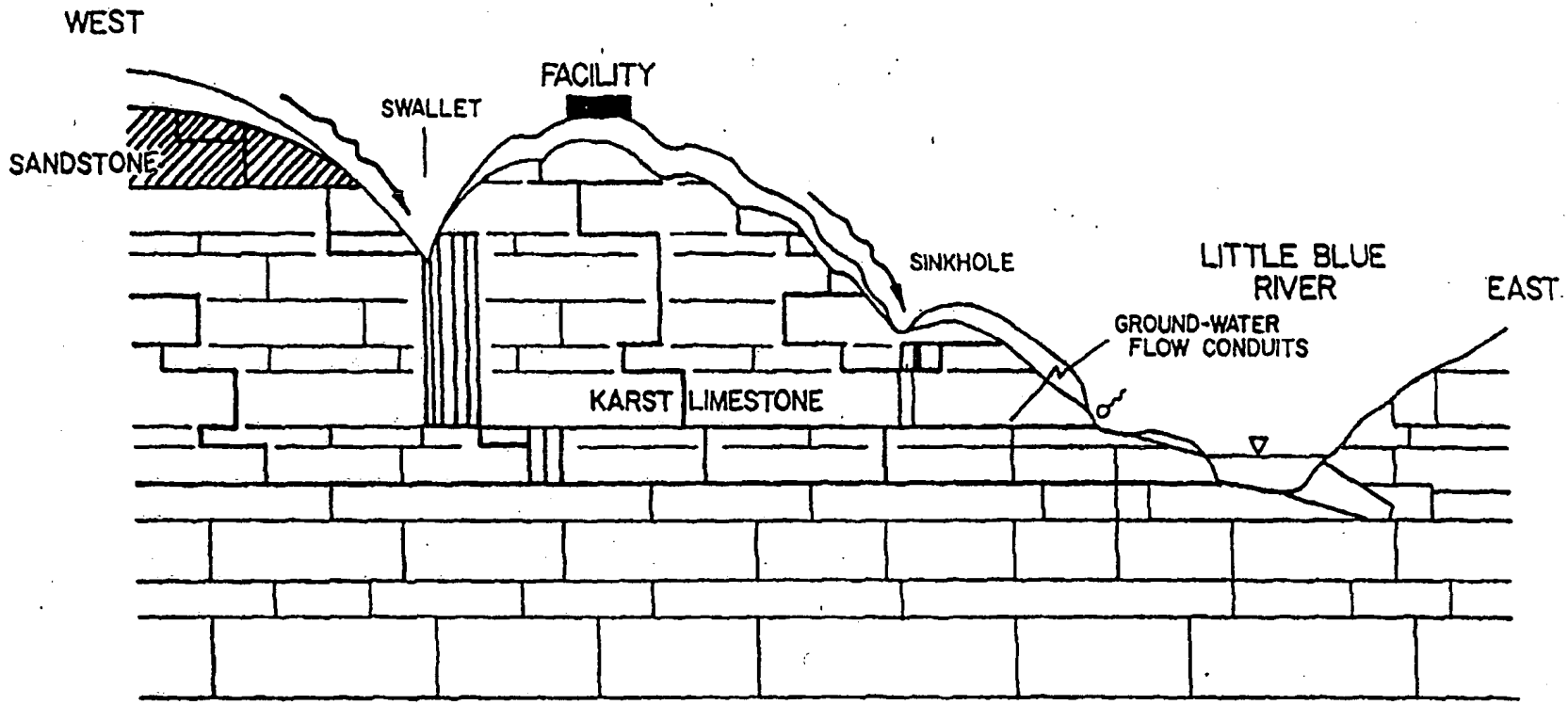
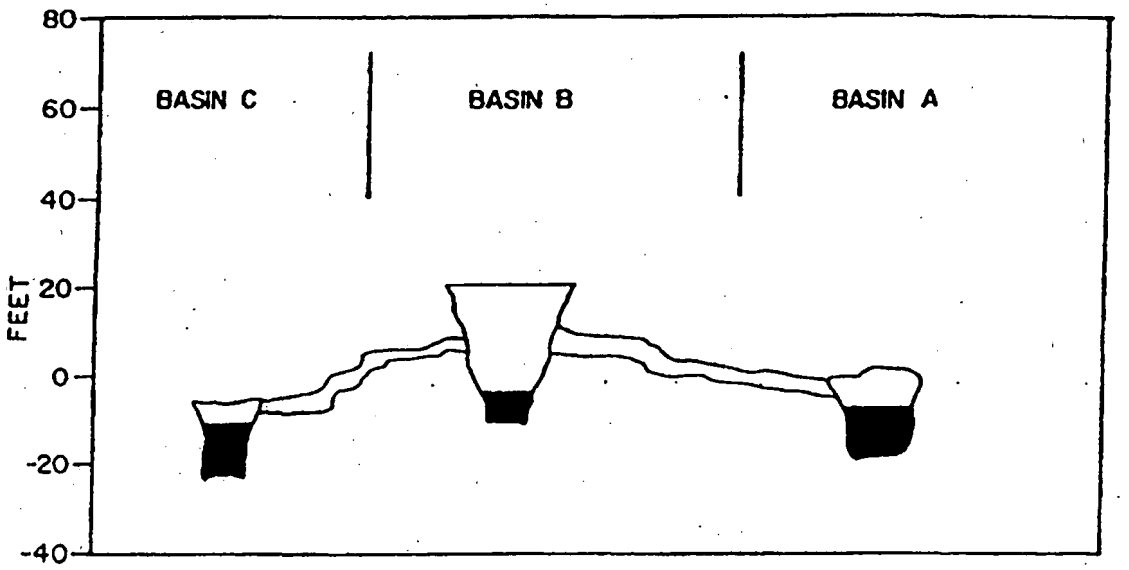
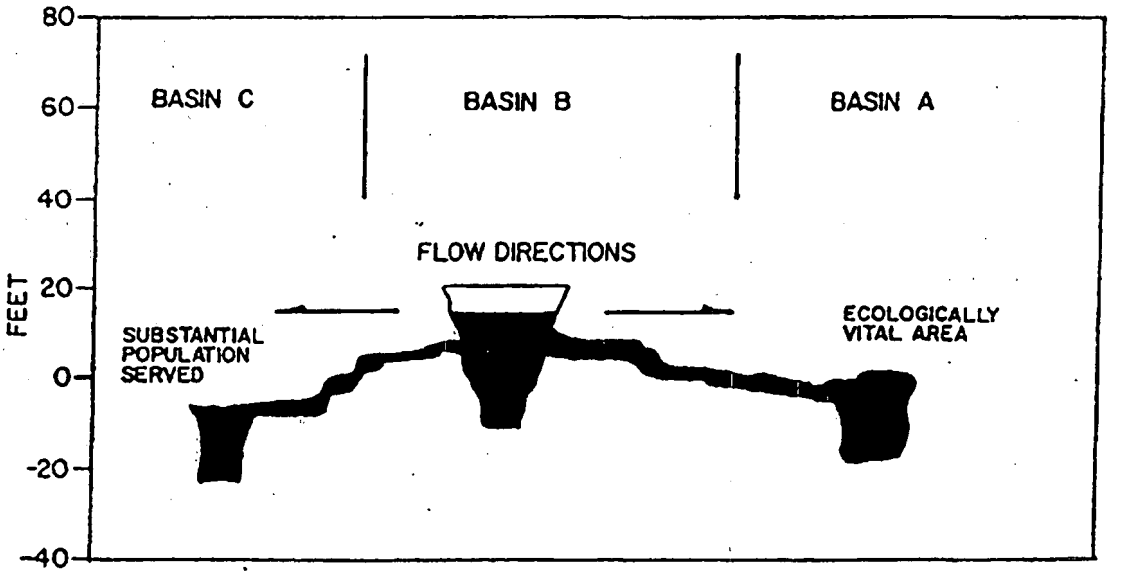


FIGURE C11-3
EXAMPLE OF OVERFLOW ACROSS GROUND-WATER BASINS



BASE FLOW CONDITIONS
(A)



HIGH INTENSITY FLOW CONDITION
(B)

Demography

Several small cities exist nearby but do not fall within the two-mile Classification Review Area. Two population centers each having populations around 3500 to 4000 individuals are found within the expanded review area. Rural residents in the two-mile Classification Review Area number approximately 100. The population is small enough, however, not to involve the issue of substantial population.

Ecologically Vital Areas

The two-mile Classification Review Area does not encompass any Federal lands designated for ecological protection or ecologically vital areas. To the northeast, within the expanded review area and along the Little Blue River, several cave streams have been designated as critical habitats for a rare and endangered aquatic species. Given that the cave stream is a discharge area for ground water, this habitat qualifies as an ecologically vital area.

Vulnerability to Contamination

Under Option A for assessing vulnerability, the DRASTIC methodology yields the following results (averaged over the review area):

	Range	Rating	Weight	Number
Depth to Water	30-50	5	5	25
Net Recharge	10+	9	4	36
Aquifer Media	Karst limestone	10	3	30
Soil Media	Thin to absent	10	2	20
Topography	6-12	5	1	5
Vadose Zone Media	Karst limestone	10	5	50
Hydraulic Conductivity	2000+	10	3	30
			DRASTIC Index (TOTAL)	196

A DRASTIC Index of 196, exceeds the 150 criterion and, therefore, the area is determined to be highly vulnerable to contamination under Option A.

Under Option B for assessing vulnerability, expert hydrogeologists in the area were consulted. Given the substantial lack of soil media and the high permeability of the aquifer, these experts agree that the area is "highly vulnerable."

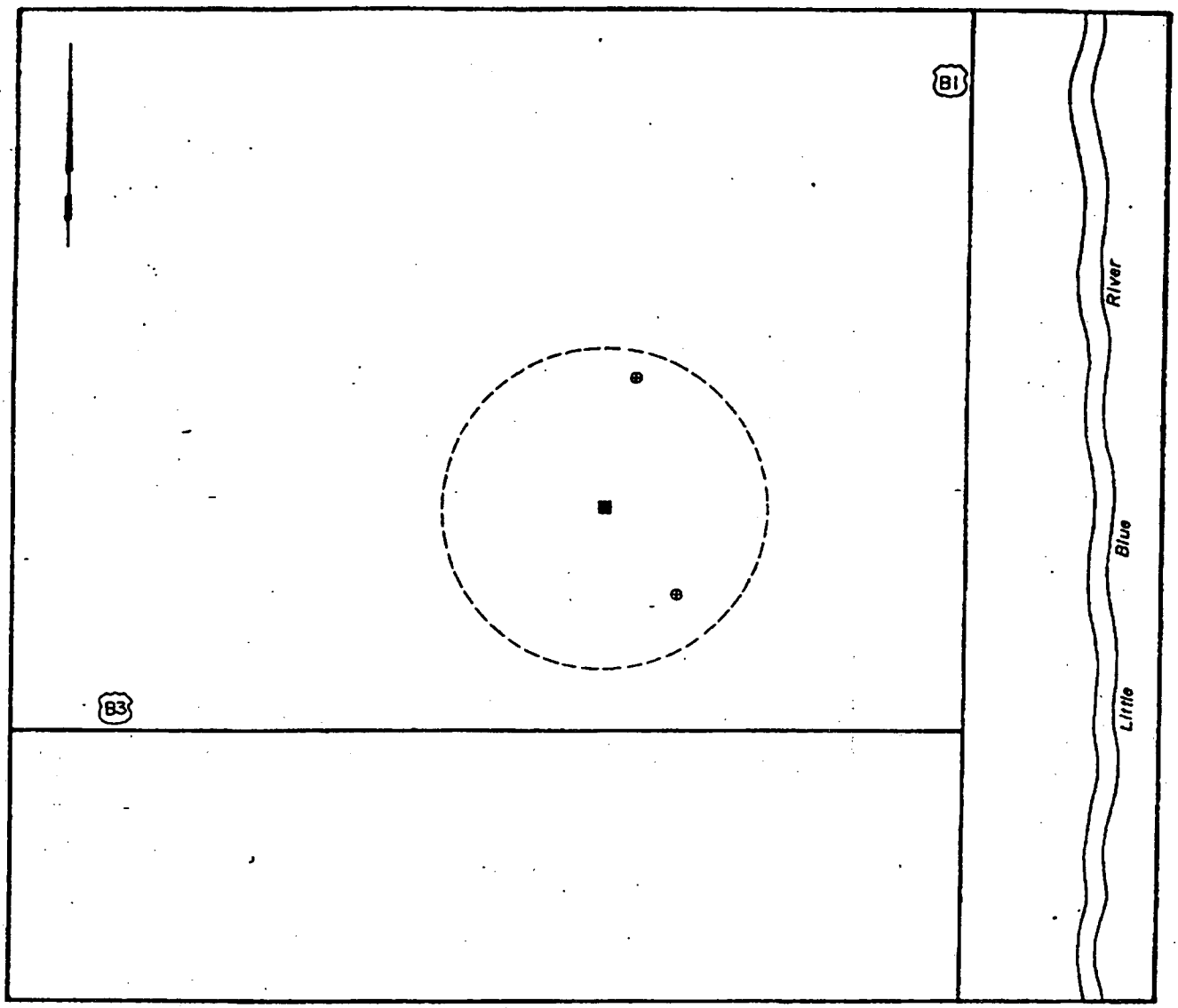
Classification Based on Two-Mile Classification Review Area

Referring to the procedural chart shown in Figure 4-1 and the associated worksheet in Table 4-1, the following classification was performed using a two-mile Classification Review Area as shown in Figure C11-4.

Step	Question/Direction	Response/Comment
1	Establish Classification Review Area (CRA) and collect preliminary information. Optional - Demonstrate subdivision(s) of the CRA.	The CRA is defined by a two-mile radius from the proposed facility. No CRA subdivision has been performed.
2	Locate any ecologically vital areas in the CRA. Does the CRA or appropriate subdivision overlap an ecologically vital area? . Yes, go to next step . No, go to Step 4	No ecologically vital areas are present in the two-mile CRA.
4	Determine location of well(s) within the CRA or appropriate subdivision. Does the CRA or appropriate subdivision contain well(s) used for drinking water? . Yes, go to next Step . No, go to Step 8	Yes, several domestic wells exist on the sinkhole plain as well as domestic spring houses along the sandstone upland region.
5	Inventory population served by well(s). Does the well(s) serve a substantial population? . Yes, go to next step . No. then the ground water is CLASS IIA-CURRENT SOURCE OF DRINKING WATER	No substantial populations are present in the CRA as determined by Option A.

FINAL CLASS DETERMINATION: CLASS IIA-CURRENT SOURCE OF DRINKING WATER

FIGURE C11-4
BASE MAP ENCOMPASSING THE TWO-MILE CLASSIFICATION REVIEW AREA



EXPLANATION

0 1 2 4 MILES

■ PROPOSED FACILITY

---- CLASSIFICATION REVIEW AREA BOUNDARY

⊕ SPRING HOUSE FOR DOMESTIC USE

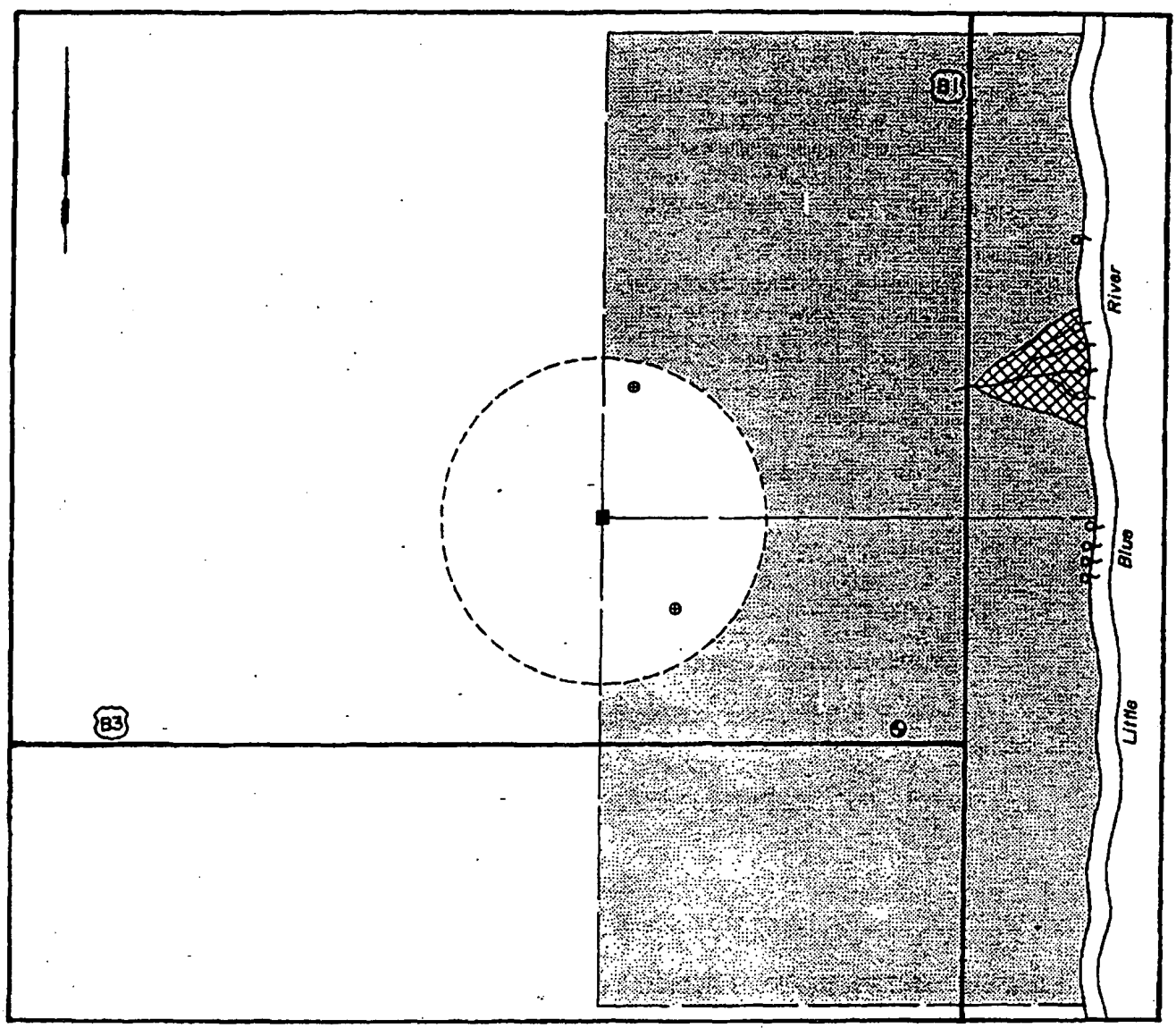
━━ ROADWAY

Classification Based on Expanded Classification Review Area

The expanded Classification Review Area is shown in Figure C11-5. The following work sheet explains the classification decisions. Note that Figure C11-5 does not show the location of the cave stream network nor the location of ground-water basin divides as shown in Figure C11-1. In the majority of Karst areas, this information will not be known.

Because this karst setting is composed of carbonate rocks having a well developed system of enlarged solution openings an expanded Classification Review Area is allowed. It will be assumed that the true location of ground-water basins and karst streams is not known. The dimensions of the expanded review area are then determined by the distance to the nearest spring-fed perennial stream; in this case the Little Blue River. The topographic high between the Little Blue River and the next stream to the east is further east of the facility. Therefore, it can be assumed under the rules of Classification Review Area expansion that ground water beneath the facility will move toward the Little Blue River. The expanded review area is shown in Figure C11-5.

FIGURE C11-5
BASE MAP ENCOMPASSING THE EXPANDED CLASSIFICATION REVIEW AREA



EXPLANATION

- PROPOSED FACILITY
- CLASSIFICATION REVIEW AREA BOUNDARY
- EXPANDED CLASSIFICATION REVIEW AREA
- SPRING HOUSE FOR DOMESTIC USE
- 3000 POPULATION WELL CENTER
- ECOLOGICALLY VITAL AREA
- SPRING / SEEP
- ROADWAY

0 1 2 4 MILES

Step	Question/Direction	Response/Comment
1	Establish Classification Review Area (CRA) and collect preliminary information. Optional - Demonstrate subdivision(s) of the CRA.	The CRA has been expanded because of the karst setting. No CRA subdivision has been performed.
2	Locate any ecologically vital areas in the CRA. Does the CRA or appropriate subdivision overlap an ecologically vital area? . Yes, go to next step . No, go to Step 4	Yes, ecologically vital areas are present in the CRA.
3	Perform vulnerability analysis. Is the CRA or appropriate subdivision a highly vulnerable hydrogeologic setting? . Yes, then the ground water is CLASS I-ECOLOGICALLY VITAL . No, go to next step	Yes, under Options A and B, the expanded CRA is a vulnerable hydrogeologic setting.

FINAL CLASS DETERMINATION: CLASS I-ECOLOGICALLY VITAL

Note: It is possible that the ground water may also be an irreplaceable source of drinking water, however, there was no need to perform an irreplaceability analysis because the ground water qualified as Class I under the ecological vital criteria.

APPENDIX E

BACKGROUND DATA:
CLASS I AND CLASS III ISSUES

TABLE OF CONTENTS

		Page
E.1	REQUIREMENTS AND SOURCE OF WATER-USE DATA.....	E-3
E.2	USE OF GEMS SYSTEM FOR ESTIMATING WELL DENSITY....	E-4
E.3	DENSELY SETTLED CRITERION.....	E-5
E.4	STATE LAW.....	E-6
E.4.1	General Background Information on Institutional Constraints.....	E-6
E.4.2	Federal Law.....	E-8
E.4.3	Interstate Compacts.....	E-9
E.4.4	Local Regulations.....	E-10
E.4.5	Treaties and International Laws.....	E-11
E.4.6	Property Law.....	E-11
E.5	IRREPLACEABILITY: THE ANNUALIZATION FACTOR.....	E-11
E.6	WATER COSTS VS. WATER RATES.....	E-13
E.7	SOURCES OF INCOME DATA INFORMATION.....	E-15
E.8	OVERVIEW OF TREATMENT TECHNOLOGIES.....	E-18
E.8.1	Air Stripping/Aeration.....	E-18
E.8.2	Carbon Adsorption.....	E-19
E.8.3	Chemical Precipitation.....	E-20
E.8.4	Desalination.....	E-21
E.8.5	Flotation.....	E-22
E.8.6	Granular Media Filtration.....	E-23
E.8.7	Ion Exchange.....	E-23
E.8.8	Ozonation.....	E-24
E.8.9	Disinfection and Fluoridation.....	E-24
E.9	SOURCE OF INFORMATION ON ECOLOGICALLY VITAL GROUND WATERS.....	E-25
E.10	RADIUS OF CLASSIFICATION REVIEW AREA.....	E-25
	REFERENCES.....	E-43

E.1 Requirements and Sources of Water-Use Data

The first step in determining whether a substantial population is affected is to identify ground waters in the Classification Review Area (CRA) serving as drinking water sources. It will be necessary to determine whether these are the sources of local town or city drinking water, and to distinguish between centralized public water systems and decentralized private wells.

If the ground water feeds public supplies, the following determinations should be made:

- Locations of wells for public water supply;
- Well depths and pumping rates, if available;
- Areas serviced by public water mains from the source being classified;
- Whether the ground water is the only source for the population it supplies;
- Percentage of water originating in the Classification Review Area used for household purposes (factoring out industrial and irrigation uses);
- Number of households supplied by public system (data are likely to be reported in this form); and
- Number of persons per household for the area, as reported by the Census Bureau, to determine the population supplied by the public system.

The first step in obtaining this information is to contact local and state organizations with responsibility for maintaining records of drinking water supplies and usage for the area. These agencies include:

- Federal/state/local geological surveys;
- State/local health departments;
- State/local water departments;
- Local water treatment facility;
- Local water utility;
- State department of natural resources; and
- State department of energy.

One or more of these organizations should maintain accurate records of public water usage, most likely in terms of the number of households or hookups supplied by the public

system. This number may be translated into an estimate of the population served by using the number of persons per household reported by county in 1980 Census of Population state summaries (see detailed references). Water used for industry or irrigation need to be disaggregated so that only drinking water usage is included.

Where public water sources do not supply the residents within the affected area, detailed information on private wells will be needed. The same agencies mentioned above may also have information on private wells. Private sector organizations that may have useful information include water companies and well-drilling firms.

E.2 Use of GEMS System for Estimating Well Density

One means of estimating private well usage in areas where no local information on private wells is available, is to use population data for the area of interest available through the Graphical Exposure Modeling System (GEMS) maintained by EPA's Office of Toxic Substances, or a private census data service (see list of organizations registered with the National Clearinghouse for Census Data Services in Appendix E).

Information on the GEMS system is available from EPA's OTS modeling team. Using the GEMS Census Data (CD) procedure, it is possible to retrieve population and housing count data from the 1980 Census for circular areas around a point, which can be designated using latitude and longitude coordinates or the ZIP code of the location. The system provides information within defined concentric rings ranging from 0.1 to 10,000km in radii. It is necessary to supply the number of sectors into which the rings are divided; the procedure allows from 1 to 16. Sectors are numbered clockwise with the first sector centered at zero degrees (the north compass point direction). The program tabulates total population and housing counts by ring distance and sector. A simple mathematic conversion can be used to transform the population counts into density.

The manner in which population data are recorded by the Bureau of the Census and reported by GEMS can result in reports of no population for some areas where people are living. This information can be verified or corrected by consulting local officials. It is unlikely that such areas would satisfy the densely settled test, however.

E.3 Densely Settled Criterion

If private wells in the CRA are found to serve at least 2,500 people, the densely settled criterion will be met if the CRA is part of a census-designated densely settled area. If it is contained in an Urbanized Area as described by the Census Bureau, the population is by definition densely settled unless it can be shown to meet any of the exceptions described under the definition of a densely settled area. Census Designated Places (CDP's) also by definition are densely settled. These are unincorporated places with a population density of at least 1,000 persons per square mile. They are outlined on Census tract maps for metropolitan areas, on block numbering area maps in nonmetropolitan areas of less than 10,000 people (see Appendix F).

Key terms used by the Census Bureau as follows:

- Metropolitan statistical area (MSA): (a) a city of at least 50,000 population, or (b) a Census Bureau-defined urbanized area of at least 50,000 with a total metropolitan population of at least 100,000 (75,000 in New England). There are 277 MSAs (as of June 30, 1984). Every state has at least one MSA.

- Urbanized area (UA): a population concentration of 50,000 or more, generally consisting of a central city together with its surrounding densely settled contiguous territory or "suburbs" (the urban fringe). There are about 420 UA's.

- Urban place: any population living within urbanized areas; or places of 2,500 or more people outside urbanized areas.

- Densely settled area: not an official statistical division, but used by the Census Bureau to indicate an area with a population density of at least 1,000 persons per square mile within an urbanized area or Census Designated Place (CDP).

Urbanized Areas may include areas which do not qualify as densely settled, (e.g., less than 1,000 persons per square mile) but are included within such geographic boundaries because they either:

- Eliminate enclaves of less than five square miles which are surrounded by built-up areas.

- Close indentations in the boundaries of densely settled areas that are no more than one mile across the open end and encompasses no more than five square miles.

- Link outlying areas of qualifying density, provided that the outlying areas are:

  (a) Connected by road to, and are not more than 1-1/2 miles from, the main body of the urbanized area.

  (b) Separated from the main body of the urbanized area by water or other undevelopable area, are connected by road to the main body of the urbanized area, and are not more than five miles from the main body of the urbanized area.

- Are nonresidential urban areas (e.g., industrial parks, office areas, or major airports), which have at least one-quarter of their boundaries contiguous to an urbanized area.

MSA's and their components are listed in the 1980 Census of Population - Supplementary Report: Metropolitan Statistical Areas and are mapped on State MSA outline maps. Urbanized area (UA) outline maps are generally contained within MSA publications.

E.4 General Background Information on Institutional Constraints

Institutional constraints on the availability of water can arise from at least six general sources. Each of these is discussed below.

E.4.1 State Law

State law creates basic rights to the withdrawal and use of surface and ground water. For example, state law may regulate the rights to or ownership of water, the withdrawal, uses and allocation of water, conjunctive use of surface and ground water, protection of instream users, and measures required to protect ground water. The law in most states, however, does not create a right to unlimited amounts of water, and may restrict where the water may be used (U.S. EPA, 1985; Council of State Governments, 1983). The states have created different methods for establishing rights to water and resolving conflicts over rights to withdraw and use water. There are three major systems of regulation of water withdrawal and use:

- The Eastern (common law) doctrine, used in about 37 states, provides that ownership of land carries with it a right to water in adjacent lakes or watercourses (a riparian right) and to water beneath the land. The use of the water, however, may be restricted. Under the absolute use doctrine it is possible for a landowner to withdraw unlimited amounts of water, without liability for damage to other landowners, and to transport the water off the land. Under the reasonable use doctrine it is possible to withdraw an amount of water necessary for the use or enjoyment of the overlying land, but the water may not be transported away from that land. Under the correlative rights doctrine, the right to withdraw ground water is based on the relationship between the size of the aquifer and the area of the overlying land.

- The Western (appropriation) doctrine, used in about 13 states, provides that water is a public resource, and rights to water may be acquired by actual use. Conflicts in priority of use are ordinarily settled by the principle of "first in time, first in right." Hierarchies of use, however, may also be established.

- Permit systems, used in about 31 states, may be used in conjunction with the common law or appropriation doctrines, and may be applied to surface and/or to ground water. Rights to water under a permit system are acquired by application to a regulatory authority. If the authority determines that no superior claim exists to the water, it records the claim, issues a permit for use, and polices the actual use. Permit systems may co-exist with other forms of water regulation, such as designated ground-water protection zones or management areas. Many permit systems specify priorities for different types of uses of water (beneficial uses), generally making domestic use, such as drinking water, the highest beneficial use and making other uses, such as commercial or industrial use and irrigation, lower beneficial uses.

Conflicts among users, or prospective users, of water are resolved by most states in three ways: the conflict may be decided by the administrative organization that administers the water rights system in the state, particularly if water use permits are required; special organizations may be created to resolve water disputes; and the state or local courts may resolve disputes. State law in certain circumstances may allow the use of eminent domain powers to shift

water from one use to another, or to allow physical access to water, and state law may grant the use of eminent domain to the Federal government for certain purposes. Frequently, when insufficient water exists for all claimed uses, lower beneficial uses may give way to higher beneficial uses.

Some states have attempted by law to restrict or preclude the export of water to users in other states, either by requiring legislative approval of water exports, by requiring reciprocity agreements with the states receiving the water, or by absolute prohibitions. All of these forms of restriction have recently been subject to legal challenge.

A number of states, particularly in the West, designate ground-water protection zones or management areas, and seek to coordinate surface and ground-water use (conjunctive management). Measures of conjunctive management may include restrictions on pumping ground water, requirements for aquifer recharge, and well spacing requirements. Some states (e.g., Texas, Nebraska) delegate aquifer protection authority to local administrative bodies.

E.4.2 Federal Law

As a user of water, the Federal government generally defers to state regulation of water. Federal laws often pertain to Federal and Indian reserved rights to water and Federal activities affecting water. In common law States, Federal rights to water are linked to ownership or control of land. In prior appropriation and permit States, Federal agencies (e.g., the Bureau of Reclamation) register claims to water. The Federal government may, however, have special access to water in certain circumstances. Statutes (e.g., the Oil and Gas Well Conversion Act) or executive orders (e.g., the Executive Order of April 17, 1926) may reserve water rights on Federal public lands for particular purposes.

For certain categories of Federal lands withdrawn from the public domain and reserved for such uses as national forests, wildlife refuges, and parks, Federal reserved rights doctrine can provide access to water irrespective of State law. The courts have created this doctrine, which holds generally that reservation of public domain lands for a particular purpose carries with it an implied reservation of sufficient water to satisfy the purposes for which the land was reserved. The right is not created by use or lost through non-use. Therefore, in certain circumstances, even if the water is being used by another person, the Federal government can obtain water for its own use. The purpose of the water is determined as of the time the land reservation

was created, and the reserved right is limited to that purpose. (For example, if the reservation was created to provide agricultural land, reserved rights to irrigation water may exist, but there are no reserved rights to water for industrial purposes.)

An Indian reserved right, similar to the Federal reserved right, has also been created by the courts. This doctrine is apparently based on the presumption that in creating an Indian reservation the President and/or Congress intended to reserve sufficient water for the use of the land. Indians may hold superior rights to water connected with reservation lands. Apparently, such rights may be sold, although it is unclear whether only the amount of water actually being used or the entire potential right may be transferred. In addition to reserved rights, in a few instances Indians also hold special water rights based on treaties (e.g., Treaty of Guadalupe Hidalgo).

Federal water resource agencies, such as the Corps of Engineers, the Bureau of Reclamation, and the Soil Conservation Service, as well as such Federally-chartered agencies as the Tennessee Valley Authority and the Bonneville Power Authority, can affect water availability, either through the water rights that they hold or through their decisions concerning water management (Congressional Budget Office, 1983). Numerous other Federal agencies and laws can affect water resource decisions indirectly. Examples of such agencies or laws include the Forest Service and Bureau of Land Management (right-of-way decisions), the Fish and Wildlife Service (requirements under the Fish and Wildlife Coordination Act), the National Environmental Policy Act (Environmental Impact Assessment requirements), Clean Water Act (dredge and fill permit requirements) and the Wild and Scenic Rivers Act and National Wilderness Preservation requirements.

E.4.3 Interstate Compacts

Conflicts among two or more states or the Federal government concerning rights to water in streams generally are resolved either through interstate compacts or through litigation (Clyde, 1982, 1984; Schwartz, 1985; Sporhase vs. Nebraska, 1984). The result in either case is usually a decision allocating the in-stream flow among the states claiming the water. In a few cases, ground water has also been allocated among states by interstate compact or court decision.

E.4.5 Treaties and International Laws

Treaties between the United States and its neighbors, Mexico and Canada, allocate the waters of rivers flowing between the countries. The 1944 Treaty of Utilization of the Waters of the Colorado and Tijuana Rivers and the Rio Grande, for example, apportions the waters of those rivers between the two countries and creates an International Boundary and Water Commission (IBWC) to apply the treaty and settle disputes. Although ground water use is not fully covered by the treaty, the IBWC has attempted to address the management of international ground-water resources.

In addition to treaties signed by the United States, certain international law proposals being developed by the United Nations and the International Law Association may sometime in the future establish general principles for the allocation of ground and surface waters between two countries.

E.4.6 Property Law

State law governs the ownership and use of land. In particular, "property law" affects physical access to water supplies through restrictions on rights of way and easements, or defining powers of eminent domain. State and lcoal law generally regulates land use and access to land by persons who are not landowners. Access to water, including the location of pipes, storage, pumping, treatment, and other facilities can be delayed or restricted by the property rights of persons whose land must be crossed or used for such facilities. Special procedures, such as easements, eminent domain, and condemnation may be required to obtain necessary rights-of-way. Special procedures vary from state to state.

E.5 Irreplaceability: The Annualization Factor

An annualization factor may be used in comparing economic feasibility in the irreplaceability test. The annualization factor (AF), also known as a real capital carrying charge, is given by:

$$AF = \frac{r}{1-1/(1+r)^n}$$

where r = real interest rate
n = life expectancy of capital equipment

The annualization factor is derived to obtain equal annual payments of capital costs in constant dollars (i.e., adjusted

for inflation). This annualization factor is equivalent to the formula used to obtain a total of n equal annual payment for a fixed mortgage in real dollars, where r is the real interest rate for the mortgage.

The choice of real interest rates depends on the costs of available financing for water supply alternatives. The U.S. Office of Management and Budget (OMB) recommends that a ten percent (10%) real interest rate be used to discount capital costs in the analysis of regulatory options. Therefore, an interest rate of ten percent can be used to derive annualization factors. Alternatively, real interest rates on tax exempt bonds used to fund water projects can be used in the analysis.

Municipalities and local governments can rely on tax-exempt bonds to finance their water supply projects. According to Standard & Poor's, the average nominal interest rate on tax exempt bonds was 9.0% in May 1985. The yield on individual bonds would depend on the bond rating. Real interest rates on tax-exempt bonds can be derived from nominal rates (i) by the following formula:

$$r = 1 - \frac{1 + i}{1 + e}$$

where: r = real interest rate
i = nominal interest rate
e = expected rate of inflation

Assuming an expected rate of inflation of 4 percent

$$r = \frac{1+.0908}{1+.04} - 1$$

$$= 1.049 - 1$$
$$= .049 \sim .05 \text{ or } 5 \text{ percent}$$

Annualization factors are calculated here for both 5 and 10 percent real interest rates.

Dereivation of the annualization factor (AF) is affected by the expected life of the capital equipment (n). The appropriate life-expectancy value to be used depends upon many factors, including the type and complexity of equipment and annual operating and maintenance schedules. Typically, a value of 30 years is a reasonable life expectancy for a water treatment plant involving conventional techniques such as sand filtration, flocculation and precipitation, and chlor-

ination. Other, simpler systems may remain operational for longer periods and certain components (such as valves, montioring equipment, or motors) may not last 30 years. Capital costs can be annualized by three single steps:

(1) Estimte capital costs
(2) Estimate annualization factor
(3) Multiply capital costs time annualization factor to obtain annualized costs.

Table E-1 provides three annualization factors that incorporate alternative assumptions for life expectancy of the capital equipment, assuming a real interest rate of five and ten percent, respectively. The values from the table above can be used directly to annualize capital costs. After capital costs are annualized, they should be added to annual O&M costs to obtain the total annual costs.

The procedure for annualizing capital costs can best be illustrated by a numerical example:

Assume	Capital Costs	= $1,200,000
	Real interest rate	= 10% or .10
	Life expectancy of capital equipment	= 30 years

Then

$$AF = \frac{r}{1-1/(1+r)n}$$

$$= \frac{.10}{1-1/(1+.1)^{30}} = \frac{.10}{1-1/17.449}$$

$$= \frac{.10}{.943} = .106$$

Annaulized Capital Costs = Capital Costs x AF
= $1,200,000 x .106
= $127,200

E.6 Water Costs vs. Water Rates

Ground-water classification for Class I - Irreplaceable would normally require an assessment of the economic costs of an alternative water supply under both the qualitative and quantitative approaches for judging irreplaceability. The discussion in this section indicates that rates changed by a water supply utility may not reflect economic costs for various reasons. This implies that when the feasibility determination is not clear-cut and when sufficiently detailed

TABLE E-1
ANNUALIZATION FACTORS

n (Life Expectancy of Capital Equipment)	AF (Annualization Factor)	
	r = .10	r = .05
15	.131	.096
30	.106	.065
40	.102	.058

cost accounts are available from the utility, these should be used in preference to the rate schedules to estimate costs.

The economic cost of the water supply may differ from the charges made to the community by the utility for a number of reasons. The utility may not set rates on the basis of economic costs of supply, or the utility may not face the true economic costs. Rates and fees may be set with reference to the average costs of the utility, whereas the economic costs of additional water supply capacity are the marginal (or incremental) costs of this capacity. Secondly, the utility may charge different rates to different types of users in such a way that one type of user (e.g., industrial users) implicitly subsides other types of users (e.g., households). The concepts are illustrated in examples below.

Consider a hypothetical system that serves 10,000 households. It has annual O&M costs of $500,000 and annualized capital expenses of $500,000 (including an allowance for an acceptable return on capital). Therefore the total annyal expenses of the system are $1,000,000. The utility charges all households served by the system the same flat rate of $100 per annum to recover costs and capital charges of $1,000,000. Suppose that the system is expanded to serve 100 additional users; O&M costs increase to $60,000, capital charges increase to $600,000. The one time costs of connecting the new users of $100,000 are recovered immediately by charging each additional user a connection fee of $100. The utility re-computes rates of 11,000 users based on total costs and capital charges of $1,2000,000, and so charges each user $109.09 ($1,200,000 divided by 11,000). The charges to the new users are the total connection fee of $100,000 plus $109,000 annually (1,000 multiplied by $109.09) for a total of $119,090. However the true costs to the system of the additional users is $109,000 connection costs plus $200,000 annually ($1,309,000 minus $1,000,000) for a total of $309,000. Therefore the rates and fee charged tot he new users understate the true economic costs. The converse is also possible; marginal costs may be lower than average costs so the charges to new users may exceed the true economic costs.

Consider a system serving 10 industrial users and 1000 households. Total system costs are $1,000,000 per annum. The system supplies supplies 200,000,000 gallons annually. Each household uses an average of 100,000 gallons per annum and each industrial user takes 1,000,000 gallons per annum. The utility charges industrial users of 0.75 cents per gallon, raising annual revenue of $75,000, and charges households a flat rateof $25 per annum, raising a further

$25,000. Total revenues are $100,000 which covers the cost of the system. Household users are charged an average of 0.25 cents per gallon, and so are implicitly subsized by industrial users. Economic costs of the system are 0.50 cents per gallon, which exceeds the implicit per-gallon charge to household, and is less than the per-gallon charge to industrial users.

A further general reason that utility rates may not reflect economic costs is that the utility does not face the full economic costs of the system. This can arise if the utility's capital expenditure is subsidized by grants and loans from State or Federal agencies, or by preferential tax treatment. This introduces a further potential source of difference between rates and economic costs.

In cases where cost accounts are not available, the financial accounts of the utility should provide some information that may be used to adjust rate schedules to more closely reflect economic oosts. For example, capital grants for construction received by the utility from state and Federal funds will be shown on the balance sheet. This can be compared with total plant costs (the book value of these fixed assets) to find the proportion of capital costs borne by the utility. Suppose 50 percent of the capital costs are paid for by grants and 50 percent by the utility. Annualized capital expenses are 60 percent of total operating expenses. In this case, the utility is effectively subsidized for 30 percent of total operating expenses. In this case, the utility is effectively subsized for 30 percent of total operating expenses (50 percent of 60 percent of total expenses). As the utility faces only 70 percent of economic costs, rates should be increased by a factor of 1.43 (100 percent divided by 70 percent) to crudely reflect this difference between rates and economic costs. Other potential distortions may be more difficult to correct (even crudely) without access to costs accounts. For example, while different types of users may be charged different rates, it may be impossible to determine whether this reflects different costs of providing a service to different types of users or cross-subsidization between user types.

E.7 Sources of Income Data Information

Income data is available from various sources; depending on the specificity, and the population density of the area. Data sources include the following:

1) County or City Level - The County and City Data Books, U.S. Bureau of the Census, 1983.

2) Census Tract Reports for each Standard Metropolitan Statistical Area.

3) Block Reports (Maps in print) and Block Group data for areas of the county which were blocked by the 1980 Census, but are not within tracts.

4) Enumeration District Reports for areas of the country (rural) which were not blocked by the 1980 Census.

5) Regional Office of the Census.

6) State Coordinating Organizations which may have compiled income data for a specific area.

7) Companies within the National Clearinghouse for Census Data Services that provide demographic studies.

County and city income figures are listed in The County and City Data Book, U.S. Bureau of the Census, 1983. The County and City Data Book shows for each county and city (defined by more than 25,000 people) the median household income for 1979.

Each standard metropolitan statistical area is broken down progressively into tracts, block groups, and blocks. The smallest unit for which income data is available from any depository library or from GPO. The reports contain both means and medians of household income from 1979.

Certain areas of the county were not tracted but were blocked. These areas may be found in unincorporated places of more than 10,000 people and in states (Georgia, Mississippi, New York, Rhode Island, and Virginia), which contracted with the Census Bureau. The unit in which income information may be found for these areas is the block group. Two sets of material should be obtained from the Census Bureau: (1) block maps, available in print and categorized by state, and (2) block group reports available as STE-1A microfiche or on computer tape. Areas not blocked in the 1980 census (i.e., rural areas) are broken down into enumeration districts that average approximately 550 people and are listed by counties within states.

Regional and state offices may also provide specialized income information. A list of the information service specialists in the Census Bureau Regional Offices and State Coordinating Organizations may be found in Appendix F.

Private demographic companies, which the Census Bureau refers to as "National Clearinghouses for Census Data Services" may also be helpful. For example, if median household income inside a 3 mile radius around a CRA were desired, a national clearinghouse would be able to provide appropriate information. A list of these organizations is available in Appendix F.

E.8 Overview of Treatment Technologies

The following discussions of treatment technologies indicate the typical area of application and limitations of particular significance and the potential problems encountered when treating water with multiple contaminants. A series of references is included that can be used for general background data. Many treatment processes, particularly those used in water polishing, develop reductions in treatment efficiencies in the presence of interfering contaminants, so that "pretreatment" is required. In existing water treatment facilities, the pretreatment requirements are met using the processes in an order which progressively removes various interferences. For example, a facility which receives a water with high levels of adsorbable organics and high suspended solids may use granular media filtration prior to carbon adsorption in an effort to minimize the levels of solids in the influent to the carbon adsorption; the load of solids to the adsorption column will disrupt this process.

If several processes in a treatment configuration have disruptive interference problems, the particular combination of processes cannot be reasonably employed to treat the water. This situation might occur if an influent contained high levels of dissolved organics and of inorganic chemical oxidants, and the treatment configuration under consideration was a combination of desalination and ion exchange. The dissolved organics, which would be removed by desalination, could severely disrupt the ion exchange efficiencies, while the chemical oxidants (removable by ion exchange) could disrupt the desalination process. This particular treatment configuration would, in this instance, be eliminated from further consideration because additional pre-treatment would be required to manage the chemical interences.

E.8.1 Air Stripping/Aeration

Air stripping and aeration can be used for removal of volatile contaminants from ground water, as well as for introduction of oxygen to the water. Air is passed through the water or the water is finely sprayed into the air, enhancing transfer of dissolved gases from the water to the

air, which may be treated further or discharged. Cost effective and efficient treatment requires continuous or semi-continuous flow. The process has been used for ammonia removal, hydrogen sulfide removal, and volatile organic carbon removal in both water and wastewater treatment operations. The treatment efficiences and design are a function of the contaminant loading to the air; water ratio, the length of contact time, contaminant volatility, and temperature. Removal efficiencies of volatile organics ranging from 10 to greater than 99.0 percent have been reported in the literature.

Although air stripping is a relatively inexpensive technology for removal of volatile contaminants, its use in public water supply systems to date has been somewhat limited. This is primarily due to an absence of need for the technology, which is in wide-spread use in Superfund remedial action and wastewater treatment operations. Traditional aeration, which is in common use among public water utilities, has typically been installed to provide oxygenation of waters, and the removal of volatile contaminants is merely a beneficial side-effect.

Temperature limitations in regions experiencing severe winters may be such that air stripping and aeration processes must be housed indoors or in thermally protected facilities. If the treated water contains high levels of suspended solids (unlikely to occur with ground waters), some pre-treatment, such as filtration or pH adjustment, may be required prior to air stripping.

Aeration and air stripping pose potential air pollution problems if large amounts of volatile contaminants in the treated waters are transferred to the air. If this is a problem, emission control devices are required. Most ground waters, however, are not likely to contain concentrations of volatile contaminants sufficiently large to warrant such controls.

E.8.2 Carbon Adsorption

Carbon adsorption treatment of ground waters entails contacting the water with activated carbon, which adsorbs contaminants and removes them from solution. Granular activated carbon, used in beds or columns, is the most commonly used form, although powdered activated carbon has been used in some wastewater treatment applications. Treatment processes can use both batch and continuous feed operations. Activated carbon adsorption effectively removes many organic and inorganic contaminants from solution.

Treatment efficiencies are a function of the type of carbon used, the concentration and type of contaminants present, the length of contact time for each unit of water, and the interval between carbon regneration or replacement. Removal efficiencies ranging from 0 to greater than 99.9 percent have been reported in the literature.

Although activated carbon adsorption theoretically can provide limitless removal of contaminants, in reality there are economic limitations to the applicability of activated carbon treatment. Removal of high concentrations of contaminants may require overly frequent carbon replacement, while hard to remove contaminants may require enormous treatment facilities with several carbon contact systems: both situations may incur excessive expense, and though technically feasible would be effectively unavailable.

Influent to the carbon adsorption process must be relatively free of suspended solids and oil/grease to prevent clogging of the adsorption beds. Suspended solids of less than 50 mg/l and oil/grease of less than 10 mg/l are recommeded concentrations to avoid interferences. Biological activity in the carbon beds may become a problem in some instances, causing clogging and taste or odor generation.

Removal efficiencies in carbon adsorption systems are affected by changes in influent flow and influent chemical composition. The presence of multiple contaminants in the influent may reduce adsorption efficiency for some of the constituents, although in some instances increased removal efficiencies have been noted with multiple contaminants. For any given water to be treated, the selection of the appropriate carbon and system design requires laboratory testing to determine the specific adsorption efficiencies and interferences for that influent.

E.8.3 Chemical Precipitation

Chemical precipitation, coagulation, flocculation, and sedimentation are all interrelated processes which are most often used to remove metals and certain organics from solution. For waters containing dissolved solids, a precipitant is added which reacts with the contaminant to form a solid, or to shift solution chemistry in such a way that the contaminant solubility is reduced. The precipitated contaminant can then be removed by gravity sedimentation or mechanical solids removal processes. Commonly used precipitants include lime, caustic, soda ash, iron salts, and phosphate salts. Some waters contain colloidal suspended

solids which cannot be readily removed using conventional sedimentation. Treatment of these contaminants, which are usually organic in nature, entails addition of a coagulant (usually alum, cuprous sulfate, or ferrous sulfate) that forces the suspended solids to agglomerate into larger particles, which can then be removed using gravity sedimentation. Some facilities add polymeric coagulant or precipitation aids, which have been shown to enhance removal efficiencies in some cases. Chemical precipitation processes can be run as batch or continuous flow operations. Treatment efficiencies depend upon the contaminant type and concentration present, the solution pH and temperature, the precipitants added, time and degree of mixing, and the time allowed for sedimentation.

Precipitation of metals from solution can be inhibited by the presence of chelating agents in the waters, such as humic materials (naturally occuring organic acids) or other organic compounds. This problem can be eliminated by using precipitants with stronger affinities for the metal than the complexion agent or by using pH adjustment to disrupt the metal complex.

Use of chemical precipitation processes generates a sludge which must be disposed of appropriately. Sludges containing heavy metals or certain organics may be considered to be hazardous wastes and as such should be disposed in RCRA-regulated facilities.

E.8.4 Desalination

Desalination processes remove contaminants from the influent using membranes to separate an enriched stream (high contaminant concentration) from a depleted stream. Reverse osmosis and ultrafiltration use a pressure differential to drive the separation, while electrodialysis depends on an electric field. The concentrated or enriched stream frequently requires further treatment, while the depleted stream is usually potable. Desalination processes have been used to purify waters to drinking water quality in certain regions of the country where fresh water is in short supply. The processes are in more widespread use for treatment of industrial process waters which must be of extremely high quality. Treatment efficiencies are a function of the molecular size and concentration of contaminants, strength of the separation driving force, membrane type, and system configuration. Removal efficiencies of greater than 90 percent have been reported in the literature.

Desalination processes are highly sensitive to variability in the influent, and drastic changes in pH, temperature, or suspended solids. Any of these factors can effectively reduce treatment efficiencies and the membrane life. The suspended solids in a desalination influent should be minimized to particle sizes 10 microns or less in order to prevent membrane fouling. Biological activity can severely impair the process efficiency, and disinfection may be required prior to desalination. The presence of chlorine may also disrupt efficient desalination, dechlorination or non-chlorine disinfection processes may be desired.

Desalination processes are very expensive and energy-intensive. Because of this, desalination is not frequently used for removal of contaminants which are readily removed via other treatment processes. However, for high TDS waters and waters with large dissolved molecules, these processes may provide cost effective contaminant removal.

E.8.5 Flotation

Flotation is used to remove oil and grease or suspended particles from the agueous phase. The process involves introduction of a gas (usually air) into solution, and subsequent attachment of the gas bubbles to particulate matter which then floats to the surface. The floating particulates can be skimmed and removed for disposal or further treatment. Surfactants and pH-modifications are often used to improve process performance. Flotation is used in many public water utilities across the nation for removal of organic matter from surface waters, but the most common use of the process is removal of oils and grease from industrial petroleum wastewaters. Removal efficiencies are a function of concentration, size, mass of contaminant particles, air loading rate, types of chemical additives used, hydraulic loading rate, and skimmer design. Removal efficiencies over 95 percent have been reported in the literature.

Flotation is effective for contaminants with densities less than or near to that of water, but is relatively ineffective for contaminants which are denser than water. It is not particularly effective at removing dissolved contaminants, although chemical additives can be used to decrease contaminant solubility. If volatile contaminants are present in the influent, flotation may result in simultaneous stripping of these contaminants from solution.

E.8.6 Granular Media Filtration

Granular media filtration is widely used to separate solids from aqueous streams. Water is fed (via gravity or applied pressure) through a bed of granular media, which may consist of sand, gravel, coke, or combinations of the three. Periodically the filter is "backwashed," which removes the filtered particles into a relatively small volume of wastewater which must be disposed or treated further. Granular media filtration is commonly used in water utilities following chemical precipitation to ensure turbidity standards are met. Filtration performance depends upon the solubility of the contaminants, the strength and size of contaminant particles, the type of granular media used, the hydraulic loading rate, and the interval between backwashings. Removal to suspended solid levels less than 10 mg/l has been reported.

E.8.7 Ion Exchange

Ion exchange processes, like carbon adsorption, operate by removing contaminants from solution onto a receptor. The ion exchange process uses a chemically reactive resin which exchanges innocuous ions for the contaminant ions in solution. The reaction is reversible, which allows a facility to regenerate the ion exchange resin and reuse it. Ion exchange processes are most commonly used to generate high quality industrial processes waters, but recent applications have also included wastewater treatment and ion exchange water softening to remove hardness in drinking water supplies. Ion exchange can be used for removal of almost any ion from solution, but is not very effective for removing uncharged contaminant species. Removal efficiencies, which have been reported in excess of 99.9 percent, are dependent upon the ionic charge of the contaminants, contaminant concentration, type of resin used, hydraulic loading, and interval between resin regeneration.

Although almost any ionic contaminant can be removed using ion exchange processes, the specific ion exchange resins used are usually specific to certain types of contaminants. Resin selectivity is based on the type (positive, or negative) and degree of charge on the contaminant ions. If several types of contaminants with varying charge are present, efficient ion exchange treatment may require a series of diffrent resins.

Changes in pH or the presence of organic and inorganic complexing agents may cause certain ionic species to form uncharged or differently charged chemical complexes, which in

turn can reduce the efficiency of ion exchange treatment. These problems are often overcome by adjusting pH so that the desired ionic species are present, or by pretreating the influent to remove complexing agents. Pretreatment may also be required if the influent to the ion exchange process contains excessive suspended solids which will clog the bed or foul the resin.

E.8.8 Ozonation

Ozonation is a chemical oxidation process in which the influent stream is contacted with ozone which breaks refractory (non-biodegradable) organic compounds into smaller, treatable or non-toxic compounds. Used alone or in conjunction with ultraviolet radiation, it is a highly effective means of treating dilute concentrations of organics. Because it is an expensive process to construct and operate, ozonation is not in common use in public water utilities across the nation. However, several individual water treatment systems use ozone rather than chlorine to disinfect their water supply. The process can achieve both effective disinfection and up to 99 percent removal of certain organic compounds. Ozonation effectively removes pesticides, chlorinated hydrocarbons, alcohols, chlorinated aromatics, and cyanides.

The efficiency of contaminant removal using ozonation is dependent upon the retention time of the process reactor, the ozone dose rate, the ultraviolet light dose rate, and the contaminant type and loading. Treatability studies are required prior to installation of ozonation processes to treat specific influent streams.

Ozonation is currently used by only a few public water supply systems, primarily as a disinfection process. It is an expensive process which is readily replaceable with chlorination for disinfection, but which has been gaining acceptance for use in public water supply systems because it does not cause any by-product trihalomethane formation. Lack of use of ozonation in public water supply treatment systems may be due to economic constraints and limited need for the technology.

E.8.9 Disinfection and Fluoridation

Two water treatment processes which are universally available are chlorine disinfection and fluoridation. Chlorine disinfection is the most commonly used means of destroying bacteria in public water supplies. Fluoridation of water supplies is used to prevent dental health problems.

The processes do not remove chemical contamination from the wastestream; they serve instead as preventive measures in control of disease and maintenance of public health.

E.9 Source of Information on Ecologically Vital Ground Waters

Tables E-2, E-3, and E-4 provide a list of U.S. Fish and Wildlife and State Heritage Program representatives who may be contacted to obtain information on the location of potential unique habitats when classifying ecologically-vital ground waters.

E.10 Radius of Classification Review Area

The EPA classification system utilizes a Classification Review Area with a radius of two miles from the boundary of the facility or activity. The radius is intended to be large enough to identify wells and surface waters which are high interconnected with ground water under the facility. The following sources of information were examinaed in the selection of this radius:

- A survey of existing contaminant plumes documented through investigations of spills, leaks and discharges
- A survey of the distances to downgradient surface waters from hazardous-waste facilities; and
- Calculations of the distances from which pumping wells draw ground water under different hydrogeologic settings.

These sources are described below.

Plume Survey

A survey of contaminant plume geometries, (i.e., length, width and depth) was prepared in connection with the development of a stochastic model of corrective action costs at hazardous-waste management facilities (Geraghty & Miller, Inc., 1984). The plume survey provides generalized information on the distances contaminants have been known to migrate regardless of time, source type or hydrogeologic setting. This was viewed as an indication of the area which may be affected if contaminants were accidentally released from the site.

TABLE E-2

LIST OF OFFICES OF ENDANGERED SPECIES
U.S. FISH AND WILDLIFE SERVICES

The Fish and Wildlife Service, a unit of the U.S. Department of the Interior, has been delegated the main responsibility for coordinating national and international efforts on behalf of Endangered Species.

In the case of marine species, however, actions are taken in cooperation with the Secretary of Commerce, through the Director of the National Marine Fisheries Service Similarly, in the area of import/export enforcement for Endangered plants, Interior cooperates with and is assisted by the Department of Agriculture through the Animal and Plant Health Inspection Service (Liaison listed on page 7).

PROGRAM MANAGER--ENDANGERED SPECIES--Mr. Ronald E. Lambertson
Associate Director-Federal Assistance
U.S. Fish and Wildlife Service
U.S. Department of the Interior
Washington, D.C. 20240
Telephone: 202/343-4646

CATEGORY COORDINATOR--ENDANGERED SPECIES--Mr. Roman Koenings
Deputy Associate Director--Federal Assistance
U.S. Fish and Wildlife Service
U.S. Department of the Interior
Washington, D.C. 20240
Telephone: 202/343-4646

Mr. John M. Murphy, Chief
Office of Program Development
and Administration
U.S. Fish and Wildlife Service
1000 North Glebe Road, Room 629
Arlington, Virginia
Telephone: 703/235-1726, 7, 8

Mailing Address for Office of Program Development and Administration

U.S. Fish and Wildlife Service
Washington, D.C. 20240

Mr. John L. Spinks, Jr. Chief
Office of Endangered Species
U.S. Fish and Wildlife Service
1000 North Glebe Road, Suite 500
Arlington, Virginia
Telephone: 703/235-2771, 2

Mailing Address for Office of Endangered Species

U.S. Fish and Wildlife Service
Washington, D.C. 20240

Dr. Kenneth R. Russell, Chief, Branch of Biological Support
Telephone: 703/235-1975, 6, 7

Mr. Brian Cole, Chief, Branch of Management Operations
Telephone: 703/235-2760, 1, 2

Chief
Federal Wildlife Permit Office
U.S. Fish and Wildlife Service
1000 North Glebe Road, Suite 600
Arlington, Virginia
Telephone: 703/235-1937, 8, 9

Mailing Address for Federal Wildlife Permit Office

U.S. Fish and Wildlife Service
Washington, D.C. 20240

Mr. Clark Bavin, Chief
Division of Law Enforcement
U.S. Fish and Wildlife Service
1735 K Street, NW., 3rd Floor
Washington, D.C.
Telephone: 202/343-9242

Mailing Address for Division of Law Enforcement

P.O. Box 28006
Washington, D.C. 20005

Mr. Thomas Striegler, Special-Agent-in-Charge, Branch of Investigations
Telephone: 202/343-9242

Dr. Richard L. Jachowski, Chief
Office of the Scientific Authority
U.S. Fish and Wildlife Service
1717 H Street, NW., Room 536
Washington, D.C.
Telephone: 202/653-5948, 49, 50

Mailing Address for Office of the Scientific Authority

U.S. Fish and Wildlife Service
Washington, D.C. 20240

Regional Endangered Species Coordinators:

The U.S. Fish and Wildlife Service is comprised of seven Regional Offices. (See map on inside back cover for geographic boundaries.) Each office has a senior official who has been designated as a Regional Endangered Species Coordinator. Additionally, each of the regions has several Field Offices. Problems of a local nature should be referred to these offices.

Region 1 Regional Director (Attention: Mr. Sanford R. Wilbur
Endangered Species Specialist)
U.S. Fish and Wildlife Service
Suite 1692, Lloyd 500 Building
500 NE. Multnomah Street
Portland, Oregon 97232
Telephone: 503/231-6131 (FTS: 8/429-6131)

Field Offices

California
1230 "N" Street, 14th Floor
Sacramento, California 95814
Telephone: 916/440-2791 (FTS: 8/448-2791)

Idaho
4696 Overland Road, Room 566
Boise, Idaho 83705
Telephone: 208/334-1806 (FTS: 8/554-1806)

Nevada
Great Basin Complex
4600 Kietzke Lane, Building C
Reno, Nevada 89502
Telephone: 702/784-5227 (FTS: 8/470-5227 or 5228)

Washington/Oregon
Building-3, 2625 Parkmont Lane
Olympia, Washington 98502
Telephone: 206/753-9444 (FTS: 8/434-9444)

Pacific Islands Administrator
300 Ala Moana Boulevard, Room 5302
P.O. Box 50167
Honolulu, Hawaii 96850
Telephone: 808/546-5608 (FTS: 8/546-5608)

Region 2 Regional Director (Attention: Mr. James Johnson
Endangered Species Specialist)
U.S. Fish and Wildlife Service
500 Gold Avenue, SW.
P.O. Box 1306
Albuquerque, New Mexico 87103
Telephone: 505/766-3972 (FTS: 8/474-3972)

Field Offices

Arizona
2934 West Fairmont Avenue
Phoenix, Arizona 85017
Telephone: 602/241-2493 (FTS: 8/261-2493)

New Mexico
P.O. Box 4487
Albuquerque, New Mexico 87196
Telephone: 505/766-3966 (FTS: 8/474-3966)

Oklahoma/Texas
222 South Houston, Suite A
Tulsa, Oklahoma 74127
Telephone: 918/581-7458 (FTS: 8/736-7458)

Texas
c/o CCSU, Box 338
6300 Ocean Drive
Corpus Christi, Texas 78411
Telephone: 512/888-3346 (FTS: 8/734-3346)

Fritz Lanham Building, Room 9A33
819 Taylor Street
Fort Worth, Texas 76102
Telephone: 817/334-2961 (FTS: 8/334-2961)

Region 3 Regional Director (Attention: Mr. James M. Engel
Endangered Species Specialist)
U.S. Fish and Wildlife Service
Federal Building, Fort Snelling
Twin Cities, Minnesota 55111
Telephone: 612/725-3276 (FTS: 8/725-3276)

Region 4 Regional Director (Attention: Mr. Alex B. Montgomery
Endangered Species Specialist)
U.S. Fish and Wildlife Service
The Richard B. Russell Federal Building
75 Spring Street, SW.
Atlanta, Georgia 30303
Telephone: 404/221-3583 (FTS: 8/242-3583)

Field Offices

Alabama/Arkansas/Louisiana/Mississippi
Jackson Mall Office Center
300 Woodrow Wilson Avenue, Suite 3185
Jackson, Mississippi 39213
Telephone: 601/960-4900 (FTS: 8/490-4900)

Florida/Georgia
2747 Art Museum Drive
Jacksonville, Florida 32207
Telephone: 904/791-2580 (FTS: 8/946-2580)

Kentucky/North Carolina/South Carolina/Tennessee
Plateau Building, Room A-5
50 South French Broad Avenue
Asheville, North Carolina 28801
Telephone: 704/258-2850 ext. 382 (FTS: 8/672-0321)

Puerto Rico/Virgin Islands
P.O. Box 3005
Marina Station
Mayaguez, Puerto Rico 00709
Telephone: 809/833-5760 (FTS: 8/967-1221)

Region 5 Regional Director (Attention: Mr. Paul Nickerson
Endangered Species Specialist)
U.S. Fish and Wildlife Service
Suite 700, One Gateway Center
Newton Corner, Massachusetts 02158
Telephone: 617/965-5100 ext. 316 (FTS: 8/829-9316, 7, 8)

Field Offices

Connecticut/Maine/Vermont/Massachusetts
New Hampshire/Rhode Island
P.O. Box 1518
Concord, New Hampshire 03301
Telephone: 603/224-9558, 9 (FTS: 8/834-4726)

District of Columbia/Delaware/Maryland
Virginia/West Virginia
1825 Virginia Street
Annapolis, Maryland 21401
Telephone: 301/269-6324 (FTS: 8/922-4197)

New Jersey/Pennsylvania
112 West Foster Avenue
State College, Pennsylvania 16801
Telephone: 814/234-4090 (FTS: 8/727-4621)

New York
100 Grange Place
Cortland, New York 13045
Telephone: 607/753-9334 (FTS: 8/882-4246)

Region 6 Regional Director (Attention: Mr. Don Rodgers
Endangered Species Specialist)
U.S. Fish and Wildlife Service
P.O. Box 25486, Denver Federal Center
Denver, Colorado 80225
Telephone: 303/234-2496 (FTS: 8/234-2496)

Field Offices

Colorado/Utah
Room 1406, Federal Building
125 S. State Street
Salt Lake City, Utah 84138
Telephone: 801/524-4430 (FTS: 8/588-4430)

Kansas/Nebraska/North Dakota/South Dakota
223 Federal Building
P.O. Box 250
Pierre, South Dakota 57501
Telephone: 605/224-8692 (FTS: 8/782-5226)

Montana/Wyoming
Federal Building, Room 3035
316 North 26th Street
Billings, Montana 59101
Telephone: 406/657-6059 or 6062 (FTS: 8/657-6059)

Region 7 Regional Director (Attention: Mr. Dennis Money
Endangered Species Specialist)
1011 E. Tudor Road
Anchorage, Alaska 99503
Telephone: 907/786-3435 (FTS: 8/907/786-3435)

TABLE E-3

LIST OF STATE NATURAL HERITAGE PROGRAM OFFICES
October 1985

Nongame Branch
ARIZONA HERITAGE PROGRAM
Arizona Game & Fish Department
2222 W. Greenway Rd.
Phoenix, AZ 85023
602/942-3000 x245
Branch Supervisor: Terry Johnson
Zoologist: Dixie Todd
Zoologist: Cecil Schwalbe
Zoologist: Jim Brooks
Data Manager: Rich Glinski
Habitat Spec.: Bruce Palmer
Wildlife Rehab: Cindy Dorothy

ARKANSAS NATURAL HERITAGE INVENTORY
225 E. Markham, Suite 200
Little Rock, AR 72201
501/371-1706
Coordinator/Zoologist: Ken Smith
Ecologist: Tom Foti
Botanist: Steve Orzell
Data Manager: Cindy Osborne

CALIFORNIA NATURAL DIVERSITY DATABASE
c/o CA Dept. of Fish & Game
1416 9th Street
Sacramento, CA 95814
916/322-2493
Section Leader: Steve Nicola
Prog. Manager/Ecol: Deborah Jensen
Zoologist: Larry Eng
Res.Asst/Zool: Carrie Shaw
Aquatic Ecol: John Ellison
Ecologist: Bob Holland
Botanist: Jim Shevock
Asst.Botanist: Cindy Roy
Data Manager: Sylvia Guce
Element Pres.Plan: Roxanne Fitzhen
Enc.Plants Coord: Susan Cochrane
SNAP Coordinator: Chris Unset

COLORADO NATURAL HERITAGE INVENTORY
Dept. of Natural Resources
1313 Sherman St., Rm.713
Denver, CO 80203
303/866-3311
Botanist: Steve O'Kane
Ecol: Susan Galatowitsch
303/860-3142

CONNECTICUT NATURAL DIVERSITY DATABASE
Natural Resources Center
Dept. of Environmental Protection
State Office Building, Rm. 553
165 Capitol Avenue
Hartford, CT 06106
203/566-3540
Biologist/Data Mgr: Nancy Murray
Ecologist: Ken Metzler
Data Manager: Megan Rollins

FLORIDA NATURAL AREAS INVENTORY
254 E. 8th Avenue
Tallahassee, FL 32303
904/224-8207
Coordinator: Steve Gatewood
Zoologist: Dale Jackson
Botanist: Dennis Hardin
Res.Spec/Data Manager: Jim Hutler
Secretary: Judith Lyons

* HAWAII HERITAGE
1116 Smith St., #201
Honolulu, HI 96817
808/537-4509
Director: Audrey Newman

IDAHO NATURAL HERITAGE PROGRAM
4696 Overland Rd., Suite 518
Boise, ID 83705
208/334-3402 or 2642
Coordinator/Zool: Craig Groves
Botanist/Ecologist: Steve Cairco
Data Handler/Biol: Pam Peterson

INDIANA HERITAGE PROGRAM
Div. of Nature Preserves, IN DNR
612 State Office Bldg.
Indianapolis, IN 46204
317/232-4078
Coordinator/Bot: Jim Aldrich
Ecologist: Mike Homoya
Plant Ecologist: Tom Post
Zoologist: Brian Abrell

IOWA NATURAL AREAS INVENTORY
State Conservation Commission
Wallace State Office Bldg.
Des Moines, IA 50319
515/281-8524
Ecologist: John Pearson
Data Handler: John Fleckenstein
Zoologist: Daryl Howell
Botanist: Mark Leoschke

KENTUCKY HERITAGE PROGRAM
KY Nature Preserves Commission
407 Broadway
Frankfort, KY 40601
502/564-2886
Director: Richard Hannon
Botanist: Marc Evans
Zoologist: Ronald Cicerello
Ornithol: Brainard Palmer-Ball
Aquatic Biol: Bill Fisher
Secretary: Julie Smither

LOUISIANA NATURAL HERITAGE PROGRAM
Department of Natural Resources
Coastal Management Division
P.O. Box 44124
Baton Rouge, LA 70804-4124
504/342-4802
Coordinator/Ecol: Nancy Jo Craig
Zoologist: Gary Lester
Botanist: Annette Parker
Data Manager: Alanna Williams

* MAINE NATURAL HERITAGE PROGRAM
Maine Chapter
122 Main Street
Topsham, ME 04086
207/729-5181
Coordinator: John Albright
Data Manager/Bot: Amy Dalpontrace

MARYLAND NATURAL HERITAGE & ENVIRONMENTAL REVIEW
Dept. of Natural Resources
C-3, Tawes State Office Bldg.
Annapolis, MD 21401
301/[illegible] or [illegible] D.C. DIRECT DIAL
301/269-3836
Coordinator/Bot: Dan Boone
Environmental Spec: Angela Nunez
Nat. Area Spec: [illegible] Richardson

* MODEL NATURAL HERITAGE PROGRAM
The Nature Conservancy
1800 N. Kent St., Suite 800
Arlington, VA 22209
703/841-5307
Zoologist: David Wilcove
Botanist: Mary Palmer
Ecologist: Being hired

MASSACHUSETTS HERITAGE PROGRAM
Div. of Fisheries & Wildlife
100 Cambridge St.
Boston, MA 02202
617/727-9194
Coordinator/Ecol: Henry Woolsey
Botanist: Bruce Sorrie
Zoologist: Scott Melvin
Data Manager: Joanne Tribble
Hab.Prot.Spec: Annie Marlowe

MICHIGAN NATURAL FEATURES INVENTORY
Mason Building, 8th Floor
Box 30028
Lansing, MI 48909
517/373-1552
Coordinator/Bot: Sue Crispin
Ecologist: Kim Chapman
Zoologist: Lori Wilsmann
Data Manager: Stu Owings

MINNESOTA NATURAL HERITAGE PROGRAM
Department of Natural Resources
Box 6
St. Paul, MN 55155
612/296-4284
Coordinator: Barbara Coffin
Botanist: Welby Smith
Ecologist: Karin Wendt
Zoologist: Lee Pfannmuller
Data Manager: Carmen Converse

MISSISSIPPI NATURAL HERITAGE PROGRAM
111 N. Jefferson St.
Jackson, MS 39202
601/354-7226
Coord/Bot/Wild.Biol: Ken Gordon
Zoologist: Bob Jones
Ecologist: Jim Wiseman

MISSOURI NATURAL HERITAGE INVENTORY
Missouri Dept. of Conservation
P.O. Box 180
Jefferson City, MO 65102
314/751-4115
Coordinator: Mike Sweet
Biologist: Dennis Figy-X310
Secretary: Diane Munsterman

MONTANA NATURAL HERITAGE PROGRAM
State Library Building
1515 E. 6th Ave.
Helena, MT 59620
406/444-3009
Coordinator/Zool: David Genter
Botanist: Steve Shelly
Ecologist: Nancy Grulke
Data Tech/Sec: Lisa Sheppard

NAVAJO NATURAL HERITAGE PROGRAM
Box 2429
Window Rock, AZ 86515-2429
602/871-4453 or [illegible]
Acting Coord/Botanist: Donna House
Data Manager: Vergil Lynn
Zoologist: vacant

(* = Proto-Heritage Programs)

NEVADA NATURAL HERITAGE PROGRAM
Dept. of Conservation & Natural Resources
c/o Div. of State Parks
Capitol Complex, Nye Bldg.
201 S. Fall St.
Carson City, NV 89710
702/885-4380
Coordinator/Sci.: being hired
Research sci.: being hired

NEW HAMPSHIRE NATURAL HERITAGE PROGRAM
c/o Society for the Protection of N.H. Forests
54 Portsmouth Street
Concord, NH 03301
603/224-9945
Coordinator/Bot: Frances Brackley
Data Manager: Edie Mantzy

NEW JERSEY NATURAL HERITAGE PROGRAM
Office of Natural Lands Management
109 W. State St.
Trenton, NJ 08625
609/984-1339 or 1170
Coordinator/Ecol: Thomas Breden
Botanist: David Snyder
Zoologist: Jim Scasicia
Data Manager: Jane Sass
Data Handler: Elena Williams

NEW MEXICO NATURAL RESOURCES SURVEY SECTION
Villagra Bldg.
Santa Fe, NM 87503
505/827-7862
Coordinator: Cathy Carruthers
Botanist: Paul Knight-7850
Botanist: Anne Cully
Data Handler: Leslie Price
Mgmt. Analyst: Denise Gross

NEW YORK NATURAL HERITAGE PROGRAM
Wildlife Resources Center
Delmar, NY 12054-9767
518/439-8014 x203
Coordinator/Zool: Pat Herlihy
Ecologist: Carol Reschke
Botanist: Steve Clemants
Data Manager: Rachel Plowinski
L.I. Botanist: Bob Zaremba 367-3225

NORTH CAROLINA NATURAL HERITAGE
Dept. of Natural & Economic Res.
Div. of State Parks
Box 27687
Raleigh, NC 27611
919/733-7795
Coordinator: Charles E. Roe
Botanist: Laura Mansberg
Ecologist: Alan Weakley
Protection Spec: Julie M. Moore
Wetlands Inv.Res.Spec: Steven Lapsis
Zoologist: Harry LaGrand, Jr.
Inv. Info. Spec: Mike Schafale

NORTH DAKOTA NATURAL HERITAGE INVENTORY
N.D. Game & Fish Department
100 N. Bismarck Expressway
Bismarck, ND 58501
701/221-6310
Coordinator/Zool: Pete, Mgr:
Botanist: Alexis Gaudry
Plant Ecologist: Bonnie Heidel
Data Manager: Patsy Crooks

OHIO NATURAL HERITAGE PROGRAM
OH DNR, Div. of Nat. Areas & Pres.
Fountain Square, Bldg. F
Columbus, OH 43224
614/265-6453
Coordinator: Bob McCance
Botanist: Allison Cusick
Botanist: Jim Burns
Zoologist: Dan Rice
Plant Ecologist: Dennis Anderson
Data Supervisor: Pat Jones
Data Specialist: MaryAnn Silagy
Data Specialist: Laurie McElaney

OKLAHOMA NATURAL HERITAGE PROGRAM
Oklahoma Tourism & Recreation Dept.
500 Will Rogers Bldg.
Oklahoma City, OK 73105
405/521-2973
Coord/Stat-Analyst: Lois Brown

OREGON NATURAL HERITAGE PROGRAM
Oregon Field Office
1234 NW 25th Avenue
Portland, OR 97210
503/229-5550
Coord/Ecologist: Jimmy Kagan
Botanist: Sue Yamamoto
Zoologist: Connie Lovescuc

PENNSYLVANIA NATURAL DIVERSITY INVENTORY
Bureau of Forestry
Department of Environmental Resources
34 Airport Road
Middletown, PA 17057
717/783-1712
Coordinator/Ecologist: Tom Smith
Zoologist: Anthony Wilkinson

PROGRAMA DEL PATRIMONIO NATURAL
Apartado 5887
Puerta de Tierra, Puerto Rico 00906
809/724-0860
Coord/Ecologist: Peter Ortiz
Bot/Data Man: Vicente Quevedo
Secretary: Myrta Hernandez

RHODE ISLAND HERITAGE PROGRAM
Dept. of Environmental Mgmt.
Div. of Planning & Development
22 Hayes St.
Providence, RI 02903
401/277-2776
Coordinator/Bot: Rick Enser
Zoologist: Chris Raithel

SOUTH CAROLINA HERITAGE TRUST
S.C. Wildl.& Marine Resources Dept.
P.O. Box 167
Columbia, SC 29202
803/758-0014
Coord/Zool: Steve Bennett
Fish & Wildl.Biol: John Cely
Envir.Planner: Stu Greuter
Botanist: Doug Reyner
Ecologist: John Nelson
F&W Bio/Preserve Mgr: Jim Sorrow
Secretary: Kaye Dial Dennis

SOUTH DAKOTA NATURAL HERITAGE
S.D. Dept. of Game, Fish & Parks
Div. of Parks & Recreation
Sigurd Anderson Bldg., B-110
Pierre, SD 57501
605/773-4226
Botanist: David Or
Data Spec: Gerald [illegible]

(TENNESSEE HERITAGE PROGRAM)
ECOLOGICAL SERVICES DIVISION
TN Department of Conservation
701 Broadway
Nashville, TN 37203
615/742-6345
Director: Don Eager
Zoologist: Paul Hamel
Plant Ecol/Prot.Plant: Larry Smith
Botanist: Paul Somers
Wildlife Ecol: Daryl Durham
Data Base Manager: Dave Shupe
Aq.Bio/Pro.Rev.Coor: Roberta Hylton

TEXAS NATURAL HERITAGE PROGRAM
General Land Office
Stephen F. Austin Bldg.
Austin, TX 78701
512/475-0860, 0861, 0821, 0800
Asst.Deputy Commissioner/Land Mgmt.Div: Ben Brown 512/475-1539
Coordinator: Tina Sandy
Zoologist: Rex Wahl
Ecologist: David Diamond
Botanist: Jackie Poole
Data Manager: Robert Murphy
Secretary: Jackie Soliz

TVA REGIONAL HERITAGE
Office of Natural Resources
Norris, TN 37828
615/494-8600
Coordinator: William H. Redmond-X2613
Project Manager: J. Ralph Jordan
Botanist: Jackson L. Collins
Nat.Areas Coord: Judith S. Powers
Zoologist: Charles P. Nicholson

*VERMONT NATURAL HERITAGE PROGRAM
Vermont Field Office
138 Main Street
Montpelier, VT 05602
802/229-4425
Coordinator: Marc DesMeules
Ecologist/Data Man: Liz Thompson

WASHINGTON NATURAL HERITAGE PROGRAM
Department of Natural Resources
Mail Stop EX-13
Olympia, WA 98504
206/753-2448
Coordinator/Bot: Mark Sheerer
Ecologist: Linda Kunze
Plant Ecologist: Reid Schuller
Secretary: Charlotte Nelson
Habitat Preserv.Spec: Betty Roderick

WEST VIRGINIA WILDLIFE/HERITAGE DATABASE
Wildlife Resources Division
DNR Charleston Center
P.O. Box 67
Elkins, WV 26241
304/636-1767
Asst. Director: Pete Zurbuch
Coordinator/Ecol: Brian McDonald
Data Handler: Sandra Mehringer
Botanist: Carrie Rouse

WISCONSIN NATURAL HERITAGE PROGRAM
Endangered Resources/4
Dept. of Natural Resources
101 S. Webster St., Box 7921
Madison, WI 53707
608/266-0924
Zoologist: Bill Smith
Ecologist: Eric Epstein
Botanist: June Dabbertpunt
Data Manager: Kathy Bleser

WYOMING NATURAL HERITAGE PROGRAM
1603 Capitol Avenue, Rm.323
Cheyenne, WY 82001
303/880-8142
Coord/Botanist: vacant

NATIONAL OFFICE HERITAGE TASK FORCE

Bob Jenkins, Vice President, Science 841-5320
Hardy Wisting, Director, Heritage 841-5325
Shelley Rodgers, Assistant Director, HFA 841-5367
Bob Chipley, Director, PS&D 841-5322
Jung Ja An, Budget Specialist 841-5368
Jack White, National Ecologist 217/387-8770
Dorothy Allard, Classification Ecol. 217/387-8770
Larry Morse, Director, Nat'l Database 841-5361
Mary Brosnan, Nat'l Databases Associate 841-5360
Margaret Orness, National Info.Man. 841-5360
Dave Mantman, Microcomputer Analyst 841-5355
Bernadette Schedewald, Microcomputer Specialist 841-5355
Ken Wright, Senior Programmer/Anal. 841-5356
Carol Hodge, Administrative Asst., HFA 841-5354
Brandy Clymire, part-time Secretary, HFA 841-5354
Ursula McGhee, Exec. Secretary, Science 841-5321

REGIONALS

EASTERN HERITAGE TASK FORCE
The Nature Conservancy
294 Washington St.
Boston, MA 02108
617/542-1908
Coordinator/Zool: Larry Master
Ecologist: Tom Reinert
Reg.Info.Mgr.: Jon Cassin
Zoologist: Dale Schweitzer
Data Manager: Marianne Stiberman

MIDWEST HERITAGE TASK FORCE
Midwest Regional Office
The Nature Conservancy
1313 Fifth St., SE
Minneapolis, MN 55414
612/379-2207
Coordinator: Steve Chaplin
Ecologist: being hired
Reg.Info.Mgr.: being hired

ROCKY MOUNTAIN HERITAGE TASK FORCE
The Nature Conservancy
1370 Pennsylvania St., Suite 190
Denver, CO 80203
303/860-8142
Coordinator/Bot: J. Scott Peterson
Ecologist: Patrick Bourgeron
Zoologist: Blair Csuti [415/777-0541]
Reg.Info.Mgr.: Robin Voigt
Data Mand/Seq: Lisa Vester

TABLE E-4

LIST OF ADDITIONAL REFERENCES

50 CFR 17.11 and 17.12, Endangered and Threatened Wildlife and Plants, January 1, 1986.

U.S. Fish and Wildlife Service, Contaminant Issues of Concern - National Wildlife Refuges, January 1986.

Guidance on Ground Water Classification: Approach to Completing Follow-up Research, January 1985, prepared by GCA Corporation for the U.S. Environmental Protection Agency - Land Disposal Branch, Washington, D.C., Contract No. 68-01-6871.

40 CFR 270.3(c), EPA Administered Permit Programs: The Hazardous Waste Permit Program.

Guidance on Remedial Investigations Under CERCLA, Chapter 9, EPA/540/G-85/002, June 1985.

Guidance on Feasibility Studies Under CERCLA, Chapter 6, EPA/540/G-85/003, June 1985.

The data base for the survey included ground-water quality investigations, consultant reports, and other publically-available literature (e.g., scientific journals). The availability of data was limited by the confidential nature of many privately-funded contamination investigations and the relatively small number of off-site investigations conducted by the government prior to the implementation of the Superfund program.

The survey found 50 contaminant plumes containing inorganic and organic contaminants. Hydrocarbon plumes consisted of dissolved and liquid phase (undissolved) materials. The sources of the plumes were spills, leaks and discharges from diverse sources including municipal and industrial sites, transportation accidents and unknown sources. Plume boundaries were defined as a detectable increase above background quality.

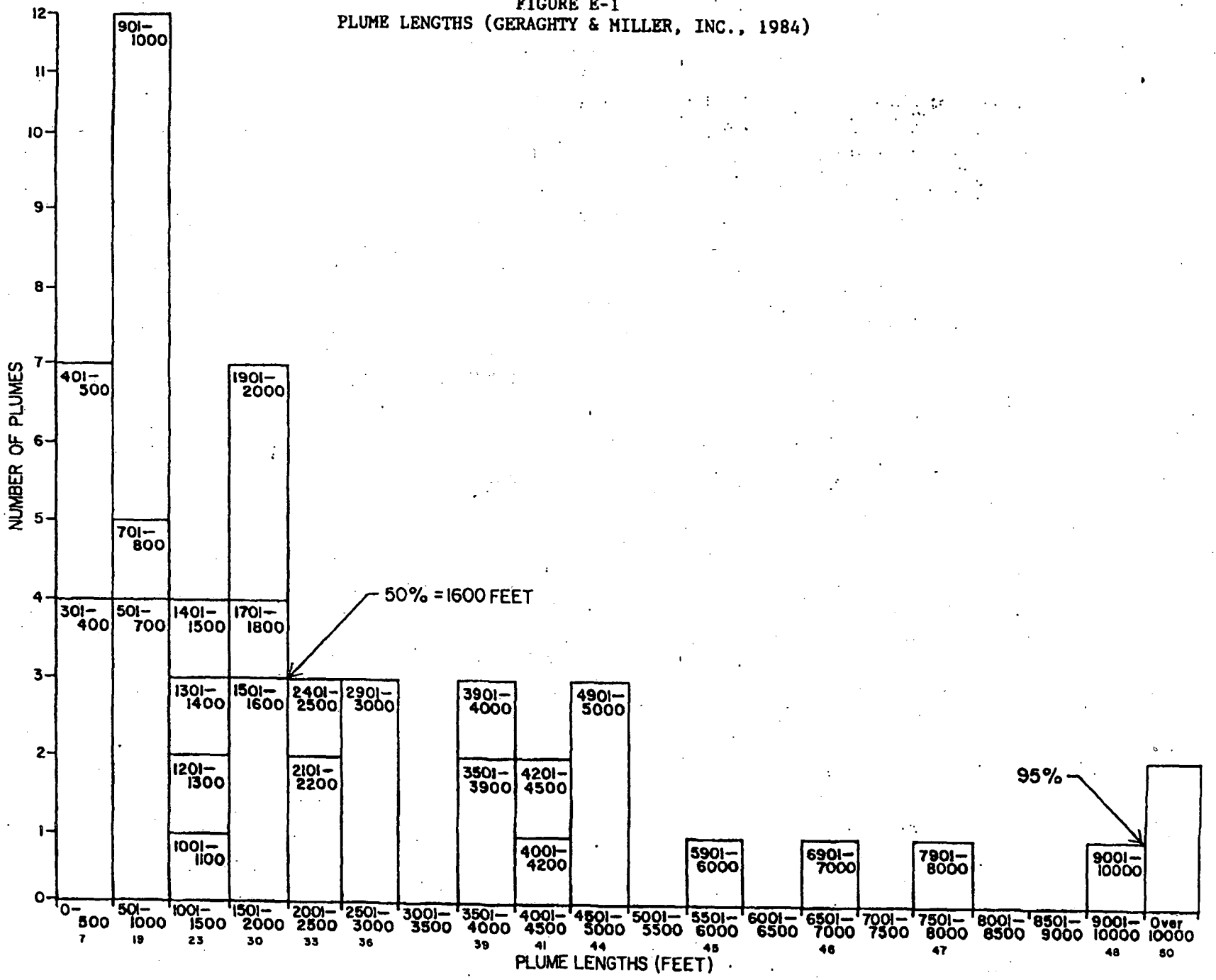
The survey showed that the median plume length was 1600 feet. Ninety-five per cent of the plumes were less than two miles in length. A histogram of plume lengths is provided in Figure E-1.

The data were too limited to determine whether the plumes in this survey had reached their maximum lengths. Theoretically, if a contamination source is continuous and the contaminant is not degraded, transformed, or immobilized in route, the plume length will eventually be equal to the distance to a downgradient discharge point. Other factors which could prevent plumes from reaching their naural discharge points include insufficient time since the contaminant release and the implementation of an effective remedial program. In some cases a steady-state condition may be reached between contaminant input by the source and dilution due to recharge. While it is now known whether the plumes in this survey had reached equilibrium, it is not likely due to their random selection that any one of the above factors had any unusual degree of influence on the results.

Distance to Downgradient Surface Waters

ICF, Inc., conducted a survey of 117 hazardous-waste management facilities for development of the EPA Liner/ Location Model (U.S. EPA, 1985). For each site, the downgradient distance to surface waters (e.g., lakes, streams, ocean, bay or marsh). This information provides insight into the distance at which a flow boundary for the shallow groundwater system is likely to be encountered. Thus, limited the area potentially impacted by a facility.

FIGURE E-1
PLUME LENGTHS (GERAGHTY & MILLER, INC., 1984)



Some of the facilities int he survey were included in EPA's "site visit" facility survey. Other sites were selected from among available Part B Permits. A site was included in the survey only if it provided information sufficient to operate the liner/location model (e.g., comprehensive facility design parameters and hydrogeologic information). Facility sites were located on U.S.G.S. topographic maps using latitude and longitude data. G&M assisted ICF by identifying the general direction of ground-water flow from the site on the topo map. Figure E-2 shows the frequency distribution histogram for distance to down-gradient surface waters. Ninety-five percent of these distances are less than two miles.

Pumping Well Capture Zones

One of the criteria for establishing the radius of the Classification Review Area was to identify highly inter-connected ground-water resources. One test of interconnection is the capture of ground water by a pumping well. It is presumed that all of the area supplying water to a pumping well should be placed in one classification.

All ground water within a flow system between a well and the upgradient ground-water divide may be assumed to be potentially flowing into the well. In addition, wells reverse ground-water flow and capture ground water from downgradient locations as well as "lateral" locations (perpendicular to the regional flow direction, see Figure E-3). Thus, the well capture zone extends in all directions from the well. To determine whether a facility to be classified may fall within a well capture zone it is, therefore, necessary to perform an inventory of wells in all directions from the site, not just in a downgradient direction.

Site-specific data would be required to establish with confidence whether a well is drawing ground water from a site. Optimally, pumping test results and accurate water table data should be obtained. In many cases calculations would need to be supplemented by modelling to estimate the area with accuracy. Such data might be used in subdividing a classification review area; however, the initial area must be large enough to identify all wells to be evaluated.

To determine whether the two-mile radius would satisfactorily identify water-supply wells capturing water from under a site (a formula developed by Todd, 1976) was used to determine the generalized dimensions of well capture zones under different hydrogeologic conditions. The formula,

FIGURE E-2
DOWNGRADIENT DISTANCE TO SURFACE WATER
(SOURCE: EPA, 1985)

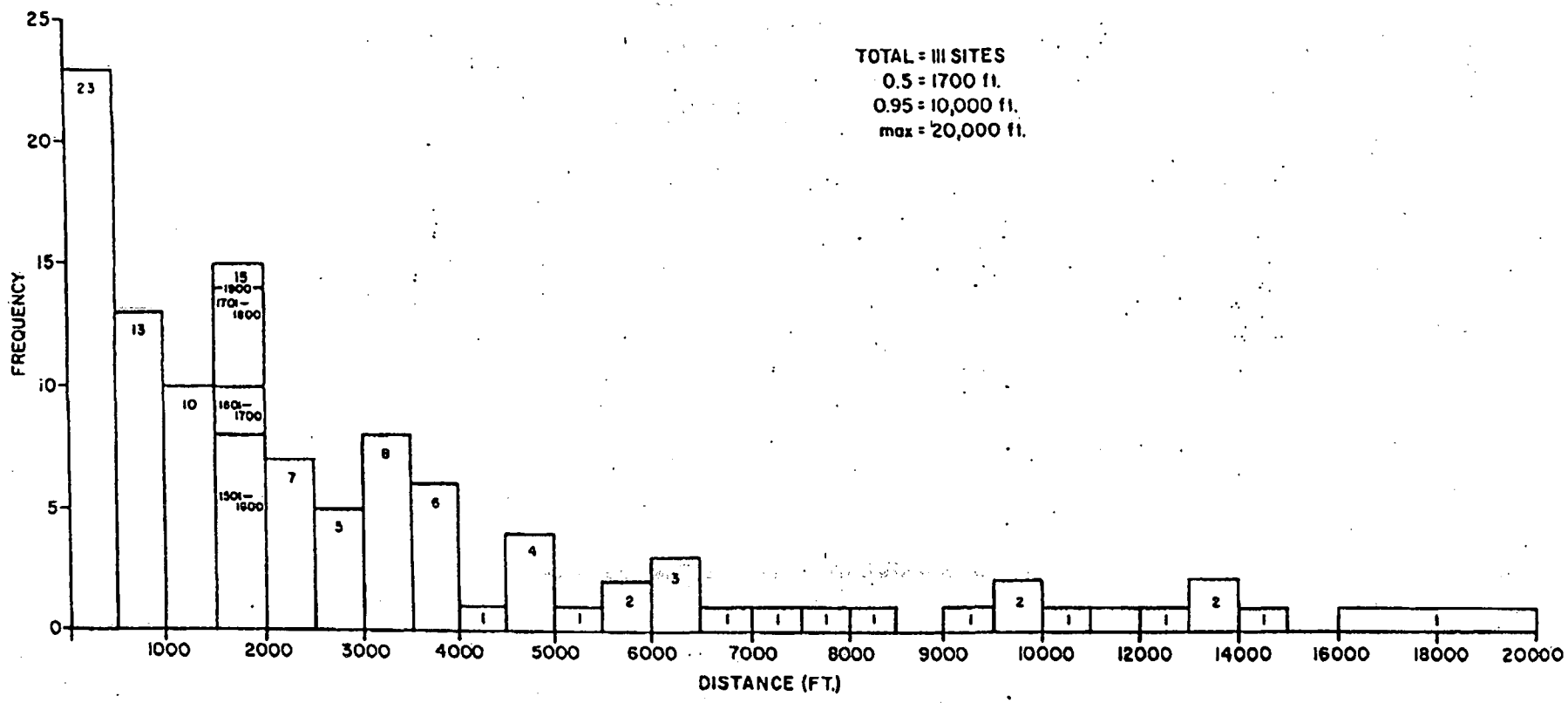
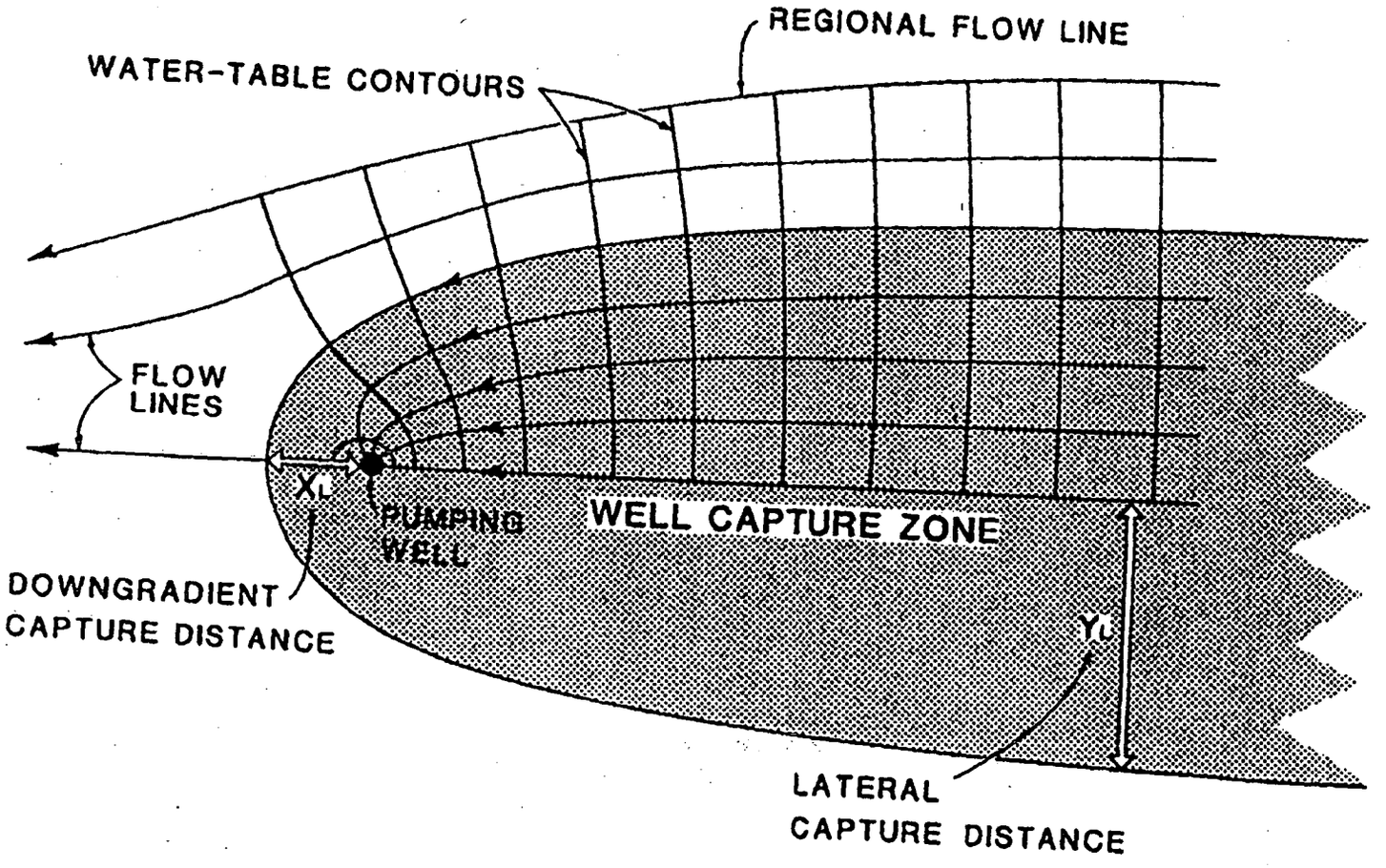


FIGURE E-3
WELL CAPTURE ZONE (FROM TODD, 1976)



illustrated in Exhibit E-5, provides a calculation of the maximum downgradient extent of well capture (XL) and the lateral distance (YL) (perpendicular to non-pumping ground-water flow gradients). Lateral and downgradient capture distances were calculated for a range of transmissivities and water-table gradients under pumping conditions of .5 to 3.0 mgd. Incompatable well yields and transmissivities were not used. Table E-5 shows the results of the calculations.

The well yields were selected to represent the common range of pumping rates for water supply wells (U.S. Geological Survey, 1984). With the exceptions noted below, water-supply wells are generally smaller than 2 mgd. The largest lateral capture distance for a 2.0 mgd supply well for the transmissivities and gradients examined is two miles. Thus, the two-mile radius would identify the majority of individual water-supply wells which could be drawing water from under a proposed facility or site in directions other than the downgradient direction.

> NOTE: Exceptions include the basalt aquifers of the Columbia Plateau and Hawaii, where common well sizes are up to 4 mgd and some may exceed 18 mgd; the Floridan Aquifer in Florida and Georgia where common yields are up to 7 mgd and may exceep 28 mgd; and the Chicot aquifer of the Lake Charles formation in Louisiana where common yields up to 3.5 mgd are found. Other regionally extensive high-yielding aquifers where wells may exceed 2 mgd include the Texas Edwards aquifer, thick members of the Atlantic and Gulf Coastal Plains, alluvium and older sedimentary basins in California and the Sparta Sands in Arkansas.

In summary, the plume survey and survey of distances to discharge boundaries support the two-mile radius in the downgradient direction. The plume data indicates that distance that contaminants are known to migrate in problem concentrations and the distance to discharge points data indicate the likelihood that a flow boundary will be indercepted. Pumping well capture distances provide the basis for including lateral and upgradient areas in the review area. Thus, the two-mile radius provides an initial identification of potentially highly interconnected ground water related to a site under classification.

TABLE E-5
LATERAL AND DOWNGRADIENT WELL CAPTURE DISTANCE (in feet)
(after Todd, 1976)

		Transmissivity/Gradient (ft/mi)		
		10,000/30-50	50,000/10-30	100,000/5-10
.5 MGD	Lateral	4400-2640	2640-880	2640-1320
	Downgradient	1400-840	840-280	840-420
1.0 MGD	Lateral	N.A.	5280-1760	5280-2640
	Downgradient	N.A.	1680-560	1680-840
2.0 MGD	Lateral	N.A.	10,560-3520	10,560-5280
	Downgradient	N.A.	3360-1120	3360-1680
3.0 MGD	Lateral	N.A.	15,840-5280	15,840-7920
	Downgradient	N.A.	5040-1680	5040-2520

Governing Equations

Lateral Distance $Y_L = Q/2Ti$
Downgradient Distance $X_L = Q/2\ Ti$

Y_L = ft
X_L = ft
Q = gpd
T = gpd/ft

N.A. = Not applicable

REFERENCES EVALUATING INSTITUTIONAL CONSTRAINTS OR WATER TREATMENT TECHNOLOGIES

American Water Works Association. Research Foundation and Keuringsinstituut voor Waterleidingartikelen (Cooperative Report). "Occurrence and Removal of Volatile Organic Chemicals from Drinking Water." Denver, CO. 1983.

American Water Works Association. Water Quality Treatment. Denver, CO. 1971.

Argo, D.G., "Control of Organic Chemical Contaminants in Drinking Water." U.S. Environmental Protection Agency Seminar, 1978.

Argo, D.R., "Use of Lime Clarification and Reverse Osmosis in Water Reclamation." Journal Water Pollution Control Federation 56:1238-1246. December, 1984.

Clyde, S.E., "Legal and Institutional Barriers to Transfers and Reallocation of Water Resources," 29 S. Dak. L. Rev. 232 (Spring 1984).

Clyde, S.E., "State Prohibitions on the Interstate Exportation of Scarce Water Resources," 53 U. Colo. L. Rev. 529 (1982).

Congressional Budget Office, Current Cost-Sharing and Financing Policies for Federal and State Water Resources Development, Special Study, July 1983.

Council of State Governments, Interstate Compacts and Agencies, 1983, provides annual listing of names and phone numbers of commissioners of interstate compacts and compact administrators, and citations to state and Federal legislative enactments of compacts.

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APPENDIX F

GENERAL CENSUS BUREAU INFORMATION; NATIONAL CLEARINGHOUSES FOR CENSUS DATA SERVICES; AND BUREAU OF THE CENSUS STATE COORDINATING ORGANIZATIONS

GENERAL CENSUS BUREAU INFORMATION

Regional Census Bureau contracts[1]:

- Atlanta, Georgia 30309: 1365 Peachtree Street, N.E., Room 625
  Telephone: (404) 881-2274

- Boston, Massachusetts 02116: 441 Stuart Street, 10th Floor
  Telephone: (617) 233-0226

- Charlotte, North Carolina 28202: Suite 800, 230 South Tryon Street
  Telephone: (704) 371-6144

- Chicago, Illinois 60604: 55 East Jackson Boulevard, Suite 1304
  Telephone: (312) 353-0631

- Dallas, Texas 75242: 1100 Commerce Street, Room 3C54
  Telephone: (214) 767-0625

- Denver, Colorado 80225: 575 Union Boulevard, P.O. Box 25207
  Telephone: (303) 234-5825

- Detroit, Michigan 48226: Federal Building and U.S. Courthouse, Room 565, 231 West Lafayette Street
  Telephone: (313) 226-4675

- Kansas City, Kansas 66101: One Gateway Center, 4th and State Streets
  Telephone: (816) 374-4601

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[1] Information in each of the 12 regional offices of the Census Bureau answer questions about census publications and products and help users locate and use census data. They also conduct workshops and make presentations on census programs and services.

- Los Angeles, California 90040: 11777 San Vincente Boulevard, 8th Floor
  Telephone: (213) 209-6612

- New York, New York 10007: Federal Office Building, Room 37-130, 26 Federal Plaza
  Telephone: (212) 264-4730

- Philadelphia, Pennsylvania 19106: William J. Green, Jr., Federal Building, 600 Arch Street, Room 9244
  Telephone: (215) 597-8313

- Seattle, Washington 98174: New Federal Building, Room 312, 915 North Second Avenue
  Telephone: (206) 442-7080

Libraries with government depositories

- 1980 Census of Population - Supplementary Report, Metropolitan Statistical Areas, Order No. PC 80-SI-18)

- Urbanized Areas; 1980

- 1980 Census reports for each state

- Census tract maps[2] for local area

- Income statistics[2]

- Enumeration Districts[3]

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[2]Customer Service Bureau, Data User Service Division, Bureau of the Census, Washington, D.C. 20233 (202) 763-4100

[3]Geography Division, Bureau of the Census, Jeffersonville, Indiana (812) 288-3213

National Clearinghouse for Census Data Services

Address List

January 1983

U.S. Department of Commerce • Bureau of the Census • Washington, D.C. 20233

The National Clearinghouse for Census Data Services is a referral service for users needing specialized assistance in obtaining and utilizing statistical data and related products prepared by the Census Bureau. This assistance ranges from informational services such as seminars or workshops to technical services such as providing tape copies or performing geocoding. The organizations listed in this brochure have notified the Census Bureau that they can supply users with the services noted below.

Organizations registered with the National Clearinghouse for Census Data Services complete a checklist describing services they provide. These may include one or all of the following:

- Preparation of computer tape copies, printouts, or special files and extracts.
- Preparation of microfiche copies, printouts from microfiche, or other micrographic services.
- Preparation of analytic reports, area comparisons, or area profiles.
- Online access to data.
- Training programs or other informational services in accessing and/or using census data.
- Special services such as geocoding, site selection, market area analysis, redistricting, or other activities using census products.

Organizations registered with the Clearinghouse are not franchised, established, or supported by the Bureau of the Census. Each organization establishes its own methods of operation, cost structure, and the clientele eligible for services. The Census Bureau does not monitor or control the prices or the quality of services offered by those organizations.

This brochure provides a listing of organizations by State. The letters A through M are used to indicate the services provided by the individual organizations. More detailed information can be obtained directly from the individual organization or from the State and Regional Programs Staff, Data User Services Division, Bureau of the Census, Washington, D.C. 20233, telephone (301) 763-1580.

Related data services are provided directly to users through the Census Bureau's Data User Services Division and the Bureau's regional offices (listed on the last page of this brochure). In many States, services similar to those offered by Clearinghouse registrants may also be provided to State and local governments and others through State data centers (consortiums of State agencies, universities, and libraries). For information on the State Data Center Program, contact a Census Bureau regional office or the State and Regional Programs Staff, Data User Services Division, Bureau of the Census, Washington, D.C. 20233, telephone (301) 763-1580.

California

Allstate Research and Planning Center, Attn: Nicholas Gannam, Allstate Insurance Company, 321 Middlefield Road, Menlo Park, 94025. 415/324-2721 (A,B,C,H,M)

Biddle and Associates, Inc., Attn: Cheryl Morgan/Barbara Dunlap, 903 Enterprise Drive, Suite 1, Sacramento, 95825. 916/929-7670 (B,C,H,L,M)

California Survey Research, Attn: Ken Gross, 152 Ventura Blvd., Suite 1101, Sherman Oaks, 91403. 213/986-9444 (B,C,H,M)

Criterion Incorporated, Attn: Bill Bamberger, 11100 Roselle Street, San Diego, 92121. 714/455-0162 (A,B,C,E,H,J,K,L,M)

David Bradwell and Associates, Inc., Attn: David Bradwell, 880 Las Gallinas Avenue, San Raphel, 94903. 415/479-4980 (B,D,H)

Demographic Research Company, Attn: Joseph J. Weissmann, 233 Wilshire Blvd., Santa Monica, 90401. 213/451-8583 (A,B,C,D,H,I,J,K,L,M)

General Research Corporation, Attn: Lynn Heidler/Michael Sharp, 5383 Hollister Avenue, P.O. Box 6770, Santa Barbara, 93111. 805/964-7724 (A,B,C,E,H,M)

National Decision Systems, Attn: Carne Goodman, 9968 Hibert Street, Suite 100, San Diego, 92131. 714/695-0060 (B,C,E,H,M)

Nobi Takahashi and Associates, Attn: Nobi Takahashi, P.O. Box 1319, Oakland, 94604 415/465-0293 (A,B,D,E,H,I,K,L,M)

Rose Institute of State and Local Governments, Attn: Robert S. Walters, Pitzer Hall, Claremont McKenna College, Claremont, 91711. 714/621-8159 (A,B,C,H,M)

Urban Decision Systems, Inc., Attn: James A. Paris, 2032 Armacost Avenue, P.O. Box 25953, Los Angeles, 90025. 213/820-8931 (A,B,C,E,H,K,L,M) (Organization also located in other states, please contact individual listed above for further information.)

Connecticut

Donnelley Marketing Information Services, Attn: Brian Becker, 1515 Summer Street, Stamford, 06905, 203/357-8735 (A,B,C,E,H,J,L,M)

National CSS, Attn: Jeffrey M. Lee, Business Research Products, 187 Danbury Road, Wilton, 06897, 203/762-2511 (A,B,C,E,H,K,L,M) (Organization also located in other states, please contact individual listed above for further information.)

Reebie Associates, Attn: David A. Isacowitz, Principal, 200 Railroad Avenue, Greenwich, 06830, 203/661-8661 (A,B,C,H,M)

Research for Policy Decisions, Attn: Norman Spector, One Financial Plaza, Hartford, 06103, 203/247-3411 (A,B,C,E,H,I,J,K,L,M)

District of Columbia

Occupations, Inc., Attn: Lloyd V. Tomme, 1260 21st Street, N.W., Suite 801, Washington, D.C., 20036, 202/659-3876 (A,B,C,E,E,H,L,M)

Florida

Behavioral Science Research, Attn: Robert A. Ladner, 1000 Ponce de Leon Blvd., Coral Gables, 33134, 305/448-7622 or 800/327-6207, outside Florida (A,B,C,D,F,H,I,L,M)

Census Group Computing Center, Attn: Paul Hanna, Florida State University, Tallahassee, 32306, 904/644-4836 (A,B,C,D,E,K,M)

Info Tech, Inc., Attn: Marlin Eby, P.O. Box 14545, Gainesville, 32605, 904/375-7624 (A,B,C,D,G,H,I,K,L,M)

St. Petersburg Times and Evening Independent, Attn: Jack Vernon / Susan McKelvey, Research Department, P.O. Box 1121, St. Petersburg, 33731, 813/893-8451 (A,B,C,D,E,H,I,J,K,L,M)

Census Access Program, Attn: Ray Jones, University of Florida Libraries, Department of Reference and Bibliography, University of Florida, Gainesville, 32611, 904/392-0363 (A,B,C,D,E,G,H,J,K,L,M)

Management Institute, Attn: G. Hartley Mallish, Michael J. White, Pamela S. Tucker, College of Business Administration, University of South Florida, Tampa 33620, 813/974-4264 (A,B,C,D,E,I,L,M)

Hawaii

Department of Budget and Finance, Attn: Tad Nakano, Electronic Data Processing Division, P.O. Box 150, Honolulu, 96810, 808/548-3117 (A,B,C,H,L)

Illinois

Concordia College, Attn: William Kammrath, 7400 Augusta Street, River Forest, 60305, 312/771-8300 (A,B,C,D,E,H,L,M)

Indiana

Research Associates, Inc., Attn: John J. Carter, P.O. Box 44640, Indianapolis, 46244, 317/268-6925 (A,B,C,H,J,K,L,M)

Louisiana

Tri-S Associates, Incorporated, Attn: Kenneth Selle/Wayne Hatcher, P.O. Box 130, Ruston, 71270, 318/255-6710 (A,B,C,D,E,H,I,L,M)

Maine

Creative Computing Services, Attn: Celeste Carey, RFD #1, Box 5590, Dryden, 04225, 207/645-3321 (A,B,C,D,H,J,K,M)

Social Science Research Institute, Attn: Garrett Bozylinsky, 164 College Avenue, Orono, 04473, 207/581-2555 (A,B,C,D,H,L,M)

Maryland

Systems Sciences, Inc., Attn: Chris Gordon, 4340 East-West Highway, #1122, Bethesda, 20814, 301/654-0300 (A,B,C,H,J,K,M)

Massachusetts

Geographic Systems, Inc., Attn: Spencer Joyner, 100 Main Street, Reading, 01867, 617/942-0051 (A,B,C,H,J,K,M)

Modeling Systems, Incorporated, Attn: Geoffrey N. Berlin, Ten Emerson Place, Suite 3-E, Boston, 02114, 617/277-6778 (H,J,K,L,M)

NERCOMP, Attn: Robert Gibbs, President, 439 Washington Street, Braintree, 02184, 617/848-6494 (A,B,C,D,E,H,L,M)

United Community Planning Corporation, Attn: Donald D. Dobbin, 87 Kilby Street, Boston, 02109, 617/482-9090 (B,C,H,I,J,K,L,M)

Urban Data Processing, Inc., Attn: Bill Maxfield, 209 Middlesex Turnpike, Burlington, 01803, 617/273-0900 (A,B,C,D,H,J,K,M)

Michigan

COMSHARE, Attn: Ted Jasirzembski, 3001 South State Street, Ann Arbor, 48106, 313/994-4800. (A,B,C,E,H,L,M) (Organization also located in other states, please contact individual listed above for further information.)

Data Research Center, Attn: Scott D. Phillips, 715 East Front Street, Traverse City, 49684, 616/947-2501 (C,H,L,M)

Data Coordination Division, Attn: Patricia C. Becker, Planning Department, City of Detroit, 3400 Cadillac Tower, Detroit, 48226, 313/224-6389 (B,D,H,I,J,M)

Inter-University Consortium for Political and Social Research, Attn: Erik W. Austin, P.O. Box 1248, Ann Arbor, 48106, 313/763-5010 (A,B,C,D,L,M)

LAM Consulting, Incorporated, Attn: Jacquard W. Guenon, 220 Albert Street, Suite 211, East Lansing, 48823, 517/337-7750 (A,B,C,E,F,H,I,L,M)

Michigan State University, Attn: Anders C. Johanson, Computer Laboratory, East Lansing, 48824, 517/355-4684 (A,B,C,D,E,H,J,K,L,M)

Oakland County Planning Division, Attn: David R. Hay, 1200 North Telegraph Road, Pontiac, 48053, 313/858-0720 (A,B,C,D,F,G,H,I)

Southeast Michigan COG, Attn: Jim Thomas, 1249 Washington Blvd., Book Building, Detroit, 48226, 313/961-4266 (A,B,G,H,I,J,K,M)

Total Environmental Systems, Inc., Attn: Robert E. Seaman, 414 North Larch Street, Lansing, 48912, 517/482-2500 (A,B,C,H,I,J,K,L,M)

Tri-County Regional Planning Commission, Attn: Jason E. Whitler, 913 W. Holmes Road, Suite 201, Lansing, 48910, 517/393-0342 (A,B,C,D,E,H,I,J,K,L,M)

Minnesota

DATAMAP, Inc., Attn: Grant I. Warfield, 9749 Hamilton Road, Eden Prairie, 55344, 612/941-0900 (A,B,C,H,I,J,K,L,M)

Mississippi

Mississippi State University, Attn: Ellen S. Bryant, Department of Sociology, P.O. Drawer C, Mississippi State, 39762, 601/325-2495 (A,B,C,D,G,H,L,M)

Missouri

MARC Research Data Center, Attn: Jon A. Nelson, 20 West 9th Street, 2nd Floor, Kansas City, 64105, 816/474-4240 (A,B,G,H,I,J,K,M)

University of Missouri-St.Louis, Attn: John G. Blodgett, Computer Center, 8001 Natural Bridge Road, St. Louis, 63121, 314/553-5131 (A,B,C,H,J,K,L,M)

Nebraska

Metromail Corporation, Attn: William Dougherty, 901 West Bond Street, Lincoln, 68501, 402/475-4591 (A,C,H,J,M)

New Hampshire

Geographic Data Technology, Inc., Attn: Donald F. Cooke, 13 Dartmouth College Highway, Lyme, 03768, 603/795-2183 (J,K,M)

New Jersey

Association of Public Data Users, Attn: Richard D. Bender, Princeton University Computer Center, 87 Prospect Avenue, Princeton, 08540, 609/452-6023 (A,B,C,D,F,H,L,M)

Princeton-Rutgers Census Data Project, Attn: Judith S. Rowe, Princeton University Computer Center, 87 Prospect Avenue, Princeton, 08540, 609/452-6052 (A,B,C,D,E,F,G,H,I,L,M)

New York

American Demographics Magazine, Attn: Peter K. Francese, 127 West State Street, P.O. Box 68, Ithaca, 14850, 607/273-6343 (L,M)

CUNY Data Service, C.A.S.E., Attn: Robert Foss, Director, Graduate School and University Center, City University of New York, 33 West 42nd Street, New York, 10036, 212/354-0640 or 790-4459 (A,B,C,D,E,H,J,K,L,M)

Demographic Systems, Incorporated, Attn: Marvin Finkelstein, Census Service Center Director, 325 Hudson Street, New York, 10013, 212/255-8707 (A,C,H,M)

Financial Marketing Group, Inc., Attn: Henry Lee, 1290 Avenue of the Americas, New York, 10104. 212/581-8725 (A,B,C,D,H,I,J,K,L,M)

Market Statistics, Attn: Edward J. Spar, 633 Third Avenue, New York, 10017 212/986-4800 (A,B,C,D,H,M)

National Planning Data Corporation, Attn: Patsy Bailey Allard, P.O. Box 610, Ithaca, 14850. 607/273-8208 (A,B,C,D,E,H,K,L) (Organization also located in other states, please contact individual listed above for further information.)

User Services, University Computing Center, Attn: Frank Rens, SUNY at Buffalo, 4250 Ridge Lea Road, Amherst, 14228. 716/831-1761 or 1771 (A,B,C,E,F,G,J,K,M)

Tri-State Regional Planning Commission, Attn: Juliette Ellis, 1 World Trade Center, 82nd Floor, New York, 10048. 212/938-3402 (A,B,C,D,H,I,J,K,L,M)

Ohio

Public Demographics, Inc., Attn: Michael Starke, P.O. Box 19005, Cincinnati, 45219. 513/681-3735 (A,B,C,D,E,H,J,M)

Oklahoma

Oklahoma State University, Attn: Eldean Bahm, University Computer Center, Mathematical Sciences Building 113, Stillwater, 74078. 405/624-6301 (A,B,C,I,L,M)

Oregon

Profiles Northwest, Attn: H. W. Cummins, 66 W. 24th Avenue, Eugene, 97405. 503/484-1318 (C,H,I,J,K,L,M)

Pennsylvania

Delaware Valley Regional Planning Commission, Attn: Ronald Fijalkowski, 1819 John F. Kennedy Blvd., Philadelphia, 19103. 215-587-3000 (A,B,C,E,H,I,J,K,L,M)

Planning Data Systems, Attn: Barry R. Cohen, 1601 Walnut Street, Suite 1524, Philadelphia, 19102. 215/665-1551 (A,B,C,D,H,J,K,M)

Robinson Associates, Inc., Attn: Morris Chitsky, Bryn Mawr Mall, 15 Morris Avenue, Bryn Mawr, 19010 215/527-3100 (D,H,I,M)

Southwestern Pennsylvania Regional Planning Commission, Attn: Wade G. Fox, Mann Building, 8th Floor, Pittsburgh, 15219. 412/391-5590/5599 (I)

The UNI-COLL Corporation, Attn: Alanna J. Kelton, 3401 Market Street, Philadelphia, 19104 215/387-3890 (A,B,C,D,E,H,J,K,M)

Tennessee

Econographics of Knoxville, Inc., Attn: Robert J. McCulloch, P.O. Box 9638, Knoxville, 37920-0638. 615/982-1225 (H,I,J,M)

Memphis State University, Attn: Lew Alvarado, Bureau of Business and Economic Research, Memphis, 38152. 901/454-2281 (A,B,C,F,H,L)

Regional and Urban Studies Information Center, Attn: Andrew S. Loebl, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, 37830. 615/574-5968 (A,B,C,D,G,H,L,M)

Texas

Houston-Galveston Area Council, Attn: Dons Davis, 3701 West Alabama, Suite 200, P.O. Box 22777, Houston, 77227 713/627-3200 (A,B,C,G,H,I,J,K,L,M)

The University of Texas at Arlington, Attn: Frank W. Anderson, Institute of Urban Studies, P.O. Box 19588, Arlington, 76019. 817/273-3071 (A,B,C,F,G,H,I,L)

Virginia

CACI, Inc., Attn: George C. Moore, 1815 North Ft. Meyer Drive, Arlington, 22201. 800/336-6600 (A,B,C,D,H,I,J,K,L,M)

Claritas Corporation, Attn: Jonathan E. Robbin, Chairman, 1911 N. Ft. Myer Drive, Rosslyn, 22209 703/841-9200 (A,B,C,D,E,H,I,J,K,M)

Data Use and Access Laboratories, Inc., Attn: Jack Beresford, 1515 Wilson Boulevard, Suite 607, Arlington, 22209 703/525-1480 (A,B,C,D,E,H,I,L,M)

International Data and Development, Inc., Attn: J. C. Barrett, P.O. Box 2157, Arlington, 22202. 703/525-7806 (A,B,C,D,H,J,K,M)

Virginia Census User Subscriber Service, Attn: Robert D. Rugg/Alexander D. Beatie, c/o The Center for Public Affairs, 921 West Franklin Street, Room 204, Richmond, 23284. 804/257-8105 or 1134 (A,B,C,E,H,L,M)

Warren Glimpse and Company, Attn: Warren Glimpse, Box 1943, Alexandria, 22313. 703/836-6800 (A,B,C,D,E,F,G,H,I,J,K,L,M)

Washington

Puget Sound COG, Attn: Cam McIntosh, 216 1st Avenue South, Seattle, 98104. 206/464-7532 (A,B,C,H,I,J,K,L,M)

Wyoming

University of Wyoming, Attn: G. Fred Doll, Institute for Policy Research, P.O. Box 3925, Laramie, 82071. 307/766-5141 (A,B)

SERVICE CODES

Computer Tape Services:

- A Tape copies
- B Printouts
- C File extracts
- D Tabulations from microdata files
- E Online access to data

Microfiche Services:

- F Microfiche copies
- G Microfiche printouts

Other Data and Information Services:

- H Preparation of analytic reports, area comparations, area profiles
- I Preparation of census map copies
- J Address matching/geocoding services
- K Assistance in use of GBF/DIME Files
- L Training programs, seminars, and/or conferences in accessing and/or using census data
- M Special informational or technical services (e.g., computer graphics, site location, redistricting, etc.)

NATIONAL CLEARINGHOUSE FOR CENSUS DATA SERVICES

ADDRESS LIST — Addendum

Delaware

Census and Data System
Attn: Edward Ratledge
University of Delaware
Willard Hall, Room 312
Main Street
Newark, Delaware 19711
302/738-8405
(A,B,C,D,E,J)

Florida

Paul E. Gagnon
Economic Research Consultant
1021 N.E. 8th Avenue
Fort Lauderdale, Florida 33304
305/463-9732
(D,H,M)

Illinois

Northeastern Illinois Planning Commission
Attn: Chuck Metalitz
Research Services Department
400 West Madison Street-2nd Floor
Chicago, Illinois 60606
312/454-0400

Maryland

Congressional Information Service
Attn: Laima Rivers
4520 East-West Highway, Suite 800
Bethesda, Maryland 20814
301/654-1550 or 800/638-8380
(F)

Ed Nichols Associates
Attn: Ed Nichols
P.O. Box 158
176 Laytonsville Road
Washington Grove, Maryland 20880
301/258-5003
(A,B,C,H,J,M)

Regional Planning Council
Attn: Josef Nathanson
2225 No. Charles Street
Baltimore, Maryland 21218
301/383-5855
(A,B,C,D,H,J,K)

New Jersey

Princeton-Rutgers Census Data Projec
Attn: Gertrude Lewis
Center for Computer and Information Servics
Rutgers University-Hill Center,
Busch Campus
P.O. Box 879
Piscataway, New Jersey 08854
201/932-2483
(A,B,C,D,E,F,G,H,L)

New York

Columbia University Center for the Social Sciences
Attn: Lauretta O'Dell
814 International Affairs Building
420 West 118th Street
New York City, New York 10027
212/280-3038
(B,C,D,E,F,G,H,L)

(Address Change)
Financial Marketing Group, Inc.
377 Park Avenue South
8th Floor
New York, New York 10010
212/685-5930

North Carolina

Personnel Research, Incorporated
Attn: Chris Northup
1901 Chapel Hill Road
Durham, North Carolina 27707
919/493-7534
(A,B,C,H,M)

(more)

Pennsylvania

K. H. Thomas Associates
Attn: Kenneth H. Thomas
University City Science Center,
Suite 200
3508 Market Street
Philadelphia, Pennsylvania 19104
215/382-2700
(A,B,C,F,G,H,I,L,M)

Rhode Island

Social Science Data Center
Attn: James M. Sakoda
Brown University
Box 1916
Providence, Rhode Island 02912
401/863-2550
(A,B,C,D,E,)

Texas

William G. Barker and Associates
Attn: Bradley M. Feinberg
1009 W. Randol Mill Road
Suite 212
Arlington, Texas 76012
817/255-0794
(B,C,E,H,J,K,M)

(Name and Services Change)
DUAL-Comm. Inc. and DUALabs
(A,B,C,D,H,M)

Virginia

Orrington Economics, Inc.
Attn: Jack Goodman
P.O. Box 3756
Arlington, Virginia 22203
703/527-5990
(M)

Washington

Sammamish Data Systems
Attn: Richard Schweitzer
1413 177th Avenue, N.E.
Bellevue, Washington 98808
206/644-2442
(B,C,H,L)

State Data Center Program

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APPENDIX G

ECONOMIC TESTS FOR DETERMINING CLASS I - IRREPLACEABLE AND CLASS III - UNTREATABLE GROUND WATERS

INTRODUCTION

I. Economic Tests for Class I-Irreplaceable and Class III-Untreatable Ground Waters

Ground-water classes are designed to provide a basis for differential protection of ground waters: Class I ground waters are those warranting higher degrees of control to provide extraordinary levels of protection, and Class III ground waters are those warranting the lesser levels of protection due to their use and value. Protection of ground water has both social benefits and social costs. The principal social benefits of ground-water protection are protection of human health and the environment and preservation of socially and economically-valuable ground-water resources. The social costs of protection result from the loss of the economic and other benefits of using the resource.

The Agency's Ground-Water Protection Strategy is based on the principle that the highest value of a ground water is as a current or potential source of drinking water. Certain ground waters warrant a high level of protection because the value of protecting their use as a source of drinking water far exceeds the potential social costs of protection. Conversely, the value of protecting certain other ground waters is very limited because it would be infeasible or inordinately expensive or impractical to use them as a source of drinking water due to contamination or other factors, and so these ground waters warrant a lower level of protection. The economic tests for Class I-irreplaceable and Class III-untreatable ground waters are designed to identify ground waters that warrant higher or lower levels of protection based on their economic value as a source of drinking water. These tests are, however, only several of many class-determining factors.

The economic test for Class I complement the technical, institutional and hydrogeological assessments of irreplaceability and untreatability. The need to include economic considerations can be illustrated by considering the result of performing classifications without applying the proposed economic tests. Failure to include the economic tests in determining class designations could result in some undesirable Class II designations. For example, ground waters that are replaceable based on technical and institutional criteria, but are highly valuable economic sources of water for a substantial population because they would be excessively expensive to replace, would be designated as Class II (in lieu of Class III) without the economic test. Similarly, a

ground water that can be treated to drinking water standards, but only at such excessive expense, by national standards, that its use as drinking water is an extremely remote possibility, would be designated as Class II (in lieu of Class III) without the economic test. Incorporating the economic test would promote more appropriate class designations and corresponding levels of protection in such circumstances.

The economic tests for determining Class I-irreplaceable and Class III-untreatable ground water have similar structures and components. They are both simple, implementable proxies for an exhaustive socioeconomic evaluation of the benefits of protection. These tests are intended for use as "screening" tools only. Classifiers may employ more detailed analyses in making a Class III untreatable classification, depending on the availability of data and site-specific factors. In whichever level of analyses is performed, site-specific factors should be considered in determining the socioeconomic value of protection.

Each test involves comparing site-specific water supply costs with a cost threshold based on local or regional income levels. The cost of a replacement or alternate water supply system is estimated to approximate the value of ground water that is currently used as a drinking water source (a Class I candidate ground water). When the costs of replacement are high, the economic value of protection is high and the ground water, therefore, warrants a high level of protection. Using a similar approach, the cost of using the ground water as a source of drinking water is estimated as a measure of the value of protecting contaminated ground water that is not currently used as a drinking water source (a Class III candidate ground water). In this case, the cost of treating the ground water is inversely related to the value of protection. If this cost is extraordinarily high and other sources are available, the economic value of protecting the ground water is low because the ground water is unlikely to be utilized or provide other beneficial uses and the ground water, therefore, warrants limited protection.

The tests utilize a percentage of local or regional household income as a cost threshold for comparison with the estimated water supply costs to make the class determinations. The use of a local household income measure to establish a cost threshold, rather than a national standard, allows the tests to reflect variations in local economic conditions, and thus, provides a measure of local economic "burden" associated with a particular cost. Variations in cost estimates among ground waters will, in general, be much

more significant than variations in income levels for class determinations using these tests.

The percentages of household income proposed as cost thresholds are based on typical water supply costs relative to household income of the service communities. Current data show that annual water supply costs typically range between 0.1 percent and 1.0 percent of household income. Mean or average costs are about 0.3 percent. Therefore, a cost threshold exceeding 0.3 percent of household income will identify inordinately high costs, and so thresholds exceeding 0.3 percent are proposed for both the Class I and Class III economic tests.

The percent threshold proposed for the Class I-irreplaceable ground water test approximates the very highest costs that people pay for a water supply. Water supply cost data show this level to be between 0.7 and 1.0 percent of household income. For Class III, the overall percent threshold is based on more average percentage of household income that people typically pay, i.e., 0.3 to 0.4 percent. For Class III an additional "treatment cost threshold" is also proposed, however, to focus the classification decision on whether or not the ground water is untreatable. If both cost assessments are above this level, the ground water is unlikely to be developed of a source of drinking water or for other beneficial uses. This portion of the test is essential in that, according to the Ground Water Protection Strategy, Class III is reserved for areas of <u>untreatable</u> ground water. Thus, the economic test must focus on this, to avoid designating as Class III, clean ground waters which are merely expensive to develop because of their depth or distance-to-population factors only.

The Agency has conducted sensitivity analyses of the effects of varying the thresholds. Varying the percent threshold has the effect of varying the number of ground waters designated as either Class I and Class III under the tests. Increasing the percentage thresholds decreases the number of Class I and Class III designations and visa versa. These analyses show that the percentage thresholds identify inordinately high costs, and set a balance so that the number of Class I or Class III designations that will be made will correctly identify ground waters deserving either higher or lower levels of protection. By setting thresholds at these levels, classifiers would not be overprotective by creating an unnecessarily large Class I group, or underprotective by making too many Class III designations. The analyses indicate that this balance is best achieved by using a

different percentage of income threshold for the Class I test than the threshold proposed for the Class III test.

The use of a Class III threshold of between 0.7 and 1.0 percent thus accords with the objective of restricting the Class I designations to "special" ground waters, yet one which results in a sizeable Class I.

In summary, the economic test criteria for Class I are met when:

Water Supply System Replacement Costs (on an annualized basis) $\geq$	0.7 - 1.0 percent of mean annual household income

A threshold of 0.3 percent to 0.4 percent is proposed for analyzing total system costs in the Class III economic test. Additional "treatment cost" thresholds are being proposed to focus the Class III test on the economic "treatability of the ground waters being classified." Recent studies by EPA's Office of Drinking Water show that ground water drinking-water supplies in water-scarce western states can cost as much as $300 per household per year. An informal survey of water utility rate increases that have been approved in recent years, indicates that rate increases over 100 percent of current rates have been proposed and rarily granted. These data provide indicators of when the additional costs of treating a particular ground water may be inordinately high. Therefore, the economic test criteria for Class III are met when:

> Annualized System Costs of an Alternative Water Supply exceed 0.3-0.4 percent of mean annual household income and
>
> The Treatment Costs of an Alternate Water Supply increase household water rates by more than 100 percent or a total of $300/household/year.

The treatment cost threshold may be adjusted to reflect regional or statewide treatment costs in comparable systems. Classifiers may wish to incorporate more detailed economic analyses which express the tradeoffs and/or benefits of protecting a candidate Class III ground water for future uses.

Ranges of values are being proposed so that classifiers will have the flexibility to apply a threshold value that is most appropriate for the situation. EPA is interested in receiving comments on the use of these economic tests, and/or other threshold values.

II. Rationale for the Economic Test of Irreplaceability (Class I)

The classifier may apply an economic test to determine whether ground waters that currently serve a substantial population (among other factors) warrant the special protection of a Class I designation.

The economic test of ground-water irreplaceability complements the assessment of the availability and suitability of an alternative water supply source by considering the economic feasibility of utilizing the alternative. Economic feasibility is determined by comparing typical costs of drinking water supplies to the income of service communities. The test designates a ground water as Class I-irreplaceable if (among other factors) the cost of utilizing an alternative water source is excessive relative to the income of the service community. Specifically, a potential replacement source is defined to be economically infeasible if the annual cost to a typical household user would exceed a percentage of the mean household income in the community.

The economic test, thus, identifies ground-water sources that are replaceable by technical and institutional criteria, but have a particularly high economic value because potential replacements are very costly, and therefore warrant a high or special level of protection.

Percentage of Income Threshold for the Class I Economic Test

The proposed threshold for the economic test is a range of 0.7 to 1.0 percent of annual household income. This range has been chosen by comparing typical water supply costs to the average annual household income of the service populations. Exhibit A presents data on typical water supply costs relative to national average household income. The data show that costs are typically between 0.1 percent and 0.3 percent of average annual household income. Water supply costs rarely exceed one percent of average household income. These data suggest that the threshold percentage of household income for the economic test should be chosen to exceed 0.3 percent to accord with the objective of identifying ground waters that are particularly costly to replace as sources of drinking water. Furthermore, sensitivity analysis of the effects of employing alternative thresholds on the number of Class I designations indicates that:

- Class I representation is fairly insensitive to economic thresholds between 1.0 percent and 0.5 percent

EXHIBIT A

TYPICAL WATER SUPPLY COSTS
RELATIVE TO NATIONAL AVERAGE HOUSEHOLD INCOME

Typical water supply costs per million gallons[a]	$450 - 1,500
Typical water supply costs per household per year[b]	$ 27 - 90
Average annual household income[c]	$26,500
Typical water supply costs as percentage of average household income	0.1 percent - 0.3 percent

[a]Source: Temple, Barker, and Sloane, Inc. 1982, Inflated to 1984 dollars.

[b]Assumes annual household usage of 60,000 gallons.

[c]Source: Average household income, 1983, Statistical Abstract of the U.S., 1986. Inflated to 1984 dollars.

- At a threshold of 1.0 percent, Class I representation is dominated by non-economic Class I criteria; and

- Class I representation is very sensitive to reductions in the threshold value below 0.5 percent.

The use of 0.5 percent or above thus accords with the objective of restricting Class I designations to ground waters for which the socioeconomic value of protection is particularly high, but the designation is not so overly restrictive that it would result in a negligible Class I.

Implementation of the Economic Test

Implementation of the economic test has two principal steps:

(1) Estimating the cost of developing an alternative source to provide drinking water to the population currently served by the ground water under review; and

(2) Comparing the costs of the alternative for a typical user household to the test percentage of average household income for the population.

Estimation of Costs for Alternative Water Source

The classifier must calculate the cost of the most economical alternate systems. He or she may base the system cost estimates on a system the same size as the one being classified, or he/she may estimate the size of the system that would be needed.

Water supply system costs can be broken down into four major components:

(1) Acquisition;
(2) Treatment;
(3) Distribution and Transmission; and
(4) Support Services.

Each of these costs elements may be incurred in developing an alternative source to supply a community with drinking water. Acquisition costs are the costs of producing or acquiring water, and can be thought of as the costs of getting the water to the treatment plant. These costs include the capital, operating, and maintenance costs of wells, reservoirs and aqueducts, and payments to suppliers for purchased water. Treatment costs include the costs of treatment plant

and equipment, and the costs of chemicals that are added to the water. Distribution and transmission costs are the costs of pumping the water from the treatment plant to the service population, and the capital and maintenance costs of the piping network. Support services costs are the costs of administrative and customer services that are not directly related to the physical process of delivering water.

Exhibit B shows the average cost structure of the small and large systems surveyed by ACT Inc. (ACT Systems Inc., 1977, 1979). Costs are separated into the four major components, with the exception of interest expenses which were not allocated to particular cost components, and have been shown separately.

Water system costs vary depending on the scale of the system. Exhibit C shows average costs for ground-water and surface-water systems serving populations in various size categories, based on survey data collected by Temple, Barker and Sloane Inc. (Temple, Barker and Sloane Inc., 1982). The data were collected in 1981 and have been inflated to 1984 dollars.

These data show that there are significant economies of scale in systems operation. Systems serving populations of approximately 300,000 have average costs of about $600 per million gallons whereas systems serving populations between 2,000 and 20,000 have average costs in the range of $1,000-$1,500. Also, for systems serving over 5,000 people, there appears to be little difference between the average costs of systems that use predominantly ground water and systems that use predominantly surface water. Cost estimates for an alternative source should, therefore, reflect the consideration of the size of the system (determined by the population currently served by the ground water under review).

Cost estimates should also reflect the scope of measures that would be needed to supply the population from an alternative source. Three basic possibilities arise when developing an alternative water source: the first possibility is that only the acquisition component of the system would be needed; the second is that both acquisition and treatment components would be needed; the third is that, in addition to acquisition and treatment components, a transmission and distribution network would need to be constructed. These situations would lead to different costs.

Acquisition costs only would be incurred when existing treatment and distribution capacity could be used with the alternative source. Source development may include such

EXHIBIT B

TYPICAL COST STRUCTURES FOR WATER SUPPLY SYSTEMS

	Small Systems[a]		Large Systems[b]	
	Percentage of Operating Expenses	Percentage of Operating Expenses Excluding Interest Charges	Percentage of Operating Expenses	Percentage of Operating Expenses Excluding Interest Charges
Acquisition	19	22	15	19
Treatment	15	18	10	13
Distribution and Transmission	36	43	31	38
Support Services	14	17	25	30
Interest Charges	16	-	19	-
Total	100	0	100	-

[a]Serving between 300 and 75,000 people.

[b]Serving over 75,000 people.

SOURCE: ACT Systems Inc., 1977, 1979

EXHIBIT C

TYPICAL WATER SYSTEM COSTS[a]
(1984 $/million of gallons produced)

Population Served by System	Source	
	Surface Water	Ground Water
1,000 - 3,300	1,085	1,493
3,300 - 10,000	1,063	924
10,000 - 25,000	795	718
25,000 - 75,000	727	710
75,000 - 500,000	596	606
over 500,000	457	574

[a]Operating expenses (including depreciation and capital charges), inflated to 1984 dollars.

SOURCE: Survey of Operating and Financial Characteristics of Community Water Systems, Temple, Barker and Sloane, Inc., 1982

measures as locating and drilling a new well field in an alternative aquifer, or switching from a ground-water source to a surface-water source.

Both acquisition and treatment costs may be incurred when a difference in water quality between existing and the alternative water source requires that additional treatment processes be added in order to meet water quality standards. For example, the ground-water supply for a community may require no treatment other than chlorination; however, switching to a nearby surface-water supply may require addition of unit processes such a coagulation, flocculation, sedimentation, and filtration to the existing treatment plant to remove contaminants entering the reservoir with surface-water run-off.

Distribution and transmission costs may be incurred in situations where the installation of a new distribution system is necessary in order to supply the community with drinking water from an alternative source. Such extensive measures would generally be required in situations where a population is currently served by a number of private wells and the alternative would require a centrally located water supply system. This situation is particularly applicable to rural settings.

Estimation of costs for an alternative water source should be conducted using site-specific information to the fullest extent possible, because the costs of developing the source can vary widely depending on site-specific factors, and because the purpose of the test is to measure the effect of these factors on costs. However, the data on average system costs and cost structures presented in Exhibits B and C may be used to estimate costs for the system components that are likely to have similar costs to the national average. In these cases, national average system component costs for certain components would be combined with site-specific or source-specific estimates for other system components.

For example, development of an alternative source for a community of 4,000 people currently served by private wells may require development of all of the components of water supply system in order to utilize a nearby lake, which is the only suitable alternative source. In this case, the distribution and transmission and support services components of the system that would be required to develop this source might be typical of systems of similar size nationwide. The national average cost estimates could be used to estimate the costs of these components. From Exhibit B we note that these

components typically comprise 60 percent of the costs of a small system (43 percent for distribution and transmission plus 17 percent for support services). From Exhibit C, we note that average costs per million gallons for surface water systems that serve between 3,300 and 10,000 people are $1,063. Thus $638 (60 percent of $1,063) could be used as the estimate of distribution and transmission and support service costs. (These costs would need to be inflated to the base year for which cost estimates are required. Further discussion of inflation adjustments can be found in Section III of this Appendix and Appendix E, which discuss the economic test for Class III ground-waters.) This estimate would then be added to source-specific estimates of acquisition and treatment costs. Acquisition costs might differ from national averages, for example, because use of the alternative source may involve purchase of expensive water rights and rights-of-way. Treatment costs might be high, for example, because the alternative source contains fertilizer and pesticide run-off from nearby agricultural land.

A number of information sources are available to estimate site-specific component costs. These sources include Federal and State agencies, architectural and engineering consulting firms, trade associations, and local water utilities. Various EPA reports on water supply and water treatment are also good sources of cost information (e.g., Culp, et. al., 1978). (Specific discussion of the use of data from Culp, et. al., is provided in section III of this Appendix in the context of cost estimation for the economic test for Class III). Other sources include the National Water Well Drilling Cost Survey (NWWA, 1979) for cost estimates of ground-water source development (acquisition costs). When utilizing cost estimates from disparate sources that refer to different time periods, care should be taken to allow for inflation (as well as local variations in labor and energy costs). EPA is expected to release updated cost information over the coming years in preparation for the implementation of the public water supply requirements of the Safe Drinking Water Act Amendments of 1986. Until these data are available, cost indices published quarterly by Engineering News Record can be used for this purpose.

Engineering costs are usually estimated in three components: capital costs (e.g., construction, capital equipment), operation and maintenance costs (e.g., labor, equipment replacement & maintenance, utilities, administration), and other costs (e.g., legal fees). Costs estimated in this way should be converted to equivalent annual costs. Annualization of capital costs is based on the expected lifetime of the capital and the cost of finance. As a first

approximation, capital costs may be annualized by multiplying by a factor of 0.1. Thus:

Annualized Capital Costs = Capital Costs x Annualization (Factor (0.1)

and

Annualized Costs = Annualized Capital Costs + O&M costs.

Appendix E provides further discussion of annualization methodology.

For cost estimation, the required system size is determined by the substantial population currently served by the ground water under review. The following standard assumptions may be used to estimate the water capacity required to serve the population:

Average Household Size	= 2.75 persons
Average Annual Household Water Usage[1]	= 150,000 gallons

For example, a population of 4,000 people would require a system with an annual capacity of 218 million gallons (4,000/2.75 x 150,000 gallons per annum). This is equivalent to a capacity of approximately 0.6 million gallons per day (MGD).

Estimated costs of system components should be expressed on a common basis before they are combined. Typically costs are expressed on a per thousand gallon or per million gallon basis. (Exhibit C presents costs on a per million gallon basis). Annualized costs can be easily expressed on this basis by dividing annual costs by the capacity of the system.

Comparison of Costs with Average Household Income

Once the costs to utilize an alternative source have been estimated, the economic test can be performed by comparing the annual cost to a typical user household with the average household income of the population currently served by the ground water under review.

[1] 150,000 gallons is used here to provide capacity for uses other than residential uses. This figure is based on an assumption of 150 gallons per person per day.

The estimated costs to a typical user should be based on the assumption that annual household water usage is 60,000 gallons. (Note that a higher assumption of water use (150,000 gallons) is used when determining system size.) Thus, if total estimated system costs are $1,000 per million gallons, the annual costs for a typical household would be $60 per household ($1,000/1,000,000 x 60,000). This figure is then compared with the average annual household income of the population served by the ground water under review. If data on the average household income of this population is not readily available, data for the county average household income may be used instead. These data are readily available from the Bureau of the Census publication entitled "County and City Data Book", which can usually be found in local libraries. Exhibit D presents state average household incomes, for reference. These aggregated data should be used instead only if more specific county data are unavailable. Again, income data should be inflated to the base year of the test.

When cost and income data have been compiled, the following division can be performed:

$$\frac{\text{Per Household Costs of Utilizing Alternative Source}}{\text{Average Household Income}}$$

The division will generally yield a ratio between 0.05 and 1 percent. If less than 0.7 percent, the ground water should be designated as Class II. If the result falls within or above the range of 0.7 to 1.0 percent, the ground water should be designated as Class I.

Example

A population of 6,000 (2,182 households) is currently served by individual wells in the Classification Review Area. The only viable alternative water source is a reservoir which is currently used largely for agricultural purposes, and is slightly contaminated by fertilizers and pesticides. Utilization of this alternative would require development of an acquisition system to pipe water to the population, a treatment plant capable of treating the water to drinking water standards, and distribution system to deliver the water to the service population. Thus, all of the system components would be required. The distribution and transmission component of the system and support services are likely to be similar to systems of similar size nationwide so national cost estimates may be used for these components. However,

EXHIBIT D

MEAN HOUSEHOLD INCOME BY STATE
(1980)

State		State	
Alabama	$21,200	Montana	$22,600
Alaska	$37,700	North Carolina	$21,800
Arizona	$25,100	North Dakota	$22,800
Arkansas	$19,700	Nebraska	$24,100
California	$28,100	Nevada	$27,600
Colorado	$27,200	New Hampshire	$24,800
Connecticut	$29,500	New Jersey	$29,400
District of Columbia	$26,300	New Mexico	$22,200
Delaware	$26,400	New York	$26,000
Florida	$23,500	Ohio	$25,600
Georgia	$23,200	Oklahoma	$23,000
Hawaii	$30,900	Oregon	$24,900
Idaho	$22,600	Pennsylvania	$24,800
Iowa	$24,600	Rhode Island	$23,900
Illinois	$28,400	South Carolina	$22,200
Indiana	$25,400	South Dakota	$20,000
Kansas	$25,000	Tennessee	$21,700
Kentucky	$21,500	Texas	$25,800
Louisiana	$23,900	Utah	$28,700
Maryland	$30,100	Vermont	$22,100
Massachusettes	$26,100	Virginia	$26,400
Michigan	$27,900	Washington	$26,700
Minnesota	$26,100	West Virginia	$21,800
Mississippi	$19,800	Wyoming	$27,700
Missouri	$23,500		

SOURCE: Bureau of the Census (1980), inflated to 1984 dollars.

acquisition and treatment must be estimated based on the specific circumstances.

Evaluation of this situation should proceed as follows:

i) Determine the system size.
The system would be required to supply a community with approximately 2,182 households. The system capacity required would be 327 million gallons annually, or 0.9 million gallons per day (2,200 x 150,000 / 365 days). 150,000 gallons per household represents a system size with capacity to supply residential, commercial, and other uses.

ii) Determine system components required.
In the case, all of the basic system components would be needed.

iii) Estimate costs of the system.
Distribution and transmission and support services components are typical of national costs, so they may be estimated using average values from Exhibits B and C. These costs are estimated as 60 percent (43 percent plus 17 percent) of $1,063 per million gallons, i.e., $638 per million gallons. Based on consultation with a local water utility, this 1981 dollar figure is inflated by 45 percent to reflect cost changes between 1981 and the year of the analysis. A cost estimate of $925 per million gallons is, therefore, used for these components.

A local engineering firm provides estimates of capital costs of $850,000 to construct a pipeline from the source and a treatment plant capable of treating the water to drinking water standards, and operation and maintenance expenses of $100,000 for the plant and pipeline in current dollars. Thus, approximate annual acquisition and treatment costs are:

	Annualized Capital Costs (Calculated by multiplying capital costs; $850,000, by annualization factor; 0.1)	$ 85,000
+	Annual O&M Costs	$100,000
=	Total Annual Costs	$185,000

In addition, fees of $200 per million gallons would be charged for use of water from the reservoir. Thus, total acquisition and treatment costs would be $795 per million gallons ($185,000 divided by 327 million gallons, plus $200).

Totalling the costs for the system gives:

$765 + $925 = $1,690 per million gallons.

iv) Comparing costs for a typical user household to the average household income.

Costs to the typical household are based on annual usage of 60,000 gallons per household. The cost estimate implies an annual cost of $101 for the typical user ($1,690 divided by 1,000,000 x 60,000).

Recent census data shows that average household income for the county is about $12,000. Thus, the test ration is:

$$\frac{\$101}{\$12,000} = 0.8 \text{ percent}$$

In this case, the costs of utilizing the alternative source are so high that the ground water is irreplaceable according to the economic test criteria, and so it warrants a Class I designation.

III. Economic Test to Indicate that Contaminated Ground Water is Untreatable (Class III)

The economic test can be applied to determine whether a contaminated ground water should be provided the level of protection of a Class II or Class III ground water. This test is provided for comment as a more rigorous test than the "reference technology approach" discussed in the main sections of these guidelines. Economic feasibility is determined in this test with reference to typical costs of drinking water supplies relative to the income of service communities. Data show that annual water supply costs typically represent between 0.1 percent and 0.3 percent of the annual average income of the service community. The economic test designates the ground water as Class III-untreatable if the cost of treating the water to drinking water standards and developing it as a source of drinking water is excessive. Specifically, the use of a contaminated ground water as a source of drinking water is defined to be economically infeasible if the annual total cost (including treatment) to a hypothetical user household would exceed a percentage of the mean annual household income in the hypothetical user population. A hypothetical user population must be used because, by definition, the potential Class III ground water is not currently used and, therefore, the test must be based on a hypothetical user population.

The economic test, thus, identifies ground-water sources which have particularly low economic value (under present or foreseeable future conditions), because treatment and use of such ground waters for drinking purposes would be very costly, and highly unlikely, even though there may be technical procedures available to render these of drinking water quality. Such ground waters, therefore, warrant a lower level of protection than other ground waters. Since this a two-step process, the actual cost of treating the ground water will be of utmost importance; again to avoid the bias of designating "clean" ground waters as Class III due to non-quality factors.

The first threshold test examines total costs over a range of 0.3 to 0.4 percent of household income. This level has been chosen with reference to typical water supply costs relative to the mean household incomes of the service populations. Typical water supply costs relative to national average household income show that costs are typically between 0.1 percent and 0.3 percent of the mean household income. These data suggest that the threshold percentage of household income for the economic test should be chosen to exceed 0.3 percent to accord with the objective of identify-

ing contaminated ground waters that are particularly costly to treat and use as sources of drinking water.

The second step focuses on treatment costs when they increase total system costs to a level which exceeds a total household cost of $300 per year or when they increase current rates more than 100 percent. These criteria are being proposed for assessing "treatability." EPA is seeking comment on these criteria.

Implementation of the Class III Economic Test

STEP 1: Determine Size of Hypothetical User Population

The first step in the economic burden test is to determine the size of the "hypothetical user population", that is, the population that could use (on a conceptual basis) the ground water as a source of drinking water. The size of the hypothetical user population is determined through two approaches, with the second being the controlling:

1) the mean population served by ground-water systems in the state, and

2) a population that could be served by the maximum sustained yield of the aquifer in question.

Exhibit E presents the mean size population served by ground-water supply systems in each state. For example, the mean population served by ground-water systems in the State of Maryland is 3,916. These data may be used for the first estimate.

The second estimate is determined based on the estimated sustained yield of the aquifer. The U.S. Geological Survey office (e.g., District Office) in the state or the state geological or water surveys will often have hydrogeological information (e.g., maps, reports, and surveys) on most aquifers within a state. Consultation with these and other individuals with local expertise and experience can likely provide a reasonable estimate of an aquifer's sustained yield. For more detailed assessments, a review of boring logs, geotechnical evaluations or other data sources will be needed. Field assessments and ground-water monitoring may also be needed to assess not only aquifer yield, but quality parameters as well. Once the sustained yield is estimated, a population equivalent can be determined based on an annual water use of 150,000 gallons per household per year. For example, geotechnical and hydrogeological data may indicate that an area in Maryland, which is being classified, has an

EXHIBIT E

MEAN POPULATION SIZE SERVED BY GROUND-WATER SYSTEMS
BY STATE OR TERRITORY

State		State	
American Samoa	1,360	North Carolina	422
Alabama	2,136	North Dakota	665
Alaska	492	Nebraska	839
Arizona	2,202	Nevada	466
Arkansas	1,848	New Hampshire	610
California	1,799	New Jersey	5,639
Colorado	732	New Mexico	1,702
Connecticut	582	New York	1,779
Delaware	1,083	Ohio	2,085
Florida	2,435	Oklahoma	1,109
Georgia	1,050	Oregon	540
Guam	3,370	Pennsylvania	742
Hawaii	8,438	Puerto Rica	3,037
Idaho	769	Rhode Island	1,690
Iowa	1,492	South Carolina	841
Illinois	2,707	South Dakota	930
Indiana	2,141	Tennessee	5,269
Kansas	1,614	Texas	1,384
Kentucky	903	Trust Territory	306
Louisiana	1,473	Utah	1,287
Maryland	3,916	Vermont	433
Massachusetts	3,072	Virgin Islands	65
Michigan	1,297	Virginia	388
Minnesota	2,513	Washington	848
Mississippi	1.557	West Virginia	842
Missouri	1,270	Wisconsin	1,331
Montana	278	Wyoming	508

SOURCE: ICF, Inc. Analysis, based on the Federal Reporting Data System Interactive (FRDS/Interactive), which identified public water supply systems (ground water and surface water).

estimated sustainable yield of 50 gallons per minute or 72,000 gallons per day (gpd). The population equivalent that could be served by this yield is 480 (72,000 gpd divided by 150 gpd/person). Because the latter, hydrogeological factor is controlling, the hypothetical user population for the aquifer under review is assumed to be 480 persons. Using the national average of 2.75 people/household, the user population of 480 is equivalent to 175 households (i.e., 480 people divided by 2.75 people/household).

STEP 2: Determine the Mean Annual Income Per Household

The second step in the economic burden test is to determine the mean annual household income of the hypothetical user population. This determination may be made by assuming it to be equal to the mean household income in the county where the ground water is located. These data are readily available from the Bureau of the Census publication entitled "County and City Data Book", which can usually be found in local libraries. When county-level data are not available, state-level data may be used as default values. Exhibit F indicates the mean annual income per household in each state as provided by the 1980 Census inflated to 1984 dollars. In the State of Maryland, for example, the mean annual income per household is $30,000 (1984 dollars).

STEP 3: Estimate The Cost of the Water Supply System

The next step is to estimate the cost of the ground-water supply system which could serve the hypothetical user population size determined in Step 1. In order to do this, it is important to consider the four major cost components of a newly developed water supply system: acquisition, treatment, delivery, and support service.

Acquisition costs are primarily the costs of acquiring and physically developing a water supply at the site. They include the cost of the land, rights of way, and well field development costs. The latter can vary depending on hydrogeologic conditions, particularly the depth of the aquifer and the geologic formation overlaying the aquifer.

Treatment costs include the costs of the treatment plant and equipment, and the costs of the chemicals that are added to the water. For a water of given quality, the costs of treatment depend on the quantity of water treated and the treatment technologies used. The capacity of a treatment plant is determined by the size of the population. (Much of the cost analysis for Step 3 will pertain to treatment costs.)

EXHIBIT F

MEAN HOUSEHOLD INCOME BY STATE
(1980)

State		State	
Alabama	$21,200	Montana	$22,600
Alaska	$37,700	North Carolina	$21,800
Arizona	$25,100	North Dakota	$22,800
Arkansas	$19,700	Nebraska	$24,100
California	$28,100	Nevada	$27,600
Colorado	$27,200	New Hampshire	$24,800
Connecticut	$29,500	New Jersey	$29,400
District of Columbia	$26,300	New Mexico	$22,200
Delaware	$26,400	New York	$26,000
Florida	$23,500	Ohio	$25,600
Georgia	$23,200	Oklahoma	$23,000
Hawaii	$30,900	Oregon	$24,900
Idaho	$22,600	Pennsylvania	$24,800
Iowa	$24,600	Rhode Island	$23,900
Illinois	$28,400	South Carolina	$22,200
Indiana	$25,400	South Dakota	$20,000
Kansas	$25,000	Tennessee	$21,700
Kentucky	$21,500	Texas	$25,800
Louisiana	$23,900	Utah	$28,700
Maryland	$30,100	Vermont	$22,100
Massachusetts	$26,100	Virginia	$26,400
Michigan	$27,900	Washington	$26,700
Minnesota	$26,100	West Virginia	$21,800
Mississippi	$19,800	Wyoming	$27,700
Missouri	$23,500		

SOURCE: Bureau of the Census (1980), inflated to 1984 dollars.

Delivery costs include transmission and distribution costs. Transmission costs are the costs of pumping the water from the treatment plant to the main distribution network. Distribution costs include the cost for the piping network which provides the water to the water users.

Support services are primarily administrative and customer service costs that are associated with the management of a water supply system.

Because a Class III candidate ground water is not currently used, it would typically be necessary to include all four of the system components in estimating the costs of developing this resource as a water supply source. Each cost component needs to be evaluated on a site-specific basis. However, default values can be used to estimate acquisition, and support services costs if it can be shown that the site has no extraordinary characteristics that would result in costs which are substantially different from the national average costs for a system of that size. Because the Class III candidate ground water is contaminated, default values should <u>not</u> be used to evaluate treatment costs. Treatment costs are strictly site-specific and are determined by the nature and level of contamination of the ground water.

Default values for acquisition, delivery, and support service costs can be derived from Exhibits G and H. Exhibit G presents annualized costs (i.e., annualized capital and O&M) for ground-water systems of various sizes, based on nationwide data. The costs are expressed as 1984 dollars per million gallons ($/MG). Thus, if the total annual water demand is known, Exhibit H can be used to estimate the annual system cost (excluding treatment costs). Exhibit H presents the relative contribution of cost components to the total water supply system cost. These percentages are based on water supply systems across the nation and grouped into two size categories: 300 to 75,000 population and greater than 75,000 population. For example, acquisition costs for a system serving a population of 5,000 typically represent 22 percent of total costs.

As an example of how to use Exhibits G and H, assume a user population of 5,000 (1,800 households). Exhibit G indicates that for a user population of this size, the annual cost of ground-water supply systems equals $924 (1984 dollars) for each million gallons produced. Because acquisition, delivery, and support services costs make up 82 percent of this total cost (Exhibit H), total costs, excluding treatment costs, to the hypothetical user population of using the ground water as a source of drinking water amount to $758

EXHIBIT G

COSTS OF GROUND-WATER SUPPLY SYSTEMS[a]
BY POPULATION SIZE CATEGORY
(1984 $/million gallons produced)

Population Served by System	Annual Cost
25 - 1,000	4,616
1,000 - 3,300	1,493
3,300 - 10,000	924
10,000 - 25,000	718
25,000 - 75,000	710
75,000 - 500,000	606
over 500,000	574

[a]Operating expenses (including depreciation and capital charges, inflated to 1984 dollars.

SOURCE: Survey of Operating and Financial Characteristics of Community Water Systems, Temple, Barker and Sloane, Inc., 1982

EXHIBIT H

COST COMPONENTS AS PERCENTAGES
OF WATER SUPPLY SYSTEM COSTS

Cost Component	System Serving 300-75,000 Population (% of total costs)[a]	System Serving Greater than 75,000 Population (% of total costs)[a]
Acquisition	22	19
Delivery	43	38
Service	17	30
Total	82	87

[a]Total costs are the sum of annualized capital costs and O&M costs.

SOURCE: ACT Systems, Inc., 1979.

(1984 dollars) per million gallons produced (i.e., $924 x 82 percent). The total annual water usage is 270 million gallons (i.e., 1,800 households x 150,000 gallons per household per year), so the annual costs to the hypothetical user population for acquisition, delivery, and support services are $204,660 (i.e., $758/mg x 270 mg).

Determining the most economic treatment system involves a series of assessments. First, the specific ground-water contamination problem in the Classification Review Area must for a Class-III determination be fully characterized. Again, the contamination problem should be areal in extent, and cannot be attributed to a specific disposal site or other activity. Much of the data may be provided in program-specific permit applications, although supplemental information may be available from USGS, local authorities, and local research organizations.

Once the contamination has been characterized, the desired water quality levels should be determined for each chemical constituent of concern. If all chemical constituents of concern are present at less than drinking water standards (MCLs) or Health Advisories, the water requires no treatment.

The next step is to identify all of the treatment trains which are capable of reducing contaminant concentrations to the desired range. Exhibit I tabulates contaminant removal efficiencies for common treatment technologies. Any treatment technology which does provide removal of any of the contaminants of concern may be eliminated from further consideration. The process of identifying the treatment trains which are capable of achieving the desired concentration levels can be done systematically by evaluating all possible combinations of treatment technologies from among the non-eliminated choices, or may be done heuristically using expert judgement.

The treatment trains identified in this process can then be costed out, and the least costly selected. Any of these treatment trains that includes another of the treatment trains as a subset, can be disregarded because it will clearly be inefficient. (In some cases, public water systems add apparently redundant technologies to remove chemical constituents for 'aesthetic' reasons, or to provide backup treatment to accommodate fluctuations in influent quality.) If no treatment trains can be identified, the ground water will automatically be Class III.

EXHIBIT 1

REPORTED TYPICALLY ACHIEVEABLE CONTAMINANT REMOVAL EFFICIENCIES[a,d]

	Air Stripping and Aeration	Carbon Adsorption	Chemical Precipitation	Desalination	Flotation	Granular Media Filtration	Ion Exchange	Ozonation
Arsenic	0[b]	50	85	95	45	60	99	25
Barium	0[b]	30	80	95		70	95	0
Benzene	98	75	70	75		40		97
Cadmium	0[b]	85	90	60	60	70	99	
Carbon Tetrachloride	98	Moderate[c]	95		75	90		
Chlordane	Good[c]	Good[c]				40		
Chromium VI	0[b]	95	98	90	50	50	96	
1,1-Dichloroethylene	98	97	98			55		
1,2c-Dichloroethylene	97	70				90		
1,2t-Dichloroethylene	75	95	30					
Dichloromethane	80	70	60	15	40	40		
2,4-D	Poor[a]	Good[c]	Good[c]					
p-Dioxane	0[b]							
Endrin	0[b]	99						Moderate[c]
Ethylene glycol	Good[c]	Good[c]						
Fluoride		0	75			30		
Formaldehyde	Good[c]							
n-Hexane	99							
Lead	0[b]	95	85	60	98	50	97	30
Lindane	0[b]	95	Good[c]	65	85	50		
Mercury	0[b]	90	80	90	75	55		
Methyl Ethyl Ketone	99							
Nitrate		15	96	70		10	90	50
PCB	0[b]	15			97	20		
Selenium	0[b]	10	70	97		60	98	99
Silver	0[b]	25	70	40	45	20	99	
Tetrachlorethylene	98	99	95	80	30	0		40
Toluene	95	75	75	50	40	65		
Toxaphene	Good[c]	99						
1,1,1-Trachloroethane	80	99	50	98		97		
Trichloroethylene	98	Poor[c]	60					
2,4,5-TP	Poor[c]	Good[c]		Good[c]	Good[c]			
Trihalomethanes	75	99	95	80	80	60	50	
Xylenes	99		90	80	97	75		

[a] Data represent the percent of contaminant which can be expected to be removed from solution using treatment systems similar to those currently installed in full scale or pilot scale water treatment operations. Percent removal are generated from available literature a listed at the end of this section, and are rounded to the nearest 5 percent (below 95 percent). These numbers are representative of achievable efficiencies, and are not absolute indicators of specific system treatment efficiencies.

[b] Although reported data were unavailable, the physical nature of those contaminants precludes effective removal via air stripping.

[c] Only qualitative data were available in the literature.

[d] Blanks indicate that no data were reported in the available literature.

To cost out the treatment trains, the individual system components should be listed. Exhibit J lists the system components typically required with each treatment technology. When using published cost curves, it is important to read the accompanying test which describes the system components included in the cost curve, and identifies which components must be costed separately. The following reference (along with Culp et al.) provide cost curves for a range of treatment technologies and system sizes:

- Estimating Water Treatment Costs, Gummerman, Culp and Hansen, EPA 600/2-79-162a.
- Treatability Manual, Technologies For the Control Removal of Pollutants, EPA 600/2-82-001C; and
- Estimation of Small System Water Treatment Costs, EPA 600/2-84-184a.

Again, updated cost assessments will likely be available from EPA or the water utility industry, under the public water supply provisions of the Safe Drinking Water Act Amendments of 1986. The costs references generally provide separate estimates of capital costs and annual O&M costs. These can be annualized based on the expected lifetime of the capital and the cost of finance. As a first approximation, capital costs may be annualized by multiplying by a factor of 0.1. Thus:

Annualized Capital Costs = Capital Costs x Annualization Factor (0.1)

and

Annualized Costs = Annualized Capital Costs + O&M Costs

Appendix E provides further discussion of annualization methodology.

Costs calculated in this way for eight standard treatment technologies are presented in Exhibit K.

As an example, the annualized costs to treat a groundwater contaminated with air stripping, precipitation, and rapid sand filtration for a system supplying a population of 5,000 (or 1,800 households) would be approximately $159,800 (the sum of $28,000 for air stripping, $62,700 for precipitation, and $69,100 for rapid sand filtration) in 1982 dollars. This figure should be inflated to a dollar figure for the base-year of the analysis. It should then be divided by the

EXHIBIT J

DEFAULT COMPONENTS OF EACH TREATMENT TECHNOLOGY

Aeration/Air Stripping

Aeration tower
In-plant pumping

Activated Carbon

Carbon columns
Backwash pumping
Washwater surge basin

Chemical Precipitation

Lime feed system
Contact clarifier
Sludge pumping
Sludge drying beds
Slugde hauling

Desalination

Reverse Osmosis
In-plant pumping

Flotation

Dissolved air flotation
Sludge pumping
Sludge drying beds
Sludge hauling

Filtration

Granular media filtration beds
Granular media
Backwash pumping
Washwater sewage basin

Ion Exchange

Pressure Ion Exchange System

Ozonation

Ozonation system

Ancillary Operations

Administrative
Raw water pumping
Polished water pumping
Clearwell storage

EXHIBIT K

ANNUALIZED COSTS OF TYPICAL TREATMENT COMPONENTS
FOR TOUR TYPICAL PLANT SIZES

Component	Population Served			
	500	2,500	5,000	25,000
Aeration/ Air Stripping	$16,500	$20,700	$28,000	$70,200
Activated Carbon	$18,800	$27,000	$33,900	$113,900
Chemical Precipitation	$35,200	$51,500	$62,700	$127,700
Desalination	$43,900	$109,500	$171,500	$595,600
Flotation	$30,100	$37,300	$48,900	$109,800
Filtration	$56,200	$61,400	$69,100	$107,700
Ion Exchange	$10,100	$26,400	$38,900	$74,800
Ozonation	$6,000	$7,000	$9,300	$19,200
Ancillary Operations	$25,900	$24,000	$46,200	$110,900

All figures are in 1982 dollars.

number of households in the hypothetical population to calculate an annual cost per household. This value in turn is divided by the annual average (mean) household income and a percentage is then derived. This value is then employed in STEP 5 to classify the ground water.

STEP 5: Classify the Ground Water

Two threshold values must be considered in completing the Class III test: first, the total system cost threshold and then secondly, the treatment cost threshold. If the value estimated in STEP 4 exceeds the proposed range of "total system cost threshold" percentages (0.3-0.4 percent) and the treatment cost component of total system costs increase water rates more than 100 percent or establish a rate greater than $300 per household per year, than the ground water is Class III. If the value is less than the proposed range of economic criteria percentages and the treatment cost threshold, then the ground water is Class II.

Because the Class III test must focus on whether or not a particular ground water source is untreatable, the classifier must focus on the treatment costs associated with similarly-sized or comparable systems. Current data show that treatment costs nationwide typically comprise 18 percent of the total cost of systems serving 300-75,000 population and 13 percent of the total costs of systems serving more than 75,000 population (ACT Systems, Inc., 1979). In making a Class III designation the classifier must compare the effect that treatment costs of the system being classified will have on household water bills. If treatment costs produce a household rate greater than $300 per year or a rate increase greater than 100 percent over current rates (or any other baseline percentage as established for similarly-sized or comparable systems within a state or region) then the ground water is Class III-untreatable.

In some cases the classifier may wish to undertake additional analyses of the treatment costs. If, for instance, a ground water resource is being classified in the arid southwestern United States where acquisition and delivery costs comprise a major part of total system costs and, yet, very costly treatment technologies would need to be employed, the classifier may wish to compare the treatment costs associated with the system being classified with typical treatment costs of similarly-sized or comparable systems elsewhere in the state or EPA region, instead of comparing them against a national standard. Again, the objective of this test is to determine which systems would

require treatment processes which are so costly that they are "economically" untreatable.

Example

A Class IIIA determination is being considered for a hypothetical site in Maryland. Past industrial activity and urban recharge have resulted in generally poor water quality of the aquifer. As a result, an application for continued land disposal activity includes a Class IIIA determination. The five steps of the Class III economic test are examined in this hypothetical problem.

STEP 1: Determine Population Size/Number of Households

Due to widespread industrial contamination, local ground water in the area has been not used for drinking in more than 30 years. Public water is supplied from a surface water source. Since the ground waters are shallow, a Class IIIB assessment is unlikely.

The US Geological Survey District Office has been consulted to obtain old water supply reports for the area as to estimate the yield of the aquifer under review. Based on these reports, the Classification Review Area would support a sustained yield of approximately 625 gallons-per-minute (gpm) which is equivalent to 0.9 mgd. This yield could reasonably serve a population of 6,000, assuming water usage of 150 gpd/person.

Exhibit E indicates that the mean population size served by ground-water systems in Maryland is 3,900. Because the 3,900 average is less than the 6,000 population (based on yield), the classifier may choose which hypothetical population figure is most appropriate. If, for instance, the ground-water resource being classified is in the path of encroaching development (even though such development will not utilize local ground water) the higher figure may be selected for analysis. In this example, the 6,000 figure is used as the hypothetical user population. This population figure represents about 2,182 households (i.e., 6,000 people divided by 2.75 people/household).

STEP 2: Determine the Mean Annual Income Per Household

In Maryland, the mean annual income per household is $30,100 (see Exhibit F). This income estimate is used in the absence of more specific survey data.