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Environmental Policy and Technology Project

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UKRAINE
Summary Report on
Water & Soil Pollution Assessment Workshop
Donetsk, September 1996

Delivery Order #09, Task U1, Activity 2.7
December 1996

Prepared for:
U.S. Agency for International Development
Regional USAID Mission to Ukraine, Belarus & Moldova

Bureau for Europe & the New Independent States
Office of Environment, Energy & Urban Development
Environment & Natural Resources Division

Prepared by:
Ukraine, Belarus & Moldova Regional Office
Environmental Policy and Technology Project
For the New Independent States of the former Soviet Union

A USAID Project Consortium Led by CH2M HILL

1

PREFACE

Under the 1992 Freedom Support Act, the United States Congress initiated a program to provide various forms of assistance to new independent states (NIS) of the former Soviet Union. Cooperative Agreements were signed between representatives of the U.S. government and each country in which assistance is to be undertaken. The U.S. Agency for International Development (USAID) was given the responsibility to coordinate all U.S. government assistance to the NIS under the Act.

Through competitive bidding, USAID awarded a multi-year contract to a team managed by CH2M HILL International Services, Inc. (CH2M HILL) to support implementation of an environmental assistance program to republics of the former Soviet Union. Under this contract, termed the Environmental Policy & Technology (EPT) Project, CH2M HILL is to assist USAID's missions in Moscow, Kyiv, and Almaty undertake a program to promote environmental improvements in the NIS. The USAID mission in Kyiv supports environmental, and other, assistance programs to Ukraine, Belarus, and Moldova. CH2M HILL established an office in Kyiv from which to perform services in these countries under the EPT Project.

This report was prepared as a contractually required deliverable under a contract between USAID and CH2M HILL. Although work on this report was conducted in cooperation with the assisted governments and USAID, the findings and recommendations are those of the CH2M HILL team. They do not necessarily represent official positions of the governments of the assisted countries nor of the United States of America.

The CH2M HILL team includes the following organizations:

- Center for International Environmental Law
- Clark Atlanta University/HBCUMI Environmental Consortium
- Consortium for International Development
- Ecojuris
- Environmental Compliance, Inc.
- Harvard Institute for International Development
- Hughes Technical Services Company
- International Programs Consortium
- International Resources Group, Ltd.
- Interfax Newsagency
- K&M Engineering
- Ogden Environmental and Energy Services Company
- Price Waterhouse
- World Wildlife Fund (US).

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NOTE ON TRANSLITERATION

Ukrainian place names used in this report have been transliterated into the English language from the Ukrainian (not Russian) language, according to the modified Library of Congress standard adopted by many Western organizations and publications, including the *Encyclopedia of Ukraine*, 5 volumes (University of Toronto Press, 1984-1993).

TABLE OF CONTENTS

Section	Page
Abbreviations, Acronyms & Glossary	iv
1.0 Introduction	1
2.0 Results	3
3.0 Conclusions	5
Appendix A: List of Workshop Attendees	7
Appendix B: Workshop Evaluation	9
Appendix C: Workshop Workbook and Presentation Materials	13

ABBREVIATIONS, ACRONYMS & GLOSSARY

CH2M HILL	CH2M HILL International Services, Inc. (a U.S.-based international environmental engineering consulting firm)
DO	Delivery Order
EPT	Environmental Policy & Technology (Project). A USAID-funded program to provide environmental assistance to New Independent Republics of the former Soviet Union
MEPNS	Ministry of Environmental Protection & Nuclear Safety (of Ukraine)
MEPNS-DO	Ministry of Environmental Protection & Nuclear Safety, Donetsk Oblast
oblast	A government territorial-administrative unit in the former Soviet Union that is still in use following Ukraine's independence. A U.S. analogue would be something between a state and a county.
TIC	(EPT Project) Technical Information Center
USEPA	U.S. Environmental Projection Agency
USAID	U.S. Agency for International Development

Section 1

INTRODUCTION

As part of a United States government bilateral assistance program, the U.S. Agency for International Development (USAID) is supporting environmental management in Ukraine. Under direction from USAID, a consortium led by CH2M HILL International Services, Inc. (CH2M HILL), is implementing part of USAID's Environmental Policy & Technology (EPT) Project by undertaking various activities that have been agreed to by representatives of the governments of both countries.

USAID authorized CH2M HILL to perform a series of tasks in Ukraine under Delivery Order (DO) #9. Task U1 (Donetsk Industrial Waste Management) includes a requirement under Activity 2.7 (Technical Workshops/Seminars) for CH2M HILL to conduct workshops in Donetsk on the " ... 'fate and transport,' 'treatability' and 'stabilization' of hazardous waste ... ", in conjunction with the U.S. Environmental Protection Agency (USEPA). At the request of USAID/Kyiv's Director for Environmental Development, the workshop was named "Water and Soil Pollution Assessment".

Under terms of the DO #9 contract, CH2M HILL is required to submit a Summary Report on each workshop. This document has been prepared in fulfillment of that obligation.

Section 2

RESULTS

The Workshop was held between 3-6 September 1996 at the EPT Project's Technical Information Center (TIC) in Donetsk, a facility previously established as a component of Task U1 of DO #9. DO #9 indicated that the Workshop was to be presented twice, to about 20 persons each time. However, the Workshop extended over 4 days, and was partly presented by representatives of USEPA. The schedules of USEPA personnel did not allow them to stay in Ukraine for the 9 days required for two Workshops, plus additional time to conduct practical field-based exercises. Only one Workshop was therefore presented, which was attended by 40 participants. The Workshop was immediately followed by practical field exercises of water and soil sampling at an industrial enterprise.

Several workshops under DO #9, Task 1, had been presented to representatives of regulatory agencies, academic and scientific institutions, and industrial enterprises in Donetsk Oblast. Using previously established mailing directories, invitations were initially drafted by CH2M HILL, and reviewed by USAID/Kyiv and the Ministry of Environmental & Nuclear Safety, Donetsk Oblast office (MEPNS-DO). Invitations were extended to representatives of MEPNS-DO; senior officials of selected industrial enterprises within the Oblast, including coke, steel, non-ferrous, petrochemicals, and mining enterprises; university faculty; and local environmental organizations. A list of participants is presented in Appendix A, and a participant evaluation is presented in Appendix B.

Presenters of the Workshop were:

- G. Alan Farmer - head of USEPA Region IV's waste management branch
- Mr. John Marlar - member of USEPA Region IV
- Mr. John Johnson - member of USEPA Region IV
- Mr. Jim Bokey - member of USEPA Region IV.
- Nicholas P. Cheremisinoff - the EPT Project's Donetsk Industrial Waste Management task leader and resident advisor in Donetsk.

Prior to the Workshop, a draft of the Workshop viewgraphs and study guide was first reviewed and approved by Dr. N. Kulichenko, Environmental Advisor at USAID/Kyiv. An English-language version of Workshop viewgraphs/handouts is presented in Appendix C. Russian-language versions were actually used at the Workshop. The Workshop was presented using sequential English-Russian translation.

The Workshop focused on the use of field sampling methods, analytical techniques, and site reconnaissance and sampling strategies for industrial enterprises, as well as waste treatment and stabilization. There was a high level of interest on the part of attendees, as witnessed by numerous questions and discussions between instructors and participants.

At the conclusion of the classroom training, a formal evaluation was made by the attendees. The evaluation consisted of a one page questionnaire in which various questions and comments regarding the quality and usefulness of the program were solicited. A copy of the questionnaire is included in Appendix B. The evaluation indicated that the Workshop was highly successful and uniformly presented.

All attendees were provided with a Certificate of Completion, which appeared to be received as a good gesture among the participants.

Follow-up field exercises were conducted by USEPA trainers for nine Ukrainian enterprise representatives. An industrial site (Stirol Chemical Plant in the city of Gorlovka) was visited and select samples of groundwater and soil were obtained. These samples were sent to a USEPA-funded water quality laboratory established at the Institute for Water & Colloidal Chemistry in Kyiv, and a USEPA laboratory in Athens, Georgia, for analysis. At the writing of this report, analyses of soil and water samples had not been completed.

Section 3

CONCLUSIONS

The Workshop appeared to be highly successful. Much of the material presented was new to the participants, however it appeared to be presented at the proper level for comprehension. A very high level of cooperation was received by enterprise representatives in discussing some of their waste management problems, and there was considerable interest in arranging for follow-up discussions with the speakers, particularly with regard to sampling strategies and the accuracy and precision of field analytical tools.

The Workshop's success points to the desirability of presenting it to representatives from other industrial oblasts in Ukraine, particularly to technical-level employees of enterprises. USAID/Kyiv may want to consider funding such presentations, preferably to be held at the Technical Information Center in order to enable participants to access references and instrumentation capabilities located there.

Appendix A

LIST OF WORKSHOP ATTENDEES

	NAME	NAME OF ORGANIZATION
1	Nataly Aldakimova	Priazovskaya Regional Inspection of MEPNS-DO
2	Victor Aleshin	Ukrainian Scientific Center of Technical Ecology
3	Olga Burkal	Novotroitskoye Ore-Management Department
4	Nadezhda Leonova	Konstantinovskaya Regional Inspection of MEPNS-DO
5	Ena Klucheva	MEPNS-DO
6	Lyudmila Kostenko	MEPNS-DO
7	Nikolay Krasnopolsky	"Donbassgeology" Association
8	Victor Krisko	Donetsk Iron & Steel Plant
9	Lyudmila Voitenko	MEPNS-DO
10	Sergey Lizenko	"Stirol" Chemical Plant
11	Alexander Marchenko	"Azovbass" Association
12	Rostislav Marchenko	"Donbassgeology" Association
13	Tatyana Moroz	MEPNS-DO
14	Georgy Nasonov	Druzhkovsky Plant of Metallurgical Goods
15	Yelena Parykina	"Khvylia" Joint-Stock Company
16	Yevgeny Polulyakh	Donetsk City Environmental Council, Firm "Ecology and Development"
17	Larisa Rubel	Donetsk Iron-and-Steel Plant
18	Victor Savchenko	Institute of Environmental Issues
19	Oleg Savchenko	Ukrainian Scientific Center of Technical Ecology
20	Valentina Skorik	"Ugleenergomontazh" Joint-Stock Company
21	Anna Tushkanova	"Alyans" Company
22	Larisa Tsykalovskaya	Gorlovkskaya Regional Inspection of MEPNS-DO
23	Nataly Chuprun	"DEIKOM"
24	Vladimir Danilov	"Azovbass" Association
25	Lidia Lisichkina	"DEIKOM"
26	Lyudmila Nikanorova	"Dobropolieugol" Association
27	Vladimir Litvinenko	Gorlovskaya Regional Inspection of MEPNS-DO
28	Gennady Abramovich	Donetsk Iron & Steel Plant
29	Vera Florinskaya	"Donbassgeology" Association
30	Vladimir Gruba	Donetsk State Technical University
31	Gennady Kliagin	Donetsk State Technical University

32	Yevgeny Matlak	Donetsk State Technical University
33	Boris Panov	Donetsk State Technical University
34	Olga Shevchenko	Donetsk State Technical University
35	Yelena Troshina	Donetsk State Technical University
36	Sergey Vysotsky	DonTEP
37	Galina Chudaeva	Donetsk State Technical University
38	Irina Marinchenko	MEPNS-DO
39	Vladimir Biryukov	MEPNS-DO
40	Eleonora Yankovskaya	Public Joint-Stock Company "Ukrainian Scientific Center of Technical Ecology"

Appendix B

WORKSHOP EVALUATION

This appendix provides a copy of the Workshop evaluation form, followed by a summary of results of the evaluation.

Attendee Evaluation Form for Water & Soil Pollution Workshop

Please provide an evaluation of the workshop. Check the number which best describes your response to each question. 1 = Poor, 2 = Good, 3 = Very Good, 4 = Excellent

	QUESTION	1	2	3	4
1	The overall quality of presentations can be rated as				
2	The quality of the presentation materials was				
3	The quality of the Director's presentation can be rated as				
4	The quality of the U.S. consultant can be rated as				
5	The overall use of the material to my enterprise is				
6	The overall use of the material to my specific job function can be rated as				
7	The quality of the training room and facilities is				
8	The quality of the luncheons provided is				
9	The overall quality of the workshop is				

Your name:_____Enterprise:_____
Date:_____

(WRITTEN COMMENTS AND RESPONSE SECTION)

1. What did you like about the Workshop ?

2. What did you NOT like about the Workshop ?

3. What additional topics would you like to see discussed under separate Workshops ?

Summary of Evaluations for Water & Soil Pollution Workshop

Response rating : 1=Poor, 2= Good, 3= Very Good, 4 = Excellent

	QUESTION	Average
1	The overall quality of presentations can be rated as	3.5
2	The quality of the presentation materials was	3.9
3	The quality of the Director's presentation can be rated as	3.8
4	The quality of the US consultant's presentation can be rated as	3.6
5	The overall use of the material to my enterprise can be rated as	3.5
6	The overall use of the material to my specific job function can be rated as	3.4
7	The quality of the training room and facilities is	3.8
8	The quality of the luncheons provided is	3.2
9	The overall quality of the Workshop is	3.7

Select Responses to Written Questionnaire

Comments to Question # 1:

The opportunity to see and handle some instruments.

The discussions on establishing site sampling schemes.

Discussions dealing with the problem of leaking underground storage tanks and methods of monitoring.

Comparisons made between the Quality Control & Quality Assurance methods of USEPA versus the current methods used in Ukraine.

Comments to Question # 2:

Insufficient documentation on the instruments and sampling tools USEPA brought.

Too much emphasis given to regulatory compliance and not enough given to reasons why enterprises should conduct their own audits or in attracting investors.

USEPA presenters seemed to favor regulatory objectives. Not enough industry viewpoint except for the TIC director.

Comments to Question # 3:

Detailed planning and scheduling of large scale site investigations.

Proper preparation of Environmental Auditing Reports, particularly with regard to lending institution requirements.

Laboratory methods on quality control and quality assurance.

Proper methodology and protocol for pollution prevention type audits.

ISO 14000 principles and the audit approach for enterprises.

Appendix C

WORKSHOP WORKBOOK AND PRESENTATION MATERIALS

Following is a copy of the English-language version of the Workshop handout materials. The materials were originally formatted to fit A4-size (international) paper, and have been reproduced onto letter-size (American)paper. Hence may of the text and illustration materials may not appear to be centered onto the page.

WATER AND SOIL POLLUTION ASSESSMENT

Training for the Environmental Auditing Specialist

A Training Program Designed and Presented by the United States Environmental Protection Agency and the Environmental Policy & Technology Project Funded by the United States Agency for International Development

Donetsk, Ukraine

September, 1996

EPA **USAID**

17

WATER AND SOIL POLLUTION ASSESSMENT

Training for the Environmental Auditing Specialist

A Workshop and Training Program Designed and Presented by the United States Environmental Protection Agency and the Environmental Policy & Technology Project Funded by the United States Agency for International Development.

Presented September 1996
Donetsk, Ukraine

DAY 1 : Morning Session

PART I . CONTAMINANT MOBILITY IN THE SUBSURFACE

9:30-10:30 *I. Definition of Fate and Transport of Hazardous Wastes*

II. Ground Water Properties Affecting Transport

A. Hydrogeological settings
  1. Definition of hydrogeological setting
  2. Aquifer
    a. unconfined
    b. confining unit
    c. confined
  3. Recharge
  4. Discharge
  5. Topography
  6. Hydrogeologic settings in Donetsk Basin

B. Unsaturated Flow
  1. Porosity
  2. Capillary fringe

C. Saturated Flow
  1. Hydraulic gradient
  2. Hydraulic conductivity/permeability
  3. Transmissivity

10:30-10:45 Coffee Break

10:45-12:00 *III. Contaminant Properties Affecting Transport*

A. Physical Properties
  1. Density
  2. Solubility
  3. Viscosity
  4. Surface tension
  5. Vapor pressure (volatility)

B. Chemical Properties
  1. Adsorption
  2. Degradation

C. Transport of Different Chemical Compounds

1. Aromatics
2. Aliphatics
3. Inorganics
4. Metals

12:00-12:30 *Group Discussion Session*

12:30-13:30 Lunch Break

Afternoon Session

PART II. STABILIZATION

13:30-14:45 *I. Definition*

II. Implementing Stabilization

A. Prioritized Areas
B. Evaluate Benefits of Stabilization
C. Collect Data
D. Select and Design Stabilization
E. Implementation

14:45-15:00 Break

15:00-16:30 *III. Types of Stabilization*

A. Source Removal
   1. Underground storage tanks
   2. Waste piles
   3. Surface impoundments
   4. Contaminated soil
B. Containment
   1. Ground water
      a. Interceptor Trench
      b. Sheet Pile Cut-Off
      c. Pump and Treat
   2. Surface Water
      a. Dikes and Berms
      b. Diversion Ditches
      c. Grading

16:30-17:00 *Group Discussion Session*

DAY 2: Morning Session

9:00-10:00 C. Capping
1. Uses
a. Minimize leaching to ground water
b. Control gas emissions
c. When waste removal not possible
d. Combined with other technologies
2. Types of Caps
a. Soil
b. Concrete/asphalt

10:00-10:30 *Group Discussion Session*

10:30-10:45 Coffee Break

PART III. REMEDIATION

10:45-12:00 *I. Remediation Technologies - Overview*

II. Ground Water
A. Pump and Treat
1. Definition
2. Design requirements
3. Advantages
a. Dependable
b. Reduces contaminant mass
c. Deep, wide-spread contamination
4. Disadvantages
a. Long operation time
b. Expensive to design, install, and operate
c. Ineffective with low hydraulic conductivity
B. Air Sparging with Soil Vapor Extraction
1. Definition
2. Advantages
a. Remediates volatile organic compounds
b. Local zones of high contamination
c. Injected air enhances biodegradation
3. Disadvantages
a. Only volatile contaminants
b. Must have permeable soil
c. Well screen easily clogged
d. May adversely affect anaerobic biodegradation

12:00-13:00 Lunch Break

Afternoon Session

13:00-14:00 C. Bioremediation
1. Definition
2. Basic requirements
3. Advantages
a. Inexpensive
b. Complete degradation
c. Simultaneous treatment
d. No need for excavation
4. Disadvantages
a. Contaminant specific
b. May form gases
c. May generate intermediate compounds

D. Natural Attenuation
1. Definition
2. Destructive vs. nondestructive processes
3. Advantages
a. Inexpensive
b. Works with other technologies
c. Non-intrusive
4. Disadvantages
a. Long time to degrade
b. Implement ground water containment

14:00-14:15 Coffee Break

14:15-15:30 *III. Soil*

A. Soil Vapor Extraction
1. Definition
2. Favorable conditions
3. Advantages
a. Good for volatiles
b. Little disturbance
c. Reduces concentration and mobility
d. Only ambient air is used
4. Disadvantages
a. Soils must be permeable
b. Need homogeneous soils
c. Depth to ground water important

B. Solidification
1. Definition
2. Process
3. Disposal/Storage in landfills
a. Engineered structure
b. Liners
4. Advantages
a. Inexpensive
b. Leaching and mobility reduced
c. Multiple compounds treated at once
5. Disadvantages

a. Volume increase
b. Not applicable on volatiles
c. Contaminants not destroyed

15:30-16:30 *Group Discussion Session*

DAY 3: Morning Session

PART IV.
FIELD SAMPLING AND INVESTIGATION TECHNIQUES

9:00-9:30 *Introduction/Purpose of Training*

9:30-11:00 *Introduction of Field Investigations* (Work Plan, Quality Assurance and Quality Control, Equipment Selection)

11:00-11:15 Coffee Break

11:15-13:00 *Field Survey Instruments for Air Monitoring and Safety Planning*

13:00-14:00 Lunch Break

Afternoon Session

14:00-16:00 *Surface Water, Sediment, and Groundwater Sampling*

16:00-17:00 *Soil Sampling*

DAY 4: Morning Session

9:00-10:15 *Temporary Monitoring Well Installation*

10:15-10:45 Coffee Break

10:45-12:00 *Waste Sampling*

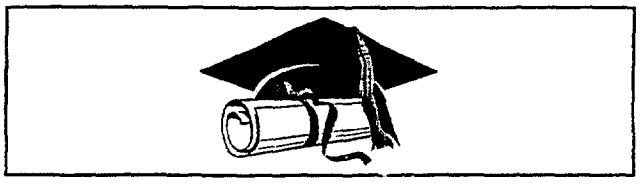
12:00-13:00 Lunch Break

Afternoon Session

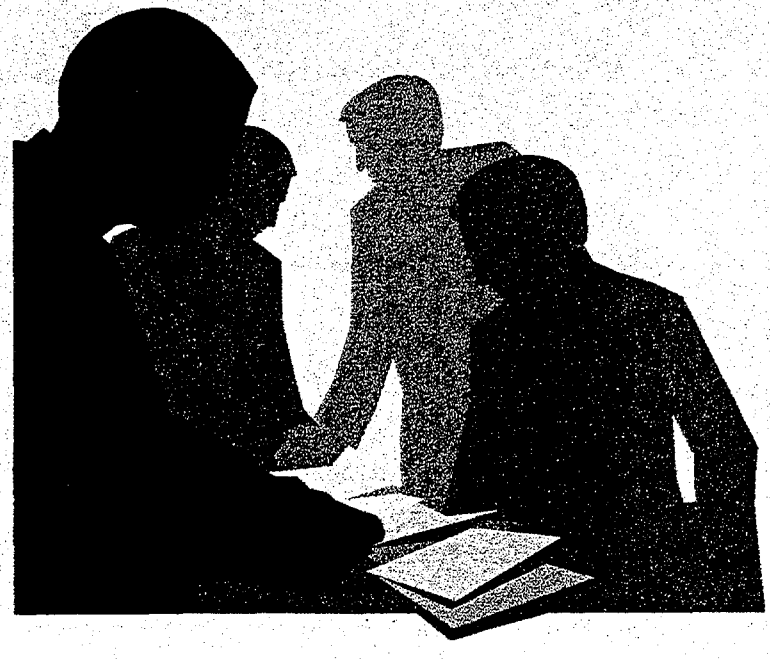
13:00-14:00 *Group Discussions and Exercises*

14:00-17:00 *Discussion and Preparation of Practical Exercise* (Review of Site, Study Plan and Safety Plan Preparation)

17:00-17:15 *Certificates for Participants*



PART I.
CONTAMINANT MOBILITY IN THE SUBSURFACE



23

WHAT WE WILL LEARN IN THIS SECTION...

I. DEFINITION OF FATE & TRANSPORT

II. GROUND WATER PROPERTIES AFFECTING TRANSPORT

- **A. HYDROGEOLOGICAL SETTINGS**
  - **1. Definition of Hydrogeological Setting**
  - **2. Aquifer**
    - **a. unconfined**
    - **b. confining unit**
    - **c. confined**
  - **3. Recharge**
  - **4. Discharge**
  - **5. Topography**
  - **6. Hydrogeologic Setting in Donets Basin**
- **B. UNSATURATED FLOW**
  - **1. Porosity**
  - **2. Capillary Fringe**
- **C. SATURATED FLOW**
  - **1. Hydraulic Gradient**
  - **2. Hydraulic Conductivity/Permeability**
  - **3. Transmissivity**

III. CONTAMINANT PROPERTIES AFFECTING TRANSPORT

- **A. Physical Properties**
  - **1. Density**
  - **2. Solubility**
  - **3. Viscosity**
  - **4. Surface Tension**
  - **5. Vapor Pressure (Volatility)**
- **B. Chemical Properties**
  - **1. Adsorption**
  - **2. Degradation**
- **C. Transport of Different Chemical Compounds**
  - **1. Aromatics**
  - **2. Aliphatics**
  - **3. Inorganics**
  - **4. Metals**

- Key Points to Be Covered:
  - Ground water properties affect the transport of contaminants
  - The hydrogeological setting should be defined to determine ground water movement
  - Physical and chemical properties of contaminants affect their movement in ground water

28

Mobility of Contaminants

- The mobility, or transport, of contaminants in the ground water may also be accompanied by the chemical transformation, or fate, of the contaminants

- **TRANSPORT** is a function of the hydrogeological parameters and the interactions between chemical, physical, and biological processes within the subsurface

- **FATE** is mainly a function of the chemistry of the contaminant in the environment

- Understanding the transport and fate of contaminants allow:
  - Prediction of arrival time and concentration of contaminants at a receptor (i.e., well);
  - Installation of ground water monitoring systems;
  - Development of effective and efficient stratigies for the remediation of contaminated ground water

Ground Water Properties Affecting Transport

- The site geology must be determined to properly assess the site-specific properties that will affect transport of contaminants in ground water

Factors that affect ground water occurrence and flow include:

- Hydrogeological setting
  - Aquifer
  - Geologic structure
  - Recharge/discharge
  - Topography

27

Ground Water Properties Affecting Transport (continued)

Additional factors that affect ground water occurrence and flow:

- Unsaturated flow
  - Porosity
  - Capillary forces

- Saturated flow
  - Hydraulic conductivity/permeability
  - Hydraulic gradient
  - Transmissivity

Hydrogeological Settings

- The composite description of major geologic and hydrologic factors which affect and control the occurrence and movement of ground water

- **Aquifer**: Water bearing strata that stores and transmits a significant quantity of water.

  - **Unconfined aquifer**, or water table aquifer, is exposed to the atmosphere through openings in the overlying soil;

  - **Confining units** are impermeable strata that separates aquifers;

  - **Confined aquifer** is overlain by a confining unit and is under sufficient pressure to raise the water level above the base of the confining unit

Hydrogeologic Settings (continued)

- **Recharge**: Input of water into an aquifer. Occurs more readily with unconfined than confined aquifers. Primary source: infiltration from precipitation; Secondary source: infiltration from surface streams

- **Discharge**: Movement of water from one aquifer to another aquifer, to the surface as springs, seeps, or streams, or through pumping.

- **Topography**: In general, the water table conforms to the surface topography. The slope of the land can be used to estimate the gradient and direction of ground water flow.

Unsaturated Flow

- The **unsaturated zone**, or vadose zone, is that portion of the soil or sediment above the water table that is not completely saturated. The open spaces, or pores, are filled with air and vapor, or soil moisture. Unsaturated flow is influenced by presence of differing vapor pressures, size and orientation of pore spaces.

- **Porosity** and **permeability** are major factors affecting flow within the unsaturated zone. Porosity is the ratio of void space to the total volume of sediment or rock. Permeability measures the interconnection of pores and measures the capacity of a porous strata to transmit fluid.

Unsaturated Flow (continued)

- **Capillary fringe** occurs at the base of the vadose zone, just above the saturated zone, and is characterized by nearly saturated conditions. In the capillary fringe, the water is drawn up from the water table aquifer into the pore spaces by capillary forces.

- **Capillary forces** include adhesive (the attraction of unlike molecules) and cohesive forces (the attraction of like molecules).

Saturated Flow

- The **saturated zone** is that portion of the aquifer where the available pore space is completely filled with fluid. The following factors affect ground water flow within the saturated zone:

- The **hydraulic gradient** is the slope of the water table (unconfined aquifer) or potentiometric surface (confined aquifer). It is the change in water level per horizontal distance along the direction of maximum head decrease.

33

30

Saturated Flow (continued)

- The **hydraulic conductivity** is the ability of an aquifer to transmit water. The hydraulic conductivity is controlled by the size and shape of pores, the permeability, and the physical properties of the fluid.

- **Transmissivity**, as applied to confined aquifers, is the aquifer's capacity to transmit water. Transmissivity is equal to the hydraulic conductivity times the aquifer thickness and defines the transmission capability of the entire thickness of an aquifer.

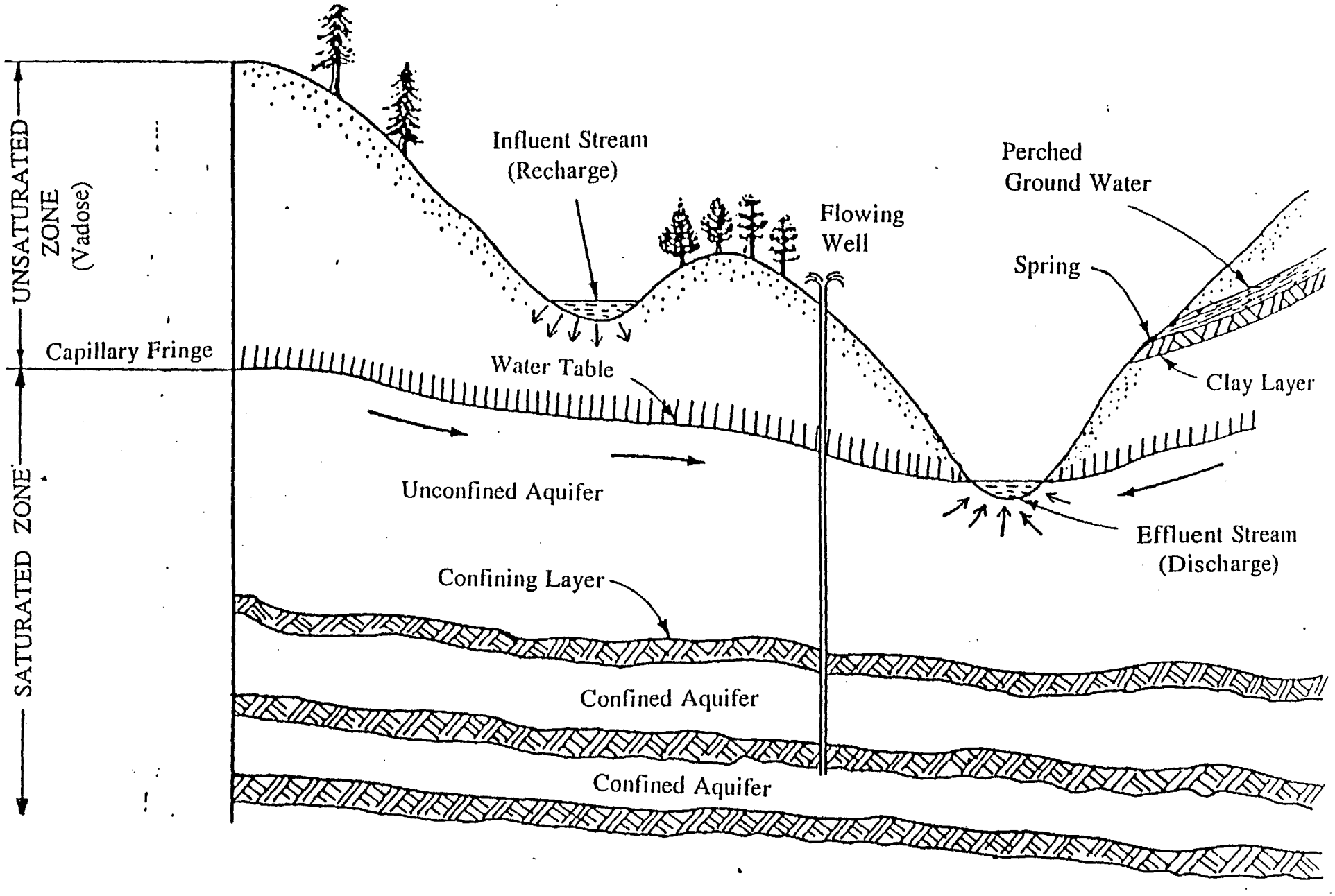
Saturated Flow (continued)

- Stream flow and ground water flow though large fractures and solution openings (karst) is turbulent. Ground water flow through a porous medium (for example, sand) is laminar which means the flow is described by essentially straight lines (at least over a short distance).

  Since flow in a porous medium is laminar, the flow can be described by using Darcy's law:

$$Q = KA(dh/dl)$$

Q = quantity of flow, in liters per day
K = hydraulic conductivity, in liters per day/meter^2
A = cross-sectional area through which the flow occurs, in meters^2
dh/dl = hydraulic gradient, in meter/meter



The Occurrence of Ground Water

Contaminant Properties Affecting Transport

- Although ground water provides the transport medium for contaminants, a number of physical and chemical properties impact on contaminant movement. These properties are independent of the properties which affect ground water movement. These properties apply primarily to organic compounds.

- **Physical Properties** Affecting Contaminant Transport
  - Density
  - Solubility
  - Viscosity
  - Surface tension
  - Vapor pressure (volatility)

- **Chemical Properties** Affecting Contaminant Transport
  - Adsorption
  - Degradation

57

Physical Properties

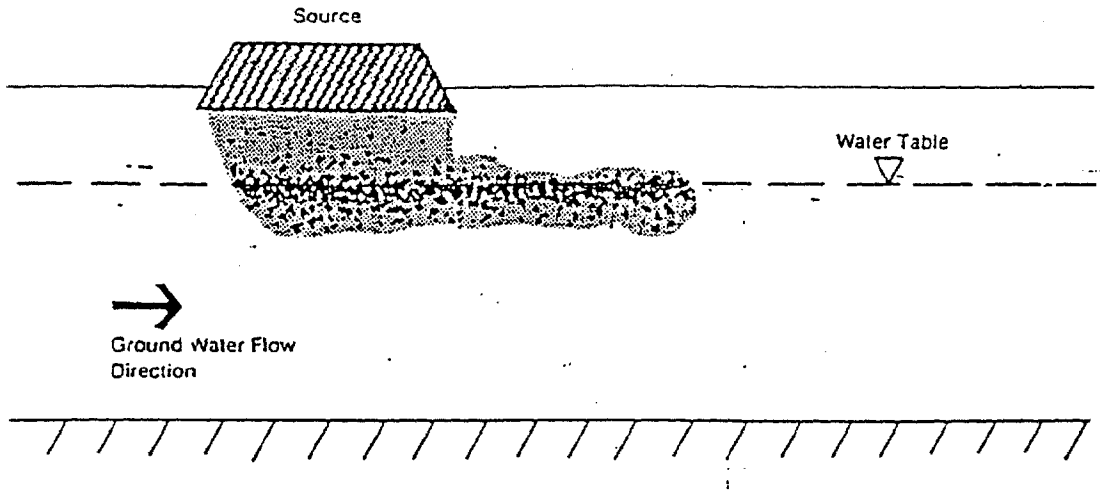
- **Density** - mass per unit volume, g/cc
  - Determines velocity and whether the contaminant will sink or float
  - Contaminants with a density greater than water (>1.0 g/cc) will tend to sink and contaminants with a density less than water (<1.0 g/cc) will tend to float
  - Data on the density of contaminants are generally obtained from published sources and can also be determined in a laboratory, especially if the waste consists of a mixture of chemicals with different densities

- **Solubility** - mg/l
  - The degree and how easily a contaminant dissolves in water.
  - Contaminants with a high solubility value (for example, acetone and alcohols) will easily dissolve in water.
  - Contaminants with a low solubility value (for example, trichloroethylene) will not easily mix with water and may exist as a **nonaqueous phase liquid**.

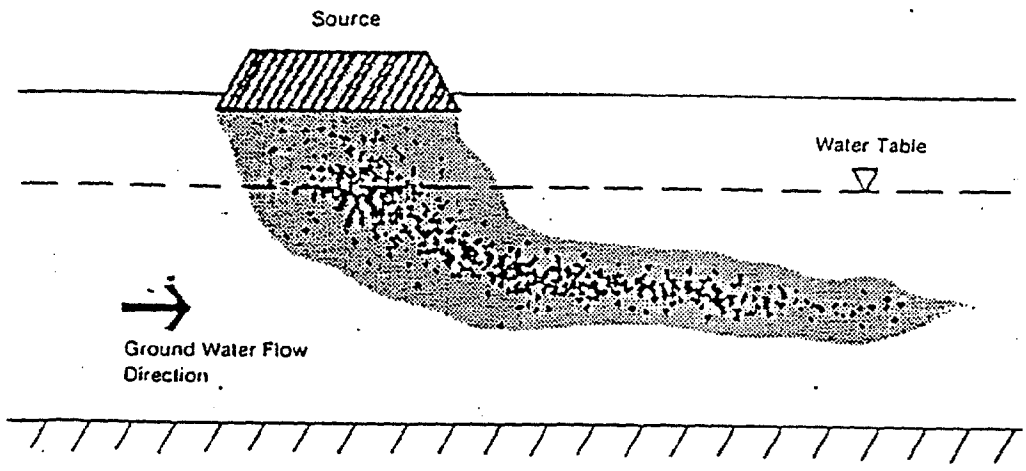
Physical Properties (continued)

- **Nonaqueous Phase Liquids** do not readily dissolve in water and can exist as a separate fluid phase. Infiltration is controlled mainly by gravity, viscosity, and capillary forces.
  - **Light nonaqueous phase liquids** have a density lighter than water and will float on top of the water table (in an unconfined aquifer) and will be drawn up into the capillary fringe.
    Examples: hydrocarbon fuels such as gasoline and heating oil
  - **Dense nonaqueous phase liquids** have a density heavier than water and will migrate downward until it reaches an impermeable unit (such as a confining unit). The liquid will accumulate in pools and movement will occur along bedding planes in the direction of the geologic dip.
    Examples: halogenated compounds such as trichloroethylene and carbon tetrachloride
  - The density of the contaminants is a factor in designing ground water monitoring systems.

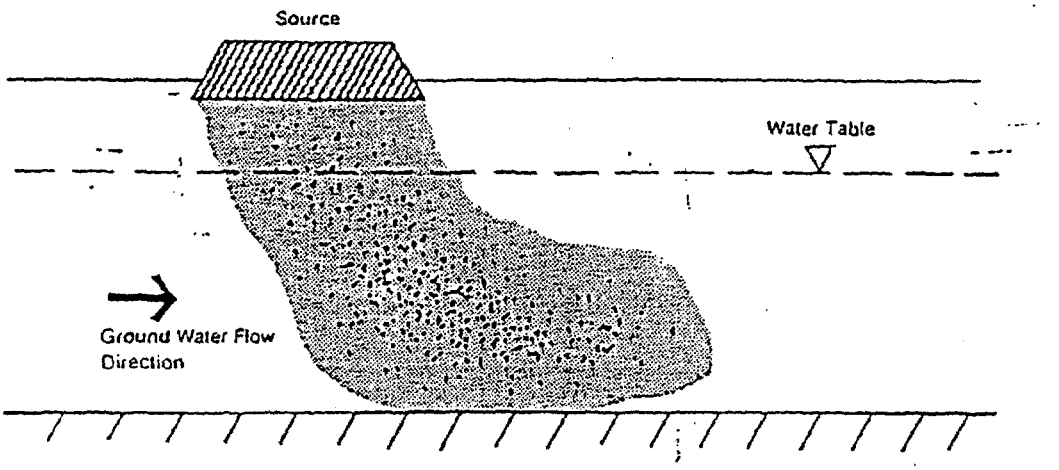
59



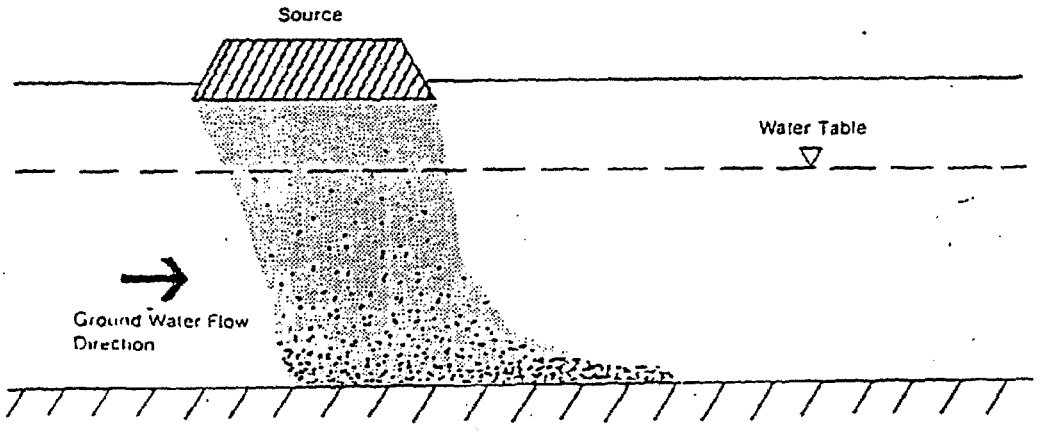
Contaminant Less Dense Than Ground Water



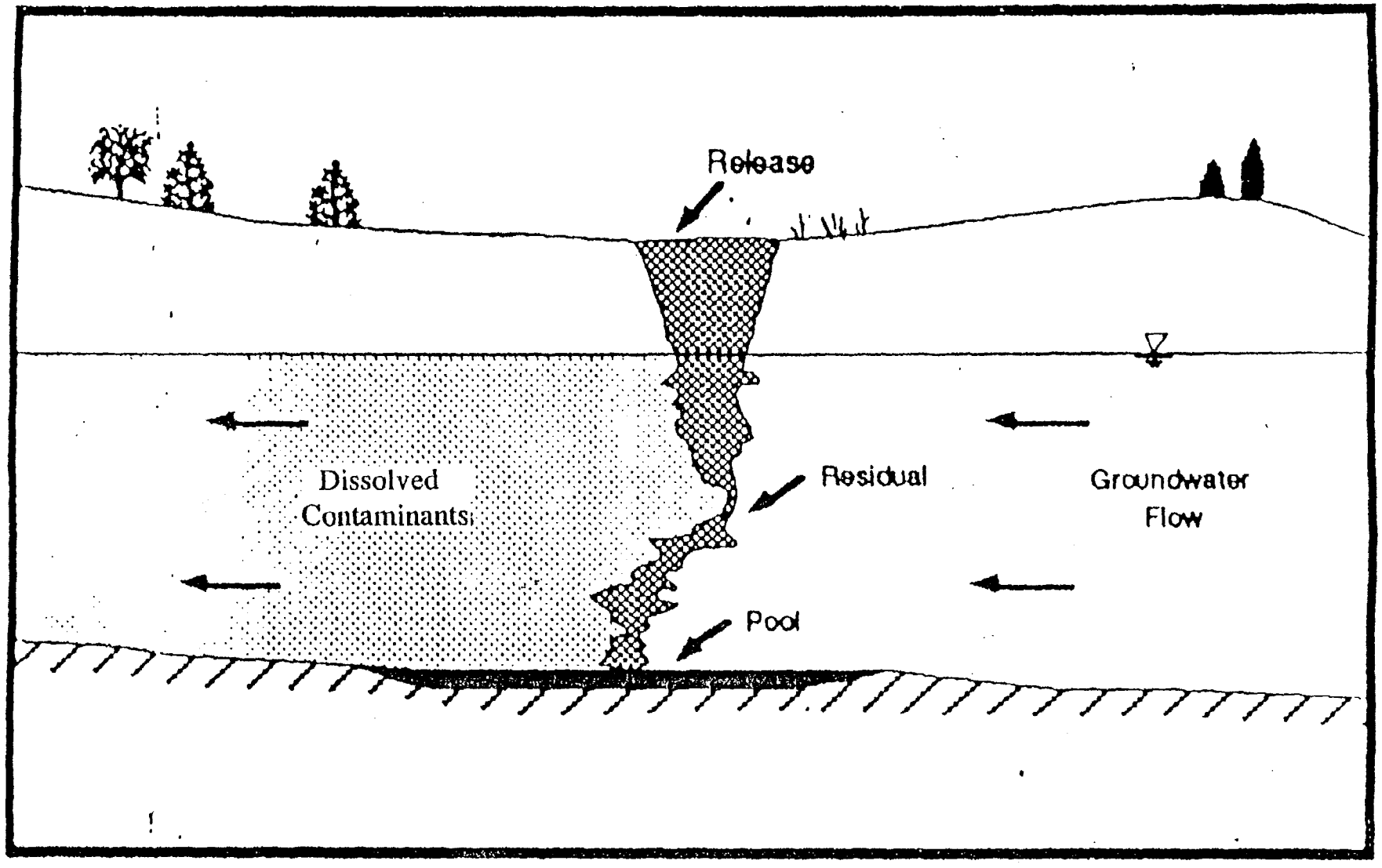
Contaminant Density Same as Ground Water



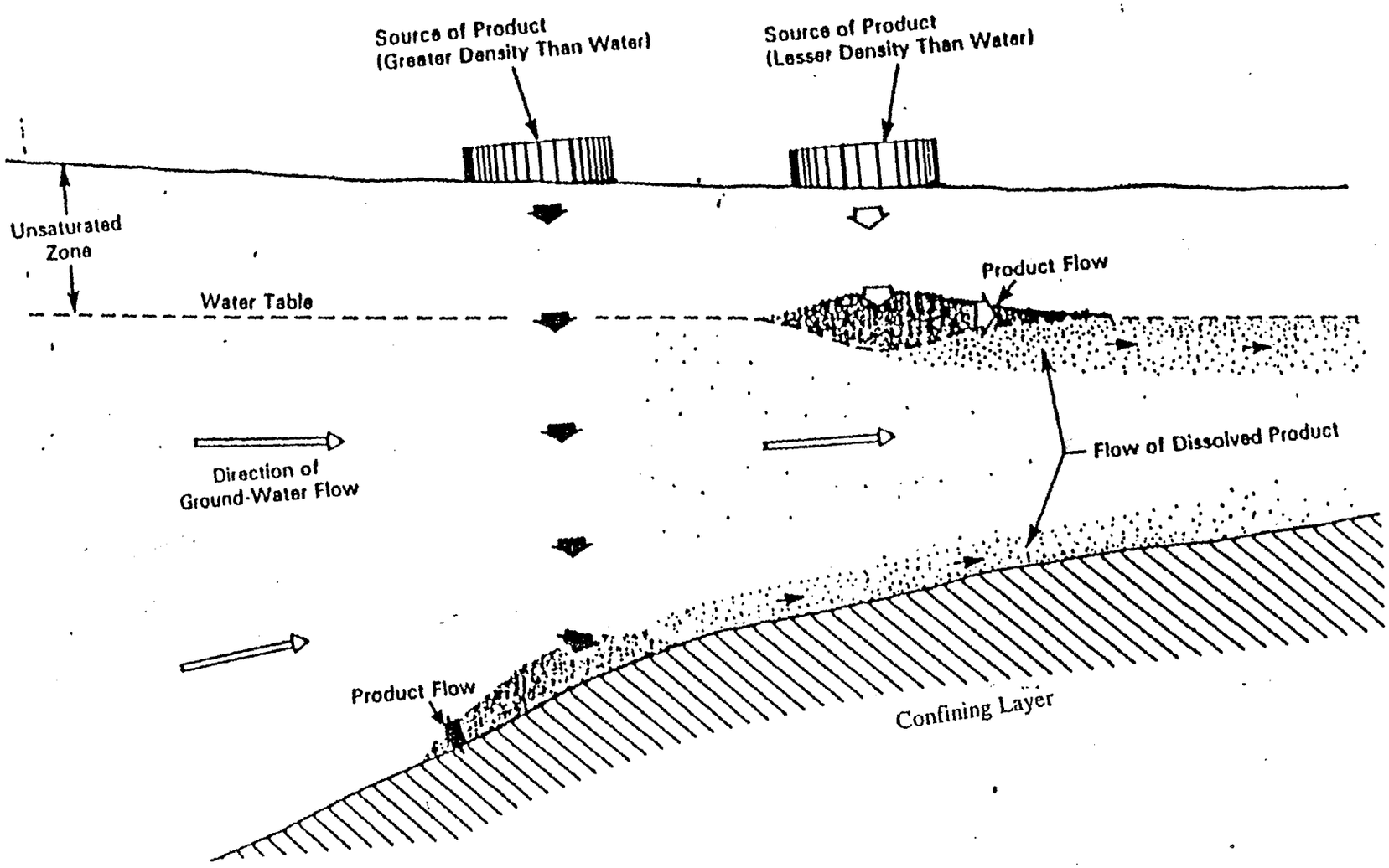
Contaminant Denser Than Ground Water



Contaminant Denser Than Ground Water
and Sinks to Bottom of Aquifer



Migration of a Dense Non-Aqueous Phase Liquid Through the Vadose Zone to an Impermeable Layer



Effects of Density on Migration of Contaminants

Physical Properties (continued)

- **Viscosity**
  - The internal resistance to flow exhibited by a fluid
  - Determines how rapidly the contaminant travels through the unsaturated and aquifer media
  - Important for designing a monitoring system and remediation system

- **Surface Tension**
  - Determines the degree to which a chemical will spread and how strongly the contaminant will be drawn into the unsaturated soils by capillary forces
  - The greater the surface tension of the contaminant, the less it will spread on the surface of the water and the higher the contaminant will be drawn up into the unsaturated zone by capillary forces
  - Used to determine the relative distribution of a spilled contaminant between the unsaturated and saturated zones
  - Used to determine how widely the plume of contamination will spread. This information will help in designing the ground water monitoring system to evaluate the movement of the contamination.

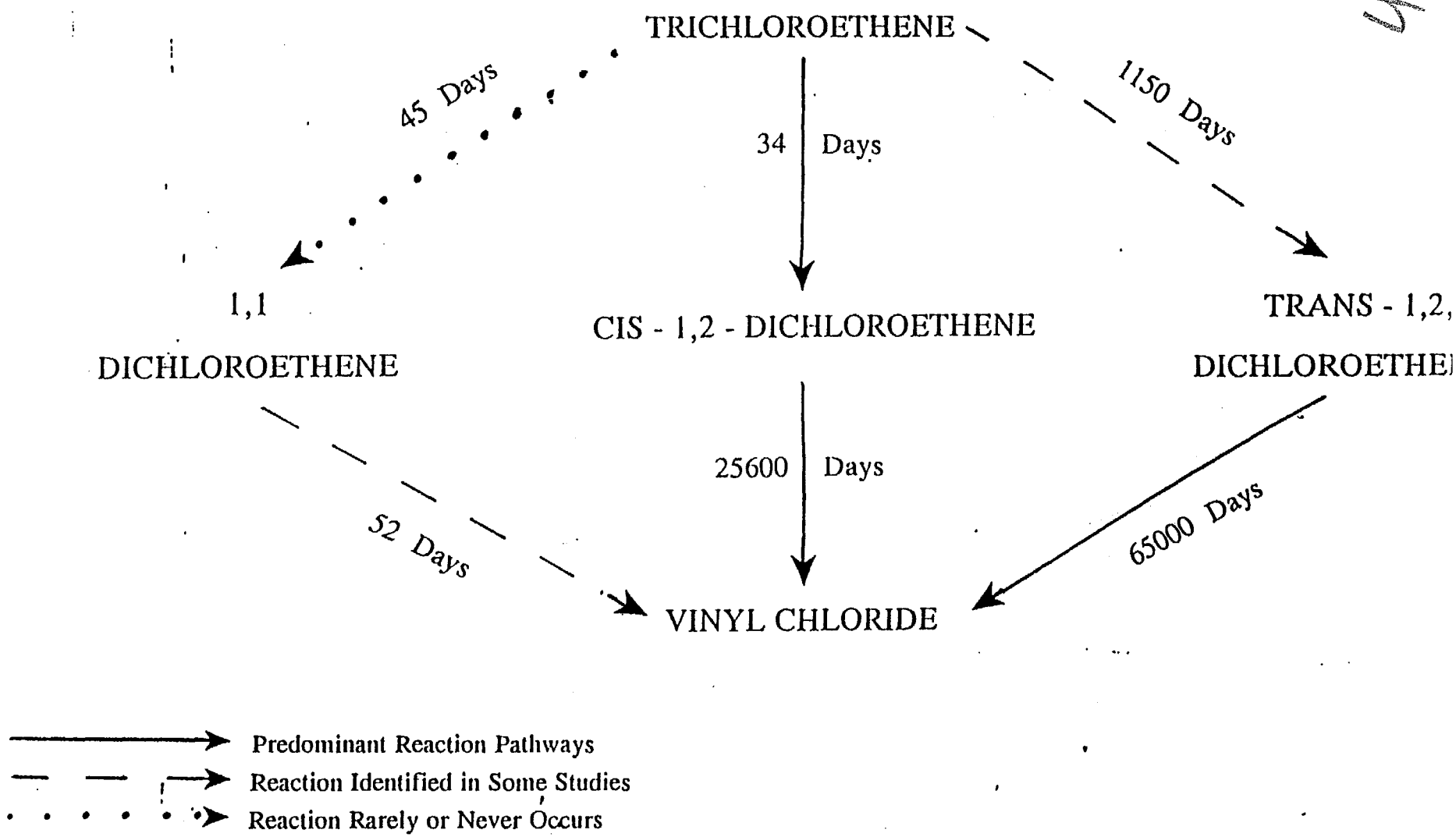
Physical Properties (continued)

- **Vapor Pressure (Volatility)**
  - Process by which a contaminant is transferred from soil or water into the atmosphere
  - Can occur in the unsaturated and saturated zones
  - Accounts for losses of contaminants into the atmosphere and the change in concentrations in the unsaturated or saturated zones
  - May cause vapor plume to form in the unsaturated zone
  - Produces soil gases containing volatiles; can cause explosions, fires, and health problems in subsurface structures (for example, mines and basements)

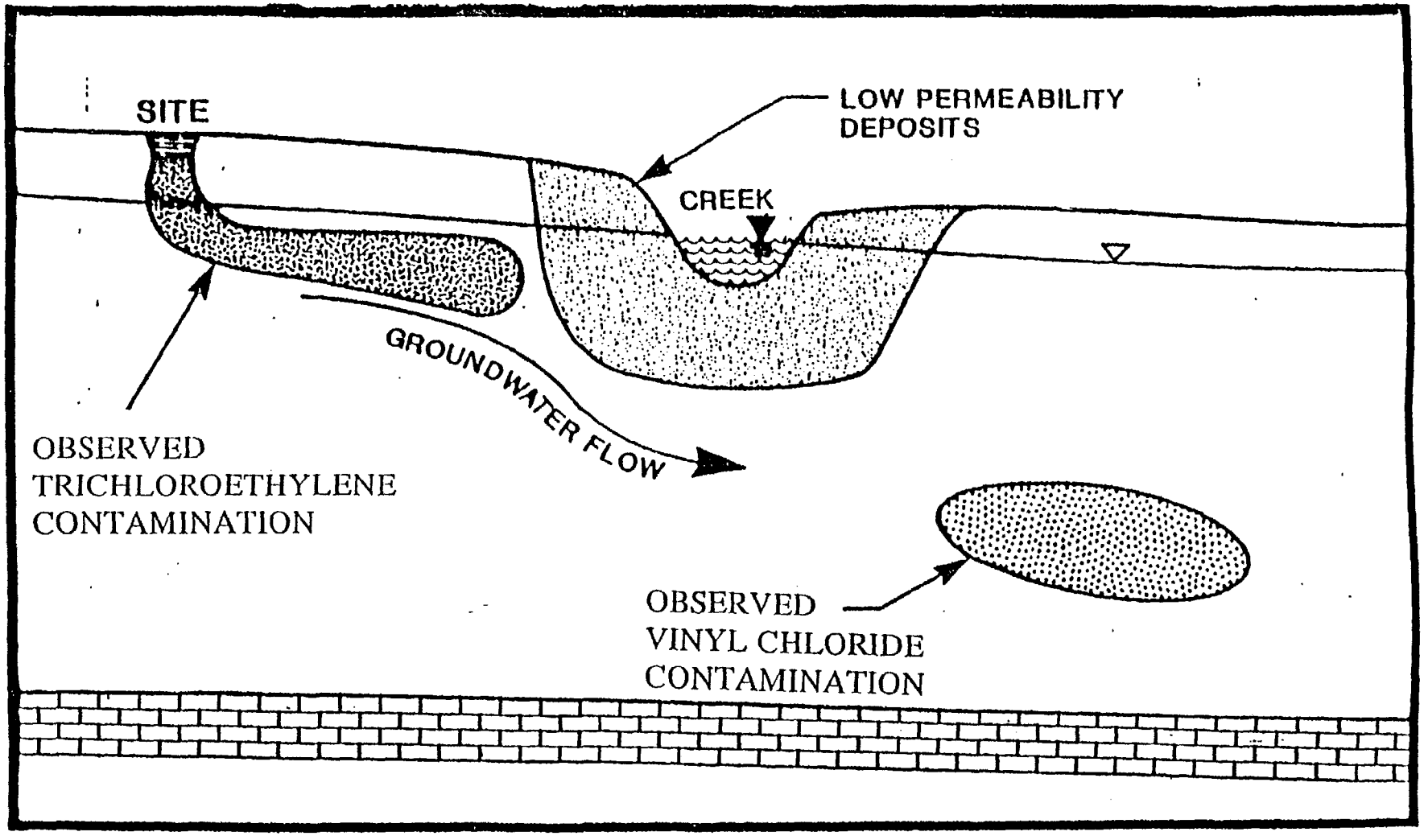
Chemical Properties

- **Adsorption**
  - The process where contaminants are transferred from solution to the surface of a solid
  - Determines the relative distribution of contaminants between the ground water and the soil; affects the contaminant transport velocity
  - Factors that control adsorption include chemical and physical characteristics of the contaminant, composition of the surface of the solid (usually soil particles), and the fluid media (usually water)

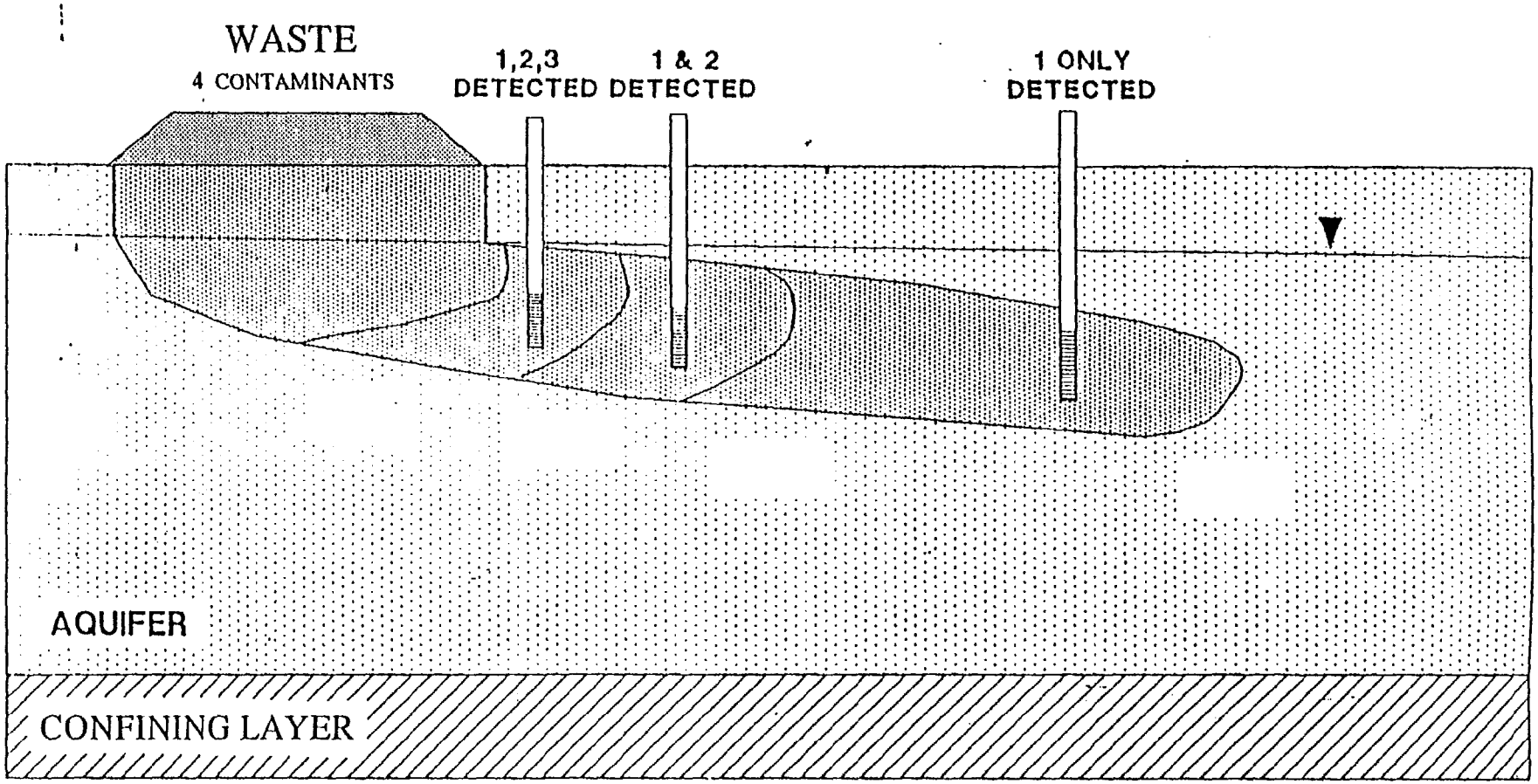
- **Degradation**
  - The process where contaminants undergo one or more reactions resulting in the disappearance or transformation of the contaminants
  - Degradation products may be stable, more toxic, or less toxic than the original contaminant
  - Although biodegradation is the most common, other types of degradation include oxidation/reduction and hydrolysis
  - Complete degradation results in carbon dioxide and water
  - Knowing the possible degradation products will help in designing the ground water monitoring system



Degradation Reaction of Trichloroethene



Multiple Contaminant Plumes Showing Degradation Products



Differential Flow of Contaminants Due to Physical and Chemical Properties

49

Transport of Different Chemical Compounds

- Chemical compounds can be divided into classes based on their stability and mobility
- These classes of compounds have unique distinguishable transport properties
- These classes of compounds pose distinguishable risks to receptors and are important analysis target parameters.

Four Chemical Pollutant Classes

- Aromatics (Ring organic compounds)
- Aliphatics (Straight chain organic compounds)
- Inorganic compounds
- Metals

Class A: Aromatics

- Examples of Aromatics
  - Aniline derivatives: used in dyes, laquers, and pesticides
  - Benzene and cogeners: used in many fuels
  - Biphenyls, such as dioxin

- Transport Properties of Aromatics
  - Not highly soluable in water
  - Large molecules which are not easily adsorbed
  - Generally in liquid organic form not miscible in water
  - Biodegrades to toxic aromatics and aliphatics

Class B: Aliphatics

- Examples of Aliphatics
  - Formaldehyde and derivatives: used as solvent for perfumes; preservative; degrades to phosgene
  - Chloro- Compounds: carbon tetrachloride used in manufacturing; tetrachloro ethylene used as a chemical solvent
  - Nitrogen Compounds: carbomates; ethylene thiourea, a degradation product of pesticides; morpholine, used in wax and dyes

- Transport Properties of Aliphatics
  - Some are polar and highly water soluable
  - Many may biodegrade to other toxic compounds
  - Long-chain aliphatics not readily adsorbed, not easily stabilized if not biodegraded (must break chain)
  - Many aliphatics may be biotreated

Class C: Inorganic Compounds

- Examples of Inorganic Compounds
  - Cyanides: used in electroplating
  - Sulfides and Ammonium Derivatives: used in many products; releases toxic acidic gases such as hydrogen sulfide
  - Toxic Metal Compounds: used in electroplating (chromic acid), paints, and coating materials

- Transport Properties of Inorganic Compounds
  - Most inorganic compounds are to some degree water soluable and mobile in ground water
  - Metal atoms not treatable except by fixation, such as solidification

Class D: Metals

- Examples of Metals
  - Elemental metals such as cadmium, mercury, and chromium
  - These and other elemental metals are widely used for product manufacture; trace quantities of certain metals pose risk

- Transport Properties of Metals
  - Limited mobility in soil and ground water because of adsorption on surface of mineral grains
  - Primary concern is direct exposure and not migration in subsurface
  - However, mobility in subsurfaces increases if soluable ions exist in an acidic, sandy soil with low organic and clay content
  - For example, hexavalent chromium (+6) in ground water is soluable and slightly mobile but trivalent chromium (+3) is insoluable and immobile
  - Fixation is possible for most metal compounds; recovery is preferred remediation for mercury

Data Requirements

- Chemical characterization of pollutants and wastes need to be known to set priorities and to design appropriate treatment process
- Sampling and analysis must be chemical specific
- Both qualitative and quantitative data are needed

PART II.
STABILIZATION

WHAT WE WILL LEARN IN THIS SECTION...

I. DEFINITIONS

II. IMPLEMENTING STABILIZATION

- A. Prioritize Areas
- B. Evaluate Benefits of Stabilization
- C. Collect Data
- D. Select and Design Stabilization
- E. Implementation

III. TYPES OF STABILIZATION

- A. Source Removal
  - 1. Underground Storage Tanks
  - 2. Waste Piles
  - 3. Surface Impoundments
  - 4. Contaminated Soil
- B. Containment
  - 1. Ground Water
  - a. Interceptor Trench
  - b. Sheet Pile Cut-Off Wall
  - c. Pump and Treat
  - 2. Surface Water
  - a. Dikes and Berms
  - b. Diversion Ditches
  - c. Grading
- C. Capping
  - 1. Uses
  - a. Minimize Leaching to Ground Water
  - b. Control Gas Emissions
  - c. When Waste Removal Is Not Possible
  - d. Combined with Other Technologies
  - 2. Types of Caps
  - a. Soil
  - b. Concrete/Asphalt

STABILIZATION

- Key Points To Be Covered:

  - **Stabilization** is an action to control imminent threats resulting from a release or potential release

  - Stabilization can be used on all media but will focus on soil and ground water

  - Different stabilization technologies can be combined for maximum protection

63

8

STABILIZATION

- Stabilization means taking whatever action is necessary to address exposures to waste releases and to control or prevent any further spread of contamination.

- The intent of stabilization is to prevent or minimize the further releases without delay when an immediate threat exists.

- Although stabilization may be applied to address releases to any medium (soil, ground water, surface water, air), a large proportion of stabilization actions will focus on soil and ground water to prevent further degradation.

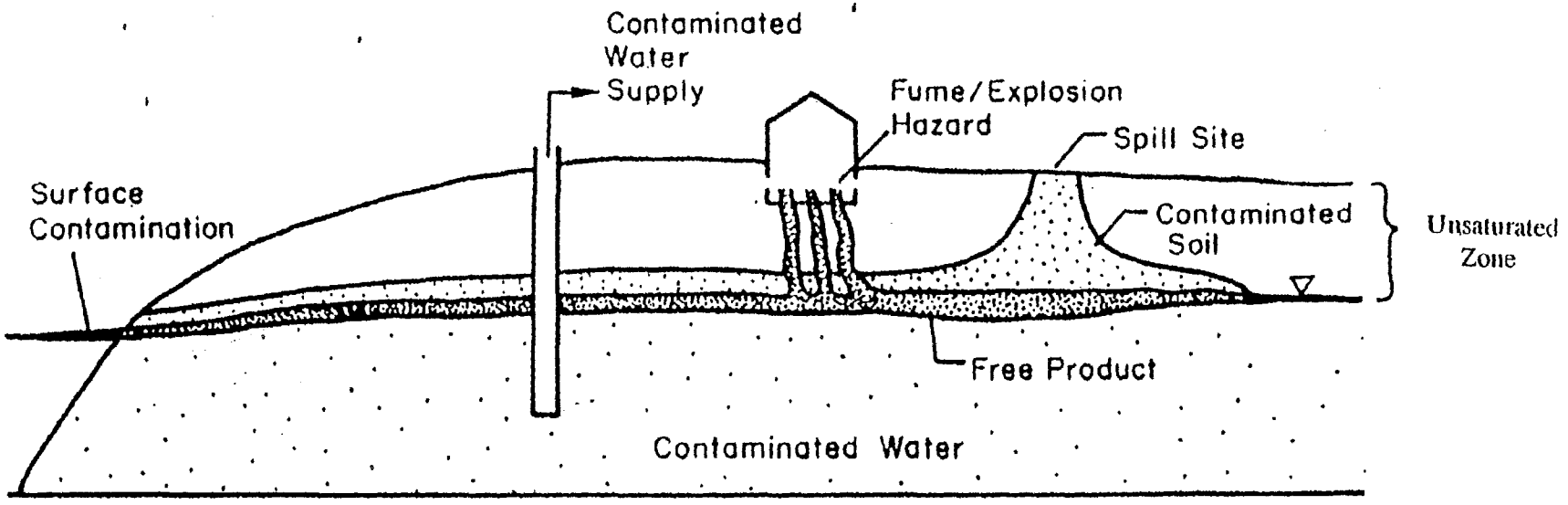
STABILIZATION (continued)

- In some cases, stabilization actions are used to prevent the migration of contamination, but does not necessarily provide the only clean up. Other stabilization actions prevent contaminant migration and also provide the degree of treatment necessary for site remediation.

- Stabilization activities should utilize conventional and innovative remedial techniques as soon as practicable.

- Examples of releases that may be candidates for stabilization include those that pose threats to human populations, ecosystems, and/or drinking water sources.

19



Multiple Problems Associated With a Release

IMPLEMENTING STABILIZATION

- Prioritize Areas
  - All areas that have released, or suspected of having released, contaminants should be prioritized for stabilization
  - Allows stabilization areas that are an immediate threat to human health and the environment to begin first
  - Focuses limited resources on stabilizing environmental problems

- Evaluate Benefits of Stabilization
  - Determine if stabilization is appropriate for the area and what benefits will be gained.
  - The types of benefits may include limited contaminant migration, reduced volume of contaminated media, and lowered risk to human health and the environment.
  - Determine if an appropriate stabilization technology exists for the contamination of concern

69

IMPLEMENTING STABILIZATION (continued)

- Collect Data
  - Often, the data required to determine the type of stabilization to be used may not be available and additional sampling will be required to determine the contaminants present and the extent of contamination.
  - Examples of data that may be required include the contaminant characteristics and concentration, depth to water table, and ground water flow rates and direction.

- Select and Design Stabilization
  - The type of stabilization action chosen will be based on a variety of factors such as the media that is contaminated, the contaminants present, and the extent of contamination
  - Historical knowledge of the area can be used to help select an appropriate stabilization action.

IMPLEMENTING STABILIZATION (continued)

- Implementation
  - After the stabilization measure has been chosen, it should be implemented as soon as practicable so that contaminant migration can be limited to the extent possible.
  - Once stabilization has been implemented, the area should be monitored to ensure that the stabilization actions are effective in controlling the contaminant movement.

TYPES OF STABILIZATION

- Stabilization actions can be used alone, they can be combined with several types of stabilization actions, and they can be implemented in phases.

- Three types of stabilization that can be used in a variety of situations include:

  - Source Removal

  - Containment

  - Capping

SOURCE REMOVAL

- UNDERGROUND STORAGE TANKS

Waste Piles

Surface Impoundments

Contaminated Soil

67

87

UNDERGROUND STORAGE TANKS

- Underground storage tanks often release contaminants to soil and ground water due to corrosion. Two stabilization actions that can be used include removal and infilling.

- For tank removal, the liquid contents of the tank are removed and the tank is dug up. Any contaminated soil should also be removed. If ground water is contaminated, then stabilization actions for ground water should be implemented. The excavated area is then filled with clean soil.

- For tank infilling, the liquid contents of the tank are removed but the tank is left in place. Grout or concrete is then pumped into the tank and it is permanently sealed off. Additional stabilization actions, such as a cap over the area, may also be needed if the soil around the tank is contaminated.

SOURCE REMOVAL

Underground Storage Tanks

☞ WASTE PILES

Surface Impoundments

Contaminated Soil

WASTE PILES

- Waste piles often leach contaminants to the soil, ground water, and surface water. The best stabilization action is removal of the waste pile and stabilization of contaminated soils or ground water that may have been caused by contaminant migration from the pile. If removal is not possible, then the following stabilization actions can be used.

- Diversion ditches, dikes, and berms can help control runoff from the waste pile. These structures can be constructed very quickly.

- A temporary cover, such as a roof or plastic sheeting, can be placed over the pile to control runoff.

SOURCE REMOVAL

Underground Storage Tanks

Waste Piles

SURFACE IMPOUNDMENTS

Contaminated Soil

SURFACE IMPOUNDMENTS

- Surface impoundments are often unlined or the lining present may have been breached leaching contaminants to the underlying soils and ground water.

- Free liquids and highly mobile wastes in the surface impoundment can be removed and treated. The remaining sludges can be solidified or stabilized in place and then covered. The cover should allow for surface water run-off.

- Often, releases from surface impoundments will contaminate the ground water which will also require some type of stabilization action. Reducing the release to ground water can be achieved by dewatering the surface impoundment which will reduce the hydraulic head.

SOURCE REMOVAL

Underground Storage Tanks

Waste Piles

Surface Impoundments

☞ CONTAMINATED SOIL

CONTAMINATED SOIL

- Contaminated soil is best stabilized by removal and subsequent treatment, such as stabilization. If the ground water is contaminated, then stabilization actions to address ground water contamination should also be used.

- If removal is not possible or feasible, then diversion ditches, berms, and dikes can be constructed to control surface water run-on and run-off.

- A temporary cap or cover can be placed over the contaminated soil to prevent the dispersal of wind blown dust.

- If the contaminated area is small, a fence can be constructed to prevent direct contact.

CONTAINMENT

- Containment stabilization technologies can be classified by media: ground water or surface water. In each medium, several stabilization technologies are commonly used.

- Stabilization of contaminated ground water may be undertaken from the final clean up or may be an incremental step in the final clean up. The stabilization technology used should be compatible with anticipated long term remediation

- Ground water containment technologies may include a variety of hydraulic and physical barriers such as interceptor trenches and drains, sheet pile cut-off walls, and pump and treat.

CONTAINMENT (continued)

- Surface water controls are necessary where an impermeable cap is used, where contaminants are on the surface or contaminated soil is on or near the surface, and where infiltration through or to contaminated soils or ground water is a significant problem. Several methods may be used in combination to obtain the appropriate degree of surface water control.

- Surface water containment technologies may include diversion ditches, dikes and grading.

GROUND WATER CONTAINMENT

INTERCEPTOR TRENCHES/DRAINS

Sheet Pile Cut-Off Walls

Pump and Treat

INTERCEPTOR TRENCHES/DRAINS

- Trenches or drains collect contaminated ground water to prevent contamination from reaching down-gradient receptors. They are usually installed perpendicular to the direction of ground water flow.

- Drains are constructed by placing a perforated pipe on gravel bedding at the bottom of a trench. The trench is backfilled with gravel followed by a cover of soil on top. Trenched are constructed the same way but are left open.

- Trenches and drains can be active (the collected liquid is pumped out) or passive (the collected liquid is gravity drained to a collection device).

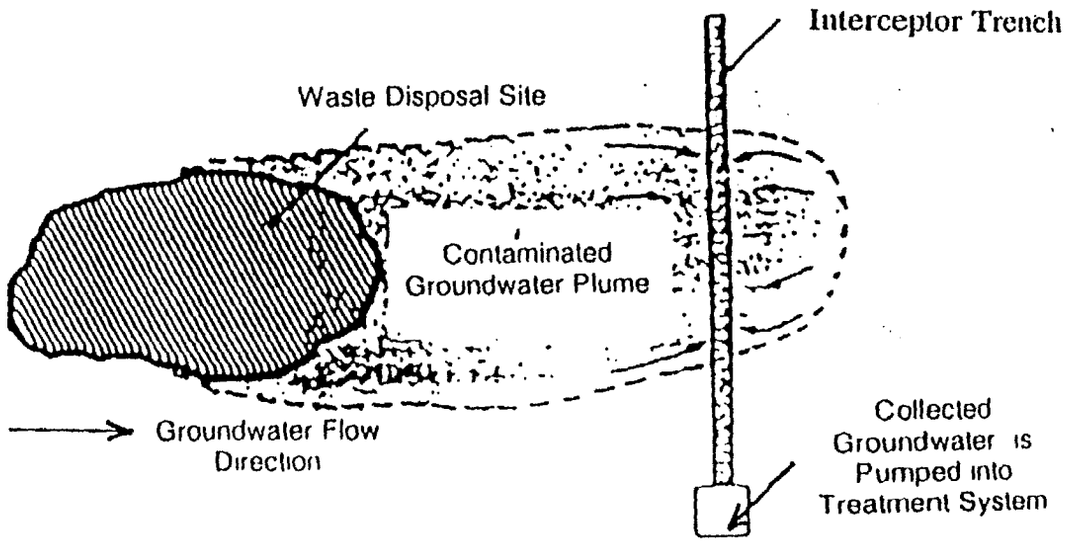
INTERCEPTOR TRENCHES/DRAINS (continued)

- Advantages
  - Relatively simple construction and inexpensive
  - Useful for collecting contaminants in poorly permeable soil
  - useful for intercepting landfill seepage and run-off

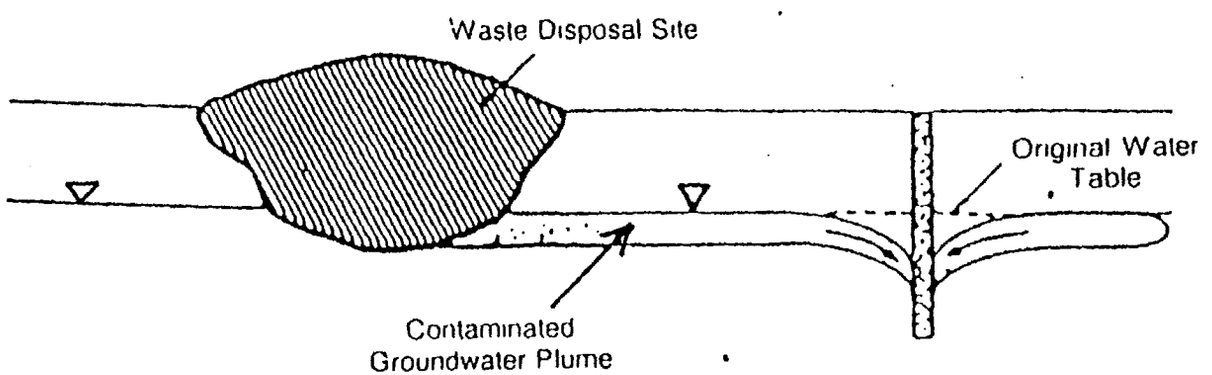
- Disadvantages
  - Open systems require safety precautions to prevent fires and explosions
  - Not useful for sites where contamination is deep
  - May interfere with other operations at the facility

79

Map View



Cross Section



Interceptor Trench to Contain Leachate Plume

GROUND WATER CONTAINMENT

Interceptor Trenches/Drains

SHEET PILE CUT-OFF WALLS

Pump and Treat

SHEET PILE CUT-OFF WALLS

- Sheet pile cut-off walls are constructed by driving individual sections of interlocking steel sheets into the ground using impact or vibratory drivers. The wall forms a thin impermeable barrier to ground water flow.

- The walls can be used to contain contaminated ground water or to divert ground water flow around or below contaminated areas. The walls should extend to bedrock or into a low permeability soil strata.

SHEET PILE CUT-OFF WALLS (continued)

- Advantages
  - Installed quickly and inexpensive
  - Effective short term measure to enhance ground water recovery or containment

- Disadvantages
  - Not suitable for very dense soils or soils with boulders present
  - Not suitable for ground water containing high concentrations of salts or acids
  - Maximum depth to which wall can be driven without damage is typically 13 meters

GROUND WATER CONTAINMENT

Interceptor Trenches/Drains

Sheet Pile Cut-Off Walls

PUMP AND TREAT

PUMP AND TREAT

- Pump and treat is the extraction of ground water and subsequent treatment at the surface. Determination of the location and depth of the extraction wells requires prior delineation of the contaminant plume and knowledge of the aquifer properties.

- The surface treatment of extracted ground water will vary depending on the contaminants present. Treatment technologies to be used may include air stripping, activated carbon adsorption, and biological treatment.

- Pump and treat is often used for remediation. For stabilization purposes it is used to halt further migration of contaminated ground water. Can be used in conjunction with other stabilization technologies such as sheet pile cut-off walls.

PUMP AND TREAT (continued)

- Advantages
  - Effective on deep (> 15 meters below surface) widespread ground water contamination
  - Keeps contamination from spreading

- Disadvantages
  - Expensive to design, install, and operate
  - Not effective on contaminants with low mobility and in aquifers with low hydraulic conductivity

SURFACE WATER CONTAINMENT

DIKES AND BERMS

Diversion Ditches

Grading

28

DIKES AND BERMS

- Dikes and berms are used for surface areas no greater than 5 acres. These are used to divert surface water from a site or to prevent mixing of different types of wastes.

- Dikes should be adequately compacted until the desired size is obtained and then grassed. Dikes are often constructed around the contaminated area so as to direct surface flow to drainage ways, such as diversion ditches, and away from the contamination.

DIKES AND BERMS (continued)

- Advantages
  - Construction costs are low assuming that the required soil is readily available
  - They can be used to provide protection against site flooding
  - They can be constructed quickly

- Disadvantages
  - Structures are temporary and are usually not used for more than 1 year
  - If improperly designed, constructed, or maintained, they may increase the infiltration into the ground water.

40

SURFACE WATER CONTAINMENT

Dikes and Berms

DIVERSION DITCHES

Grading

DIVERSION DITCHES

- Diversion ditches or channels are either sodded or lined with boulders and are used to carry large amounts of flow from areas larger than 5 acres.

- The diversion ditches intercept run-off either preventing the surface water from flowing across contaminated areas or preventing contaminated run-off from flowing across uncontaminated areas.

- Advantages
  - Simple, well-established construction techniques minimize costs
  - Collects and transfers water better than dikes and berms.
  - They are more permanent than dikes and berms.

- Disadvantages
  - Maintenance is required, especially in sodded waterways.
  - Improperly constructed, designed, and maintained ditches and channels can increase erosion and the rate of surface water infiltration

SURFACE WATER CONTAIMENT

Dikes and Berms

Diversion Ditches

GRADING

GRADING

- Grading describes the reshaping of the surface of a particular site in order to reduce infiltration and erosion while redirecting run-off from the site.

- Grading is usually performed in conjunction with revegetation which may further decrease infiltration and erosion. Without revegetation, grading may increase erosion.

- Advantages
  - Relatively low cost if cover materials are readily available
  - Reduction of ponding minimizes infiltration
  - Reduction of run-off velocity and soil erosion

- Disadvantages
  - Not applicable to smaller areas without space for gradual grading
  - Costs increase if appropriate fill material is not readily available
  - Periodic regrading may be necessary if subsidence occurs

CAPPING

- **Capping** is the placement of an impermeable layer, such as compacted soil or asphalt, over buried waste or a contaminated ground water plume.

- Capping minimizes the contact between infiltrating rainwater and the emplaced wastes which will minimize leaching to ground water. Capping is also used to control gas emissions, to reduce erosion, and to isolate plumes of contaminated ground water.

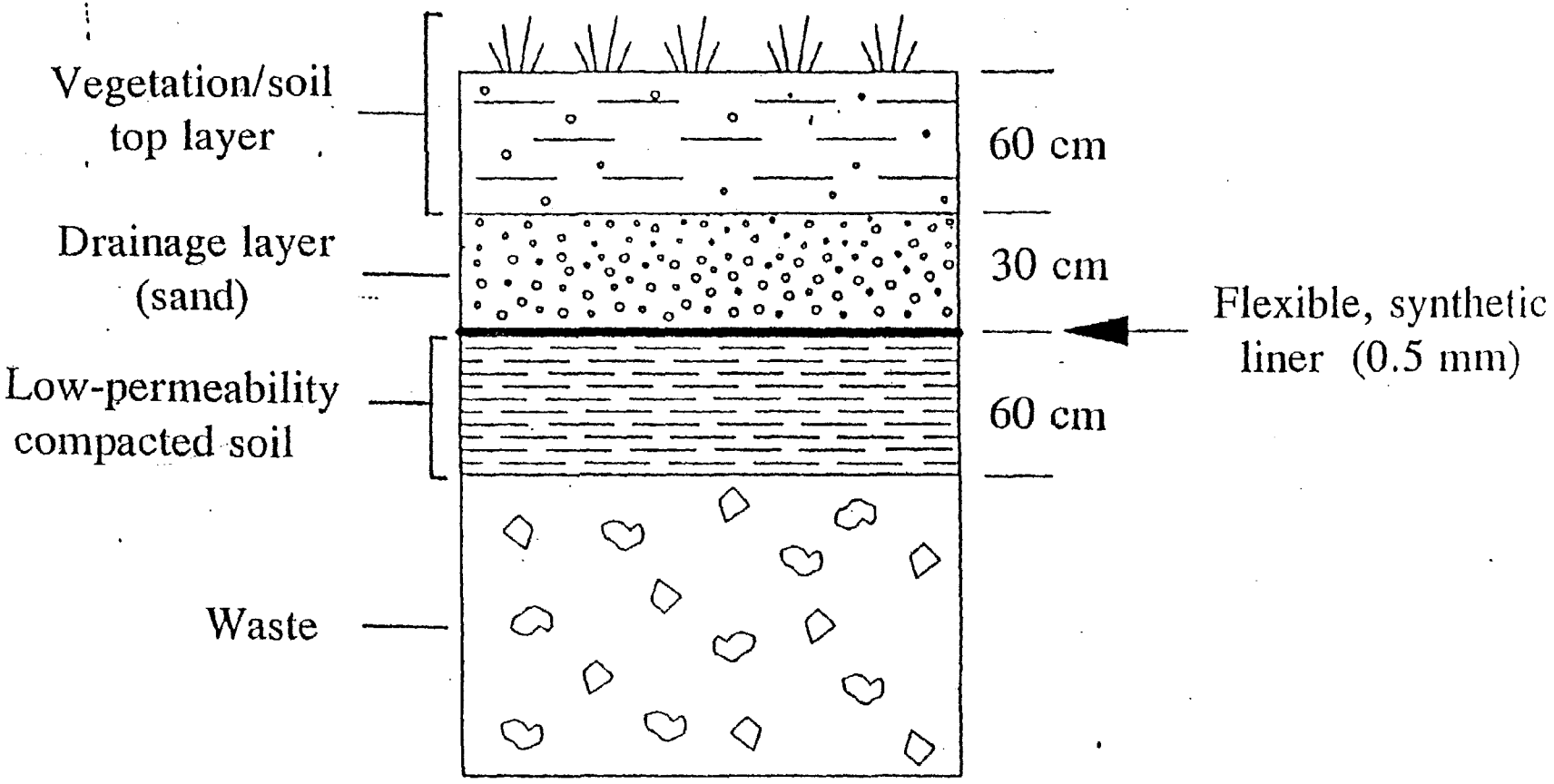
- Capping is done when the contaminated material is to buried or when extensive subsurface contamination precludes excavation and removal of wastes.

- Capping is often done in conjunction with ground water extraction or containment technologies.

CAPPING (continued)

- Single-Layered Caps
  - Used when the cap is meant to be temporary, where there is very little precipitation, or when the capped waste is not leached by infiltrating rainwater.
  - Natural soil is not recommended because of the tendency to shrink and crack.
  - Most effective single-layered caps are made of concrete or asphalt.

- Multi-Layered Caps
  - Used when the cap is to permanently cover wastes.
  - Most common is a system consisting of four layers: an upper vegetative protective layer of topsoil or fill, a drainage layer of sand, a flexible, synthetic liner, and a low permeability compacted soil.



A Typical Multi-Layered Cap

CAPPING (continued)

- Advantages
  - Relatively inexpensive, especially if the proper soils are readily available
  - Waste can be left in place and are not disturbed which may create additional contamination problems

- Disadvantages
  - Requires maintenance and monitoring to ensure integrity
  - May not be effective if buried waste is below the water table
  - Not recommended for use in areas prone to flooding

PART III.
REMEDIATION

Design for the Environment

EPA

98

WHAT WE WILL LEARN IN THIS SECTION...

I. DEFINITIONS

II. GROUND WATER

A. Pump and Treatment Technologies

1. Definitions
2. Design Requirements
3. Advantages
   a. Dependable
   b. Reduces Contaminant Mass
   c. Deep, Wide-Spread Contamination
4. Disadvantages
   a. Long Operation Time
   b. Expensive to Design, Install, and Operate
   c. Ineffective with Low Hydraulic Conductivity

B. Air Sparging with Soil Vapor Extraction

1. Definitions
2. Advantages
   a. Remediates Volatile Organic Compounds
   b. Local Zones of High Concentration
   c. Injected Air Enhances Biodegradation
3. Disadvantages
   a. Only Volatile Contaminants
   b. Must Have Permeable Soil
   c. Well Screen Easily Clogged
   d. May Adversely Affect Anaerobic Biodegradation

C. Bioremediation

1. Definitions
2. Basic Requirements
3. Advantages
   a. Inexpensive
   b. Complete Degradation
   c. Simultaneous Treatment
   d. No Need for Excavation

4. Disadvantages
a. Contaminant Specific
b. May Form Gaea
c. May Generate Intermediate Compounds

D. Natural Attenuation
1. Definitions
2. Destructive versus Nondestructive Processes
3. Advantages
a. Inexpensive
b. Works with Other Technologies
c. Non-Intrusive
4. Disadvantages
a. Long Time to Degrade
b. Implement Ground Water Conatainment

III. SOIL

A. Soil Vapor Extraction
1. Definitions
2. Favorable Conditions
3. Advantages
a. Good for Volatiles
b. Little Disturbance
c. Reduces Concentration and Mobility
d. Only Ambient Air Is Used
4. Disadvantages
a. Soils Must Be Permeable
b. Need Homogeneous Soils
c. Depth to Ground Water Important

B. Solidification
1. Definition
2. Process
3. Disposal/Storage in Landfills
a. Engineered Structure
b. Liners
4. Advantages
a. Inexpensive
b. Leaching and Mobility Reduced
c. Multiple Compounds Treated at Once
5. Disadvantages
a. Volume Increase
b. Not Applicable on Volatiles
c. Contaminants Not Destroyed

REMEDIATION

- Key Points To Be Covered:
  - **Remediation** is the long term cleanup of a release
  - Stabilization technologies can be expanded and used for remediation
  - Remediation should address the contaminant source and any affected media
  - Different remediation technologies can be combined to effectively remediate a site

REMEDIATION

- **Stabilization** is the immediate action to control imminent threats resulting from a release or a potential release. **Remediation** is the long term cleanup of a release.

- Technologies used for stabilization can be expanded and used for remediation. One or more of these technologies can be combined (along with stabilization technologies) in order to achieve optimum cleanup.

- The remediation of a site should address the contaminant source area and if the ground water is contaminated, remediation should also address the contaminant plume. Examples of contaminant sources include leaking landfills, leaking tanks, and spills.

- The technologies used for ground water remediation fall under two general approaches:
  - Use of engineered structures to contain the ground water
  - Natural or induced in-place treatment

REMEDIATION (continued)

- Examples of **ground water** remediation technologies include:
  - Pump and treat
  - Air sparging (in conjunction with soil vapor extraction)
  - Bioremediation
  - Natural attenuation

- **Soil** remediation technologies include:
  - Soil vapor extraction
  - Solidification

GROUND WATER REMEDIATION

- PUMP AND TREAT

Air Sparging

Bioremediation

Natural Attenuation

PUMP AND TREAT

- **Pump and treat** is the extraction of ground water and subsequent treatment of the extracted ground water at the surface by such treatment methods as air stripping or carbon adsorption. The treatment will depend on the contaminants present.

The design of an effective pump and treat system consists of six steps:

1. **Characterize the Geology and Hydrology**
   - Site geology and hydrology are used to determine the location and depth of extraction wells.
   - Hydrogeological conditions favorable to pump and treat are high hydraulic conductivity and homogeneity of the subsurface soils. Heterogeneous aquifer conditions with low permeability zones restrict contaminant flow toward extraction wells.

PUMP AND TREAT (continued)

2. **Characterize Contaminant Chemistry**
   - Contaminant characteristics are used to determine the transport of the chemicals and to properly design the pump and treat system.
   - Chemicals with low mobility and dense nonaqueous phase liquids are difficult to extract from the ground water.

3. **Locate Sources of Contamination** and Mitigate Their Impact
   - The contaminant source must be removed, whether it is on the surface or in the vadose zone.
   - Unremoved contaminants will continue to leach into the ground water and will prolong the cleanup.

4. **Locate the Extraction Wells to Combine Plume Containment and Source Remediation**
   - Extraction wells should be located at the downgradient edge of the plume to stop further migration.
   - Additional extraction wells located in the source area will extract the greatest contaminant mass.

PUMP AND TREAT (continued)

5. **Phase in Construction of Succeeding Extraction Wells**
   - Information gained from the first extraction well can be used to design and locate additional wells.
   - This approach ensures the most efficient location and design of each pumping center.
   - Multiple extraction wells pumping at small rates works better than one well pumping at a large rate, especially if the contaminant plume is widespread.

6. **Monitor the Remediation System**
   - Monitor wells at each pumping center and at the margins of the contaminant plumes will help locate additional extraction wells for the most efficient remediation.

107

PUMP AND TREAT (continued)

- Advantages
  - Dependable technology that has been used for many years
  - Reduces contaminant mass
  - Effective on deep, wide-spread contamination

- Disadvantages
  - Long operation time
  - Expensive to design, install and operate
  - Effectiveness reduced in aquifers with low hydraulic conductivity and heterogeneous soils and contaminants with low mobility

GROUND WATER REMEDIATION

Pump and Treat

AIR SPARGING

Bioremediation

Natural Attenuation

AIR SPARGING

- **Air sparging** injects air into the saturated zone to strip away volatile organic compounds dissolved in the ground water and adsorbed to soil. The volatile contaminants transfer in a vapor phase to the unsaturated zone and are captured and removed by soil vapor extraction.

- Air sparging is always coupled with soil vapor extraction which removes organic vapors from the unsaturated zone.

- Air sparging increases the oxygen content of the ground water which enhances aerobic biodegradation. Subsurface biodegradation lowers the level of volatiles which must be extracted.

- Most effective in soils with vertical and horizontal permeability
  - If vertical flow is restricted, contaminants may migrate laterally into uncontaminated areas
  - Air sparging most applicable in sandy soils

AIR SPARGING (continued)

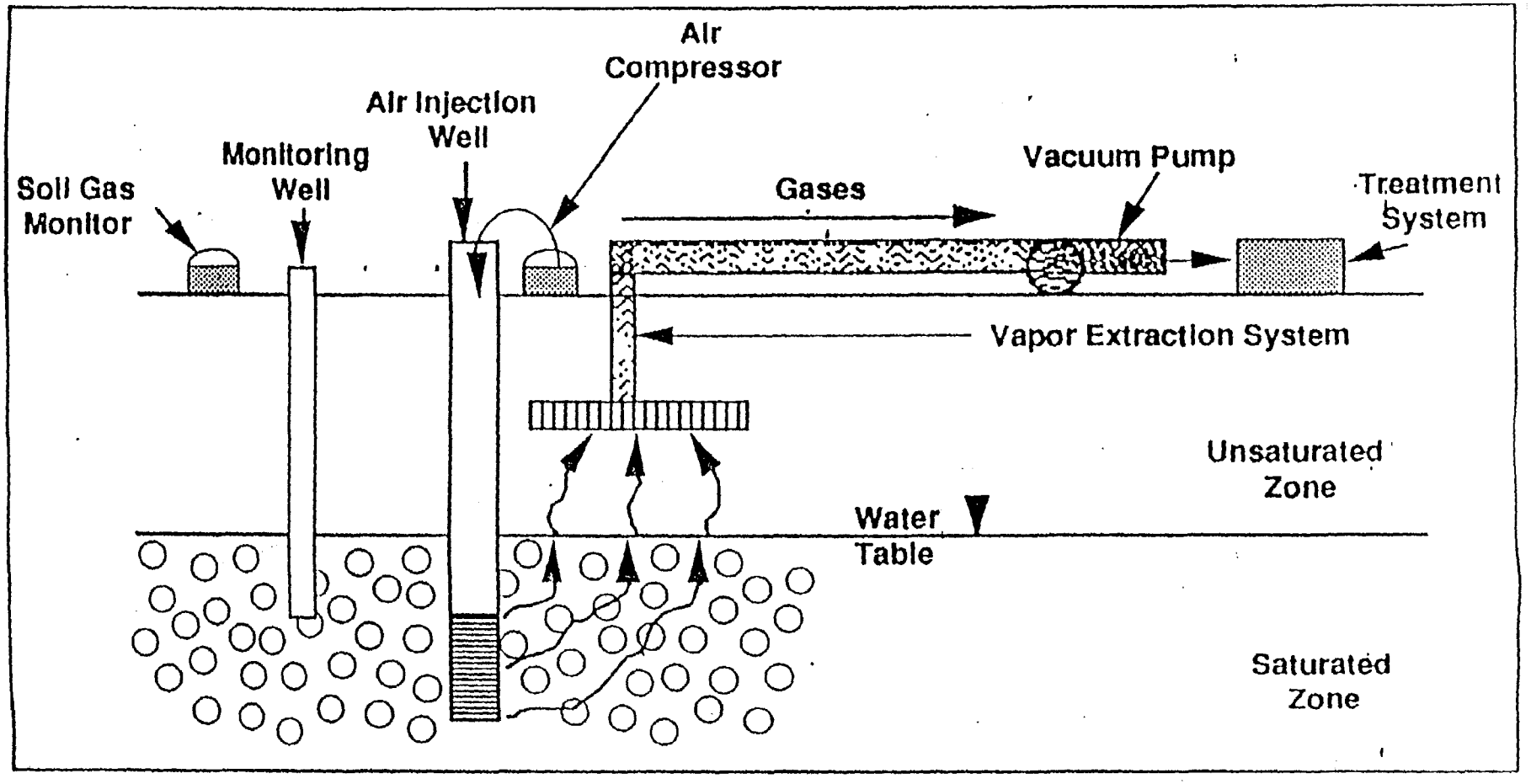
- Injection Wells
  - Screen lengths vary for 1 to 3 meters
  - Well spacing must be sufficient to affect the entire zone contamination. Spacing is typically less than 8 meters.
  - Well placement must take into account depth to ground water, hydraulic conductivity, contaminants, and extent of contamination

- Air Injection System
  - A blower or compressor introduces air into the subsurface through the top of the well casing.
  - The volume of air extracted should exceed the volume of sir injected to prevent subsurface pressure buildup.

AIR SPARGING (continued)

- Advantages
  - Remediates volatile organic compounds
  - Effective for treating local zones of high contamination
  - Injected air enhances subsurface aerobic biodegradation

- Disadvantages
  - Not effective on inorganic compounds
  - Must have permeable soil
  - Well screens easily clogged due to enhanced bacterial growth and oxidation of metals
  - May adversely affect the biodegradation of chlorinated solvents which undergo anaerobic biodegradation



Air Sparging System with Soil Vapor Extraction

Fig 3

GROUND WATER REMEDIATION

Pump and Treat

Air Sparging

BIOREMEDIATION

Natural Attenuation

BIOREMEDIATION

- **Bioremediation** is a treatment based on aerobic and anaerobic bacteria activity. Microorganisms and nutrients are added to the contaminated ground water where they degrade the contaminants. Bioremediation can be done in the subsurface or above ground as part of a pump and treat system.

- Under favorable conditions, most organic compounds can be biodegraded into carbon dioxide and water or organic acids and methane. Readily biodegradable compounds include petroleum hydrocarbons, alcohols, phenols, esters, and ketones.

- Basic requirements for biodegradation
  - **Presence of appropriate microorganisms**, preferably indigenous ones that can degrade specific contaminants at the site
  - **Energy source** in the form of organic carbon
  - **Carbon source**
  - **Nutrients** which include nitrogen, phosphorus, calcium, magnesium, iron, and trace elements
  - **Acceptable environmental conditions** such as temperature (15-45^{0}C), pH (5.5-8.5), salinity, and hydrostatic pressure

115

BIOREMEDIATION (continued)

- The contaminant plume must be monitored to ensure that the bioremediation is working and to ensure that the plume is not migrating.

- Advantages
  - Inexpensive; minimal mechanical equipment requirements
  - Results in partial or complete degradation of the contaminant
  - Simultaneously treats contamination adsorbed onto soils and dissolved in ground water
  - No need for excavation, transportation, and disposal of wastes

- Disadvantages
  - Highly sensitive to toxins and environmental conditions
  - Gases may be formed which must be vented
  - May generate undesirable intermediate compounds

GROUND WATER REMEDIATION

Pump and Treat

Air Sparging

Bioremediation

NATURAL ATTENUATION

NATURAL ATTENUATION

- **Natural attenuation** is achieved when naturally occurring mechanisms work to bring about in place destruction of contaminants. Mechanisms can be classified as destructive or nondestructive based on how the contaminants are attenuated.

- Destructive processes include:
  - Biodegradation (both aerobic and anaerobic)
  - Abiotic oxidation
  - Hydrolysis

- Nondestructive mechanisms include:
  - Sorption
  - Dilution (caused by dispersion and infiltration)
  - Volatilization

NATURAL ATTENUATION (continued)

- Natural attenuation should be used in these instances:
  - It will not result in unacceptable contaminant migration
  - Ability exists to adequately monitor the contaminant plume
  - Active remediation measures can be used if cleanup is not achieved
  - In combination with active remediation measures in areas of high contaminant concentration
  - To "finish up" active remediation

- Site characterization should provide data on the location and extent of contaminant sources; location, extent, and concentration of contaminant plume; geologic setting and stratigraphy; and hydrogeologic parameters such as hydraulic conductivity

- A monitoring well system must be used to monitor the plume migration over time and to verify that natural attenuation is occurring at rates sufficient to protect potential downgradient receptors.

120

NATURAL ATTENUATION (continued)

- Advantages
  - Generally less expensive than alternatives
  - Works in conjunction with other technologies
  - Non-intrusive - allows continued use of site

- Disadvantages
  - May take a very long time to degrade
  - May need to implement containment of the contaminated ground water until degradation is complete

SOIL

- A specific goal of treating contaminated soils is to prevent contaminants from leaching into ground water, migrating off site, and threatening drinking water supplies.

- Soils may be treated in place or by excavating and then treating.

- The decision to treat in place or excavate depends on extent, depth, and volume of contamination, type and concentration of contaminants, soil characteristics, and site hydrogeology.

- In place treatment should be considered when
  - Contamination is widespread, in both area and depth
  - Contaminated material is sot easily excavated
  - Site characteristics and soil properties allow for in place treatment.

121

SOIL (continued)

- Excavation should be considered under the following conditions:
  - The need to remove the contaminant source is immediate
  - Site conditions prohibit or limit the effectiveness of in place treatment
  - The treatment technology under consideration requires or would be enhanced by excavation

- Soil treatment technologies may be used independently, in combination with each other, or in series with other technologies.

SOIL VAPOR EXTRACTION

Solidification

123

124

SOIL VAPOR EXTRACTION

- **Soil vapor extraction** consists of the removal of contaminants by drawing air through a zone of contaminated soil. Air is injected into the unsaturated zone in the area of contamination causing the compounds to volatilize. A series of extraction wells remove the volatile compounds and pass them through an air/water separator and treatment unit.

- Soil vapor extraction can be used alone to remediate the unsaturated zone and is often used in conduction with air sparging to treat contaminated ground water.

- Soil vapor extraction should be considered if these conditions exists:
  - Dominant contaminant form is vapor phase
  - Soil temperature $>20^0$C (can inject heated air)
  - Soil air conductivity $>10^{-4}$ cm/s
  - Moisture content of soil $<10\%$ by volume
  - Contaminated soil is homogeneous
  - Vapor pressure of contaminant >100 mm of Hg
  - Water solubility of contaminant <100 mg/l

SOIL VAPOR EXTRACTION (continued)

- The air/water separator decrease the velocity of the vapor stream and allow gravity fallout of water droplets and sediments. They can be very simple devices, such as a large steel drum. The small amount of accumulated liquids can be treated in a small activated carbon unit.

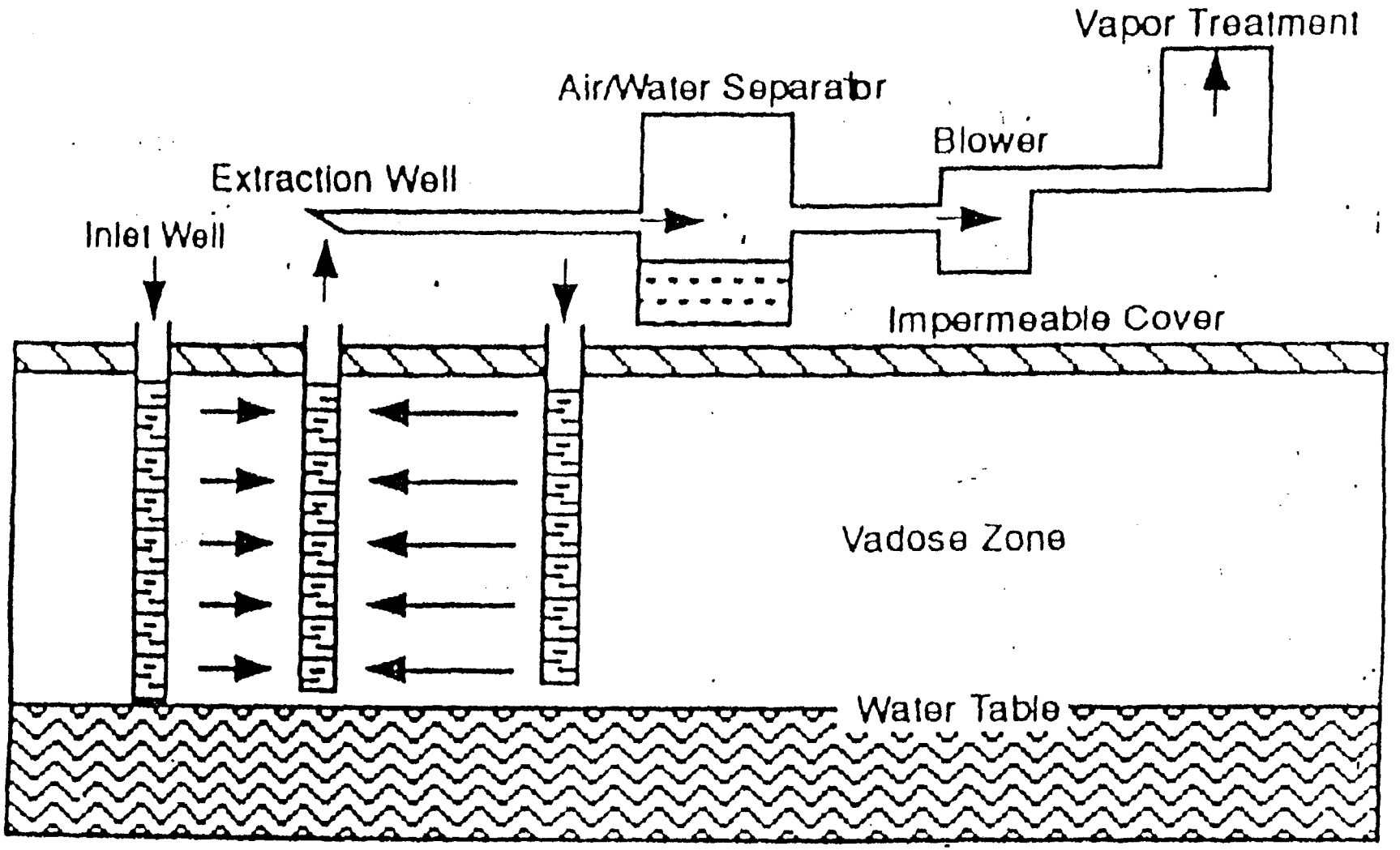
- Vapors removed normally require treatment prior to release to the atmosphere. The most common treatment is carbon adsorption. If vapor treatment is not required, diffuser stacks can provide safe emission of the extracted vapors.

125

SOIL VAPOR EXTRACTION (continued)

- Advantages
  - Good for volatile compounds
  - Conducted in place and requires little disturbance to site
  - Process reduces contaminant concentration and mobility
  - Only ambient air is introduced into contaminated zone

- Disadvantages
  - Soils must be permeable, porous, and fairly homogeneous
  - Cleanup effectiveness can be difficult to verify in heterogeneous soils
  - Not effective if depth to ground water < 1 meter or if contaminant phase is solid or strongly sorbed to soil



Soil Vapor Extraction System

127

SOIL REMEDIATION

128

Soil Vapor Extraction

SOLIDIFICATION

SOLIDIFICATION

- **Solidification** uses additives or cements to physically or chemically immobilize the contaminants in soil. Solidification process may be applied to either excavated or in place soils.

- Mixing of soil and reagent can occur in place by using heavy digging machinery or by an injector device with augers and a paddle assembly to mix the materials. Excavated soil can be mixed in a vessel such as a drum.

- Solidification is applicable to soils contaminated with metals and other inorganics, in addition to nonvolatile and semivolatile organic compounds. Solidification is not recommended on soils contaminated solely with volatile organic compounds since compounds can be released during mixing.

130

SOLIDIFICATION (continued)

- The following information will determine if solidification is appropriate:
  - Physical and chemical characteristics of the contaminated soil
  - Environmental setting and future use of the site (especially if waste is treated in place)
  - Contaminants and concentrations present in soil
  - Physical and chemical stability of the additive or reagent once it is mixed with the soil (may require a small scale test)

- The solidification process involves the following steps:
  - **Pretreatment of soils**: facilitates solidification process; includes removal of boulders, dewatering, homogenization of soil, or removal of volatile organic compounds (usually by soil venting)
  - **Removal of contaminated soils**: required where soils are excavated
  - **Storage of materials**: storage required for excavated soils awaiting treatment, chemical reagents, and treated soils; area should be dry and protected from wind
  - **Mixing and metering of materials**: mixing is the most important step in the solidification process
  - **Disposal of the solidified product**

SOLIDIFICATION (continued)

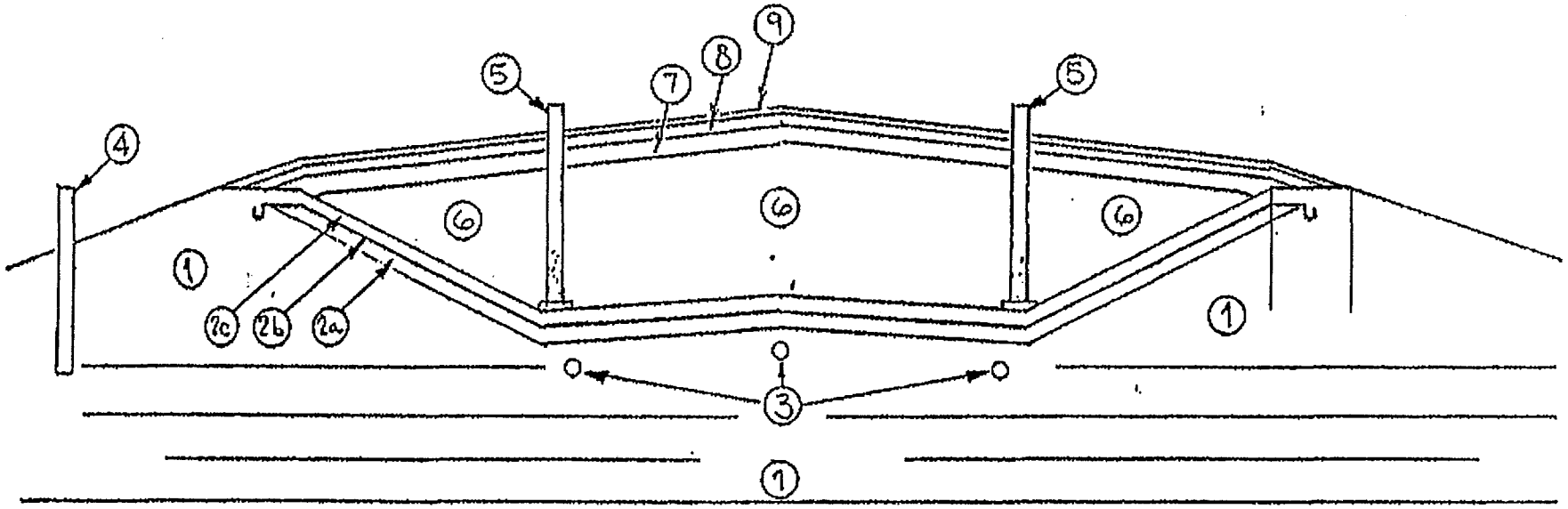
- Disposal/Storage in Landfills
- Engineered Structure
- Liners

SOLIDIFICATION (continued)

- Disposal/Storage in Landfills
  Selection of a landfill site must consider the following:
  - Amount and type of waste to be disposed
  - Topography
  - Geology and hydrology
  - Climate
  - Avalibility of fill material

- Landfill: An Engineered Structure
  - Liners: Compacted clay bottom, synthetic liner, 0.5 meter thick compacted clay
  - Leachate Control: Sump pumps to collect any liquid
  - Cap/Cover: Covered with compacted clay, top soil, and vegetation.
  - The landfill is constructed partially above ground and the final cap is sloped to allow for surface water runoff

* A landfill should never be considered when the water table is close to the surface so that the bottom of the landfill is at or below the water table.



1. Impermeable clay subsoil
2. Triple linear system
   a. compacted clay
   b. synthetic liner
   c. compacted clay
3. Under-drain monitoring system
4. External monitoring wells
5. Monitoring wells/leachate collection
6. Waste
7. Soil cover/cap
8. Impermeable clay layer
9. Topsoil and ground cover

CROSS-SECTION OF A LANDFILL

SOLIDIFICATION (continued)

- Advantages
  - Additives and reagents available and relatively inexpensive
  - Leaching or mobility of contaminants greatly reduced
  - Soils contaminated with several types of compounds may be treated in one step

- Disadvantages
  - Volume of waste may increase significantly
  - Not applicable on soils contaminated solely with volatile organics
  - Does not destroy contaminants

PART IV.
FIELD SAMPLING AND INVESTIGATION TECHNIQUES

WHAT WE WILL LEARN IN THIS SECTION...

I. INTRODUCTION TO FIELD INVESTIGATIONS

II. FIELD SURVEY INSTRUMENTS FOR AIR MONITORING AND SAFETY PLANNING

III. SURFACE WATER, SEDIMENT AND GROUND WATER SAMPLING

IV. SOIL SAMPLING

V. TEMPORARY MONITORING WELL INSTALLATION

VI. WATER SAMPLING

INTRODUCTION TO FIELD INVESTIGATIONS

- WORK PLANS
- FIELD QUALITY ASSURANCE AND QUALITY CONTROL
- EQUIPMENT SELECTION

137

138

PREPARATION OF A FIELD INVESTIGATION WORK PLAN

Slide No. 2

WORK PLAN :

Objectives

The objectives of the field sampling investigation should be clearly defined. A rational, site based procedure for meeting the objectives must be presented.

WORK PLAN :

Site History

Site history should include :

- Any information obtained from interviews of facility personnel
- An accurate map of the area to be investigated
- Any analytical results from previous sampling investigations .
- Former and current site activities and waste disposal practices .

WORK PLANS :

Field Procedures

- The plan must state how samples will be collected .
- Soils - augering , drill rig, etc.
- Ground water - temporary monitoring wells , portable wells .
- The order in which the samples are to be collected

Slide No. 5

142

WORK PLAN :

- Selecting Sample Locations
- Based on information provided prior to arriving on site .
- Observations made during the investigation.

WORK PLANS :

Selecting the appropriate sampling equipment and cleaning procedures of the equipment .

- Collecting samples for trace analysis (ug /l , ng/l , ug/kg) may require extreme cleaning requirements . Soap and water wash , potable water rinse , solvent rinse and deionized water rinse.
- Collecting samples for mg/l , mg/kg , or % concentrations of a contamination - less requirements - soap and water wash and portable water rinse .

- **Select equipment that will not add to the contaminants of concern. For example do not use sampling equipment made out of plastic for trace organic contamination determination.**

DEFIFINITIONS: SAMPLE TYPES

- Grab sample - A individual sample collected from a single source
- Composite sample comprised of individual aliquot.
- Split sample - Two or more samples collected from the same source material at approximately the same time .

146

DEFINITIONS : CONTINUED

- Areal Composite Sample - Individual grab samples collected on an areal basis .
- Vertical composite sample - Individual grab samples collected on a vertical basis .
- Surface Soil Sample - Collected from an interval at the surface to 30.5 cm .
- Sub-surface Soil Sample - Collected at an interval below 30.5 cm. of the surface .

DEFINITIONS: CONTROL VS BACKGROUND

- Control sample - Collected up stream or upgradient from a source to isolate the effects of the source from the medium being sampled.
- Background sample - Collected from an area similar to the one being studied which is known to be free of pollutants and contaminants of concern .

147

CHAIN- OF - CUSTODY

Slide No. 12

REPRESENTATIVENESS

- Degree to which sample data accurately and precisely represents a characteristic of a population , parameter variations at sampling point , or an environmental condition .

ACCURACY

- Reflect the bias in a measurement system.
- Difficult to measure for entire study.
- Sources of error: Sampling procedure, field contamination, preservation, handling, sample matrix, sample preparation and analysis.

PRECISION

- Measurement of reproducibility
- Precision is unique to each site
- Determined by collecting duplicates or splits

151

SAMPLE VARIABILITY

- Sample heading variability
- Temporal variability
- Spatial variability

SAMPLE HANDLING VARIABILITY

- Variability introduced by the sampling and /or handling procedures.
- Causes Include Incorrect Sampling Procedures and Cross Contamination.

TEMPORAL VARIABILITY

- **Contaminant concentrations which are dependent on time related variables such as time of day, season .**

SPATIAL VARIABILITY

- Contaminants which vary as function of location . The level of spatial variability is site and contaminant specific . When spatial variability is high , a single sample is likely to be representative of the average contaminant concentration .

SAMPLING EQUIPMENT SELECTION

- Materials of construction (plastic, stainless steel , glass)
- Compatability with matrix (design)
- Matrix affects of equipment (pH adsorption)
- Ease of use (size / power / complexity)
- Decontamination

SELECTION OF SAMPLE CONTAINERS

- **Select containers that have been properly cleaned and are made of material that will not result in sample contamination**

22

SAMPLE COLLECTION

- First collect control and background samples
- Begin sampling in the area of least contamination
- Collect samples expected to contain high concentrations of contaminants last .

SAMPLE PRESERVATION

- Use preservative required by the laboratory

FIELD RECORDS

- Use a bound notebook
- Use non-erasable , water-proof ink
- Field records should be direct and concise
- Correct errors by crossing a single line through the error , initial and date.

FIELD RECORD CONTENTS

- Documentation of sample collection
- Description of sampling activity
- Methodology used to collect the sample
- Equipment calibration information
- Investigation personnel involved in the study.

162

FIELD RECORD CONTENTS (CONTINUED)

- Auxiliary information
- Site sketches
- Field observations
- Facility or site contacts

SAMPLE IDENTIFICATION

- Sample Station ID
- Station location
- Date(s), Time(s)
- Type of sample
- How the sample vas preserved
- Required analyses
- Signature of sampling personnel

SAMPLE CUSTODY

A Sample is Under Custody If

- It is in your possession
- It is in your view
- Locked to prevent tampering
- Placed in a secure area

FIELD SURVEY INSTRUMENTS FOR AIR MONITORING AND SAFETY PLANNING

165

166

DESIRABLE CHARACTERISTICS OF FIELD AIR SURVEY INSTRUMENTS

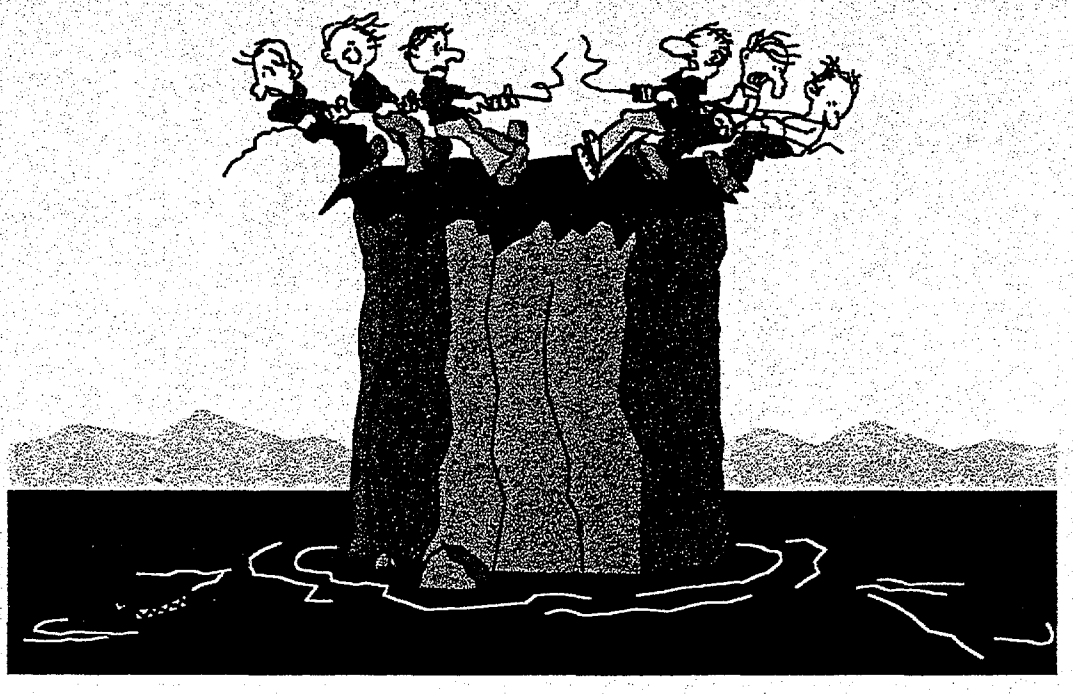
- Portability, reliability, sensitivity, selectivity, inherent safety, direct reading with short response time

CORRECT USE OF FIELD AIR SURVEY EQUIPMENT CAN

- Provide a warning that unsafe conditions exist on site
- Help the investigator determine personal protection needs
- Help the investigator determine where to collect samples

NOTE: A negative response on a field survey instrument does not insure a safe environment!

SURFACE WATER SAMPLING



SLIDE NO. 1

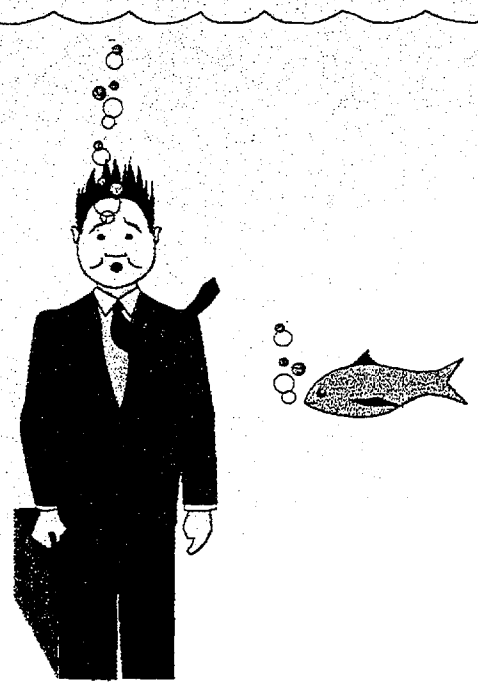
168

PRIORITIES OF SAMPLING

- GROUND WATER, SURFACE WATER STREAMS AND LEACHATE
- PONDS, LAGOONS, PITS, PILES, ETC.
- WASTE STREAMS FROM PROCESSES
- ON-SITE SPILLS AROUND DRUMS, TANKS, ETC.
- OPEN AND SAMPLE DRUMS AND CONTAINERS -- LAST

TYPES OF SURFACE WATER

- SURFACE STREAMS (RIVERS, CREEKS, DRAINAGE DITCHES)
- LAKES AND PONDS
- SPRINGS, SEEPS AND LEACHATE

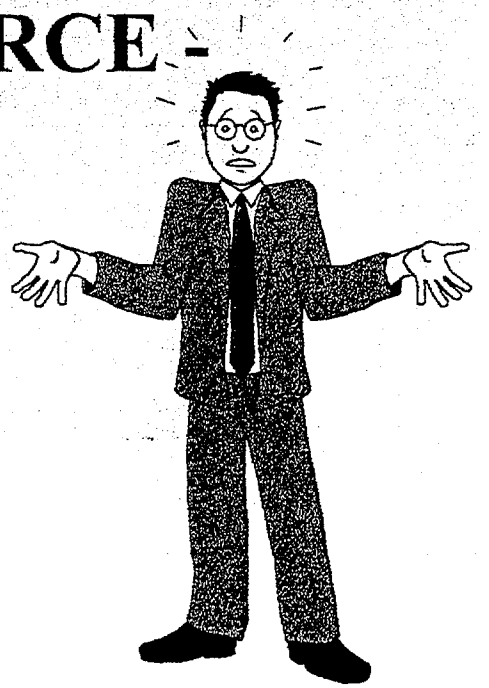


170

SLIDE NO. 3

WHERE TO SAMPLE

- UPSTREAM - <u>CONTROL</u>
- DOWNSTREAM - <u>MIXED</u>
- NEAR POINT SOURCE - <u>BIASED</u>



171

MIXING OF WASTES

THE FOLLOWING ARE PHYSICAL CHARACTERISTICS WHICH CAN INFLUENCE STREAM MIXING

- TEMPERATURE
- TURBIDITY
- DEPTH
- SLOPE
- TURBULENCE
- CHANGE IN DIRECTION
- NATURE OF BOTTOM

172

TYPES OF MIXING
VERTICAL

- FIRST MIXING TO OCCUR
- MIXING IS FROM TOP TO BOTTOM
- LAMINAR FLOW WILL INHIBIT VERTICAL MIXING
- DENSITY STRATIFICATION CAN PREVENT MIXING
- MIXING OCCURS WITHIN A TENTH TO LESS THAN 2 KILOMETERS (175 TO 1800 METERS)

173

TYPES OF MIXING
LONGITUDINAL

- DOWNSTREAM MIXING
- LEVELS OUT *HIGHS AND LOWS* IN WASTE CONCENTRATION
- CROSS SECTIONAL VARIATION AND CHANGE IN FLOW DIRECTION ARE MAJOR CAUSES OF LONGITUDINAL MIXING

174

TYPES OF MIXING
LATERAL

- OCCURS WELL AFTER VERTICAL MIXING
- MOST EFFECTIVE IN DEEPER WATER WITH SLOW VELOCITY
- CHANGE IN DIRECTION ENHANCES MIXING
- MIXING OCCURS OVER DISTANCES OF KILOMETERS

175

SAMPLING IN STREAMS

- FACE UPSTREAM, SAMPLE DIRECTLY INTO CONTAINER
- COLLECT FROM SURFACE TO MIDSTREAM DEPTH
- COLLECT VOLATILE ORGANIC SAMPLE AT SURFACE
- DO NOT ROLL (UNDULY DISTURB) THE SEDIMENT
- AVOID FLOATING MATERIAL
- WEAR GLOVES

SAMPLING FROM STREAM BANKS

- FACE UPSTREAM, SAMPLE DIRECTLY INTO CONTAINER
- SAMPLE FROM THE OUTSIDE OF BENDS
- SAMPLE AS IF IN THE STREAM
- IF TOO SHALLOW, USE A DIPPING CONTAINER
- SAMPLE AT MID DEPTH OR AT 1.5 METERS
- COLLECT VOLATILE ORGANIC SAMPLE AT SURFACE
- WEAR GLOVES

177

SAMPLING FROM PLATFORMS

- Stay Away From Piers and Pilings
- Sample from Downstream Side of Platforms
- Uncertainty of Lateral Mixing May Require Cross-Sectional Sampling
- Wear Gloves

EXAMPLES OF WATER SAMPLES

SEDIMENT SAMPLING

181

FACTORS CONTROLLING SEDIMENTATION

- Look for Sinks, Not Gravel or Sand
- Turbulence Controls Scouring and Sedimentation
- Shallow, Turbulent Stream Can Act as a Horizontal Trickling Filter (Biological Growths)
- Deep Water Offers Less Opportunity for Contact of Solids with Bottom Slime
- Pooled Areas on the Inside of Flow Patterns Offer the Best Location For Sedimentation

SEDIMENT SAMPLING IN STREAMS

- Face Upstream
- Do Not Roll (Unduly Disturb) Bottom
- Sample with Spoon, Push Tube, etc.
- Collect Several Aliquots and Composite
- Wear Gloves

WHERE TO LOCATE LEACHATE ?

- Toe of Landfills
- Interface with Stream
- Stains, Green or wet Areas

SEDIMENT OR SOIL WITH LEACHATE

- Usually Discolored
- Usually Damp or Wet
- High Contaminant Level

LEACHATE - HOW TO SAMPLE

- Sample Directly into Container or Dip
- Dig a Reservoir and Dip Sample
- Install a Weir, Dip Sample
- Install a Shallow Well

GROUND WATER SAMPLING

- Permanent Monitoring Wells
- Temporary Monitoring Wells (for tomorrow)
- Process and Potable Wells

PERMANENT MONITORING WELLS

Slide No. 63

DETERMINE THE ORDER OF SAMPLING

- Progress From Least contaminated to Most Contaminated Wells
- Otherwise Risk Cross-Contamination

NOTE CONSTRUCTION AND CONDITION OF WELLS

- Check Condition of Pad (Intact with no Cracks)
- Well should Be Secured With Locked Protective Casing
- Protective Casing Should Have "Weep" Hole

MONITOR BREATHING ZONE AT WELL

- Monitor Breathing Zone with Appropriate Instrumentation for the Site
- Stop Activity if Action Levels are Exceeded

PACK PLASTIC SHEETING AROUND WELL

- Provides Protection Against Cross Contamination
- Avoid Stepping on Plastic to Maintain this Protection

Slide No. 70

MEASURE THE STATIC WATER LEVEL AND TOTAL DEPTH OF WELL

- All Measurements Are From Top of Casing
- All Measurements to Nearest 0.01 foot (or couple of mm)
- Instrument Should be Decontaminated Between Wells and Handled With Gloved Hands

FIELD CLEANING PROCEDURES FOR SOUNDERS, TAPES AND PUMPS

- Wash with laboratory detergent and tap water
- Rinse with tap water
- Rinse with deionized water
- Protect between wells in plastic or foil

183

CALCULATE THREE WATER COLUMN VOLUMES (WCVs)

- Three (3) water column volumes is minimum to purge the well

CALIBRATE ALL INSTRUMENTATION

- pH meter calibrated using two buffers bracketing anticipated pH conditions
- Check conductivity against standard
- Re-calibrate each time turned back on.

PURGING

What is Purging ?

- Purging is the Process of Removal of stagnant Water from inside the well casing and screen and the adjacent gravel pack. This forces replacement with fresh formation Water

EQUIPMENT USED FOR PURGING

- A variety of Devices Can be used Including Bailers, Peristaltic Pumps, Bladder Pumps, Centrifugal Pumps and Electric Submersible Pumps
- Selection is a Function of Depth and Amount of Water to be Removed

EQUIPMENT PLACEMENT DURING PURGING

- Purging is Conducted From Top of Water Column
- If Level Drops During Purging, Chase it
- If Purged to Dryness, Well is Evacuated

PURGING - HOW MUCH ??

- 3-5 WCVs
- Minimum 3 WCVs and Stable pH, Conductivity, Temperature and Turbidity
- After 5 WCVs if Parameters Not Stable
- Or After Evacuation to Dryness

PURGING - DECONTAMINATION

- All Equipment Used For Purging Must Be Cleaned Properly Before Use in Another Well

SAMPLING EQUIPMENT - PERISTALTIC PUMPS

Best Used With Vacuum Jug / Transfer Cap Assembly

- Samples For Volatiles Must be Collected Some Other Way
- Limited To Where Operating Head is Within the Limit of Suction (up to 20 meters)
- Pump Rate About One Liter/Minute is Good
- Variable Speed Pump is Better

102

BLADED PUMPS

- Practical only in dedicated situations (too dificult to clean between wells)
- Only Pump We Accept For All Parameters

OTHER PUMPS FOR SAMPLING

- **Not recommended because of problems caused by construction materials (brass, galvanized steel, Rubber, Plastics) or operating characteristics (Turbine aeration, vacuum, etc.)**

203

BAILERS -GENERAL

- Teflon or stainless steel construction
- Closed-Top construction with leader
- Nylon haul rope, discarded after use
- Secure to person or well
- Immerse gently when sampling

BAILERS - ADVANTAGES AND DISADVANTAGES

- Simple manual device
- Can be used in wells of most diameters and depths
- May aerate the sample and cause turbidity

206

SAMPLING- GENERAL CONSIDERATIONS

- Change gloves as needed
- Put plastic sheeting down
- Collect sample for Volatiles first
- No bubbles
- Preserve all samples -quickly
- Record everything in field logbook

SAMPLING WATER SUPPLY WELLS

- Industrial process wells
- Municipal portable wells
- Private, residential portable wells

Slide No. 110

121

WATER SUPPLY WELLS

- Sample As Close to the Pump as Possible
- Allow for Storage in tanks, if Present
- Take care in Collection of Samples for Volatiles
- Remove Hoses From Spigots, if Present

SOIL SAMPLING

208

BASIC CONSIDERATIONS OF SOIL SAMPLING

- Biased and Systematic Samples
- Surface and Subsurface Samples
- Grab and composite samples

012

BIASED SAMPLES

- Selected based on high probability that analytical results will be prejudiced high or low.
- Background sample are biased samples which are anticipated to be free of contamination of concern.
- Soil samples collected at stained or stressed areas are biased samples - anticipated to be contaminated.

GRID-BASED SAMPLING

- Systematic approach to sampling large sites
- No single grab size is appropriate for all sites (50 m, 100 m, 200 m, etc.)
- Can integrate different size grids at a site.

212

SURFACE SOIL SAMPLES (0 TO 30.5 CM)

- May comprise majority of soil samples collected at a site.
- Collected to define presence and surface distribution of contaminants.

SUBSURFACE SOIL SAMPLES (30.5 CM TO ?)

- May be limited in scope, (depth and number of locations during an investigation) because of difficulty
- Used to define vertical extent of contamination

214

GRAB AND COMPOSITE SAMPLES

GRAB SAMPLES

- Collected to identify and quantify compounds at a specific location (surface) or interval (subsurface)
- Limited in extent, comprised of minimum amount of soil for sample volume.

216

COMPOSITE SAMPLES

- Areal composites comprised of subsamples from different surface locations
- Vertical composites comprised of subsamples from different vertical intervals
- Number of subsamples should range from 2 to 9.
- Sample should represent an average of all the subsamples
- Difficult to collect good composite samples of hard, clayey soils.

SAMPLING METHODOLOGY - EQUIPMENT

- Manual (hand operated) collection techniques and equipment for surface and shallow subsurface soils.
- Powered equipment for deep subsurface soils and resistant shallower soils

217

212

MANUAL TECHNIQUES - SURFACE SOILS (0 - 30.5 CM)

- Remove vegetation and root material
- Use spoons, shovels, hand-augers, push tubes, post-hole diggers.

MANUAL TECHNIQUES - SHALLOW SUBSURFACE SOIL (GREATER THAN 30.5 CM)

- Hand-auger most common method
- Depths greater than 3 meters is difficult to sample with hand-augers unless assisted by powered equipment

POWERED SOIL SAMPLING EQUIPMENT

- Types of equipment often used: power augers, drill rig and back hoes

TEMPORARY MONITORING WELLS

PURPOSE

- Evaluate Ground Water Conditions
- Establish Approximate Extent of Contaminant Plume
- Use Data to Design Permanent Monitoring Well System

222

GOAL

- **Obtain Representative samples of Good Quality**

CHARACTERISTICS OF TEMPORARY WELLS

- Installed for short time
- Removed After Sampling
- No Bentonite Seal, Annular Seal or Surface protection

CONSTRUCTION - TRADITIONAL

- Standard Well Screen and Riser Pipe
- Directly in Borehole
- Usually Successful

CONSTRUCTION ALTERNATIVES

- Use of Sand Filter Pack

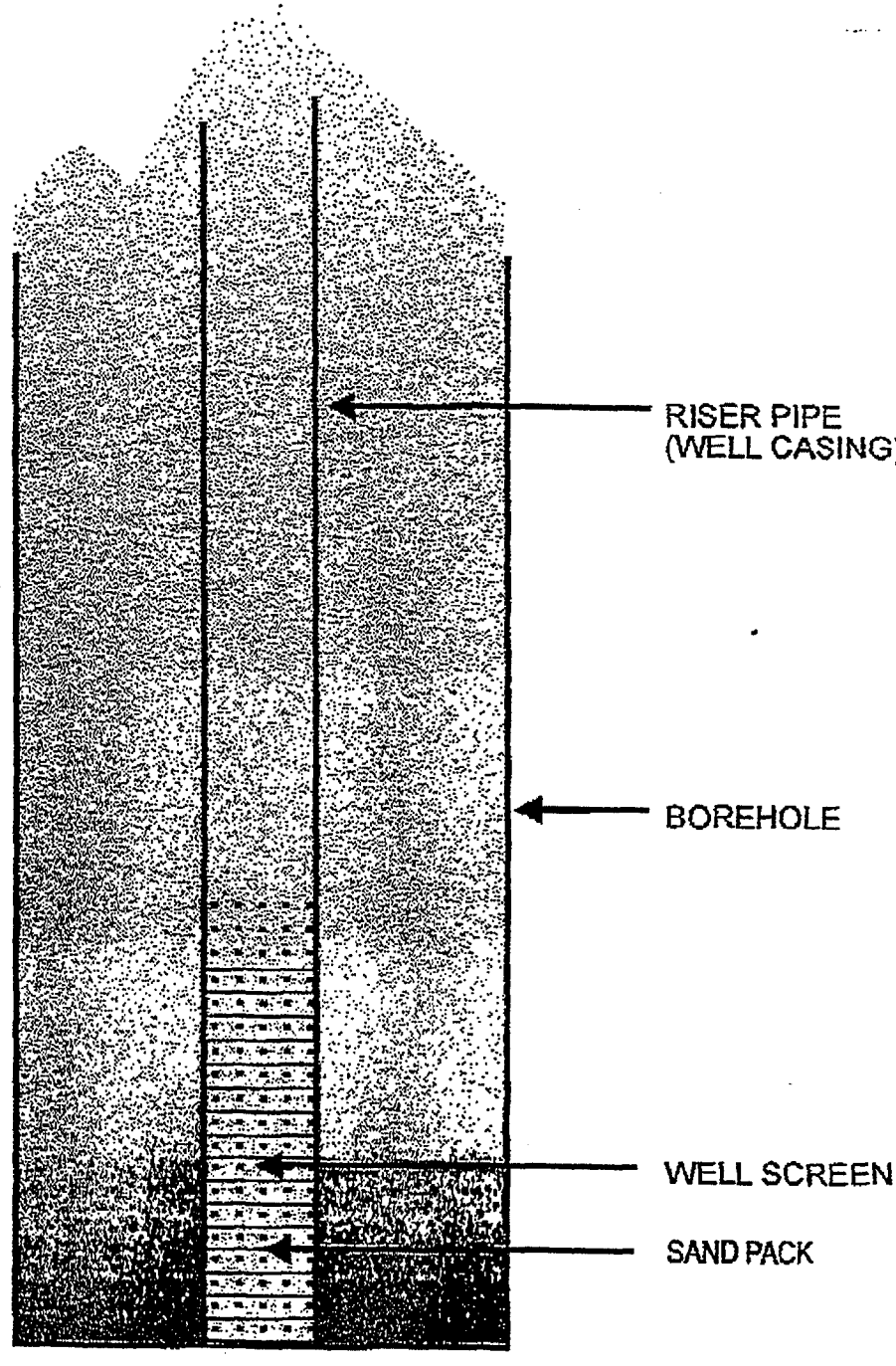
INNER SAND PACK

TRADITIONAL SAND PACK

DOUBLE SAND PACK

WELL - IN -A - WELL

TEMPORARY WELL INSTALLATION
FIGURE 1



INNER
SAND PACK

DG1194

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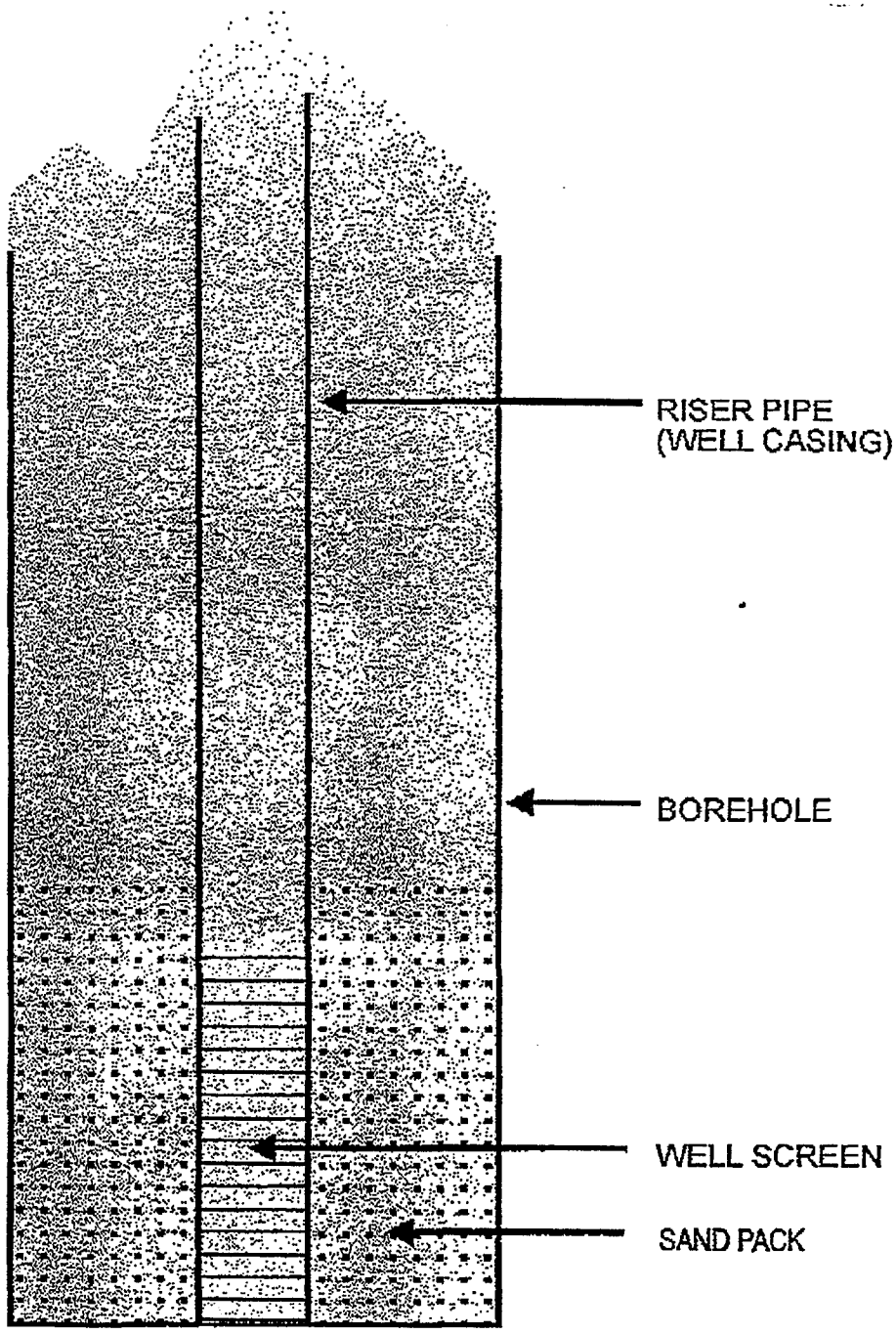
TEMPORARY WELL INSTALLATION
FIGURE 2



TRADITIONAL
SAND PACK

DG1194

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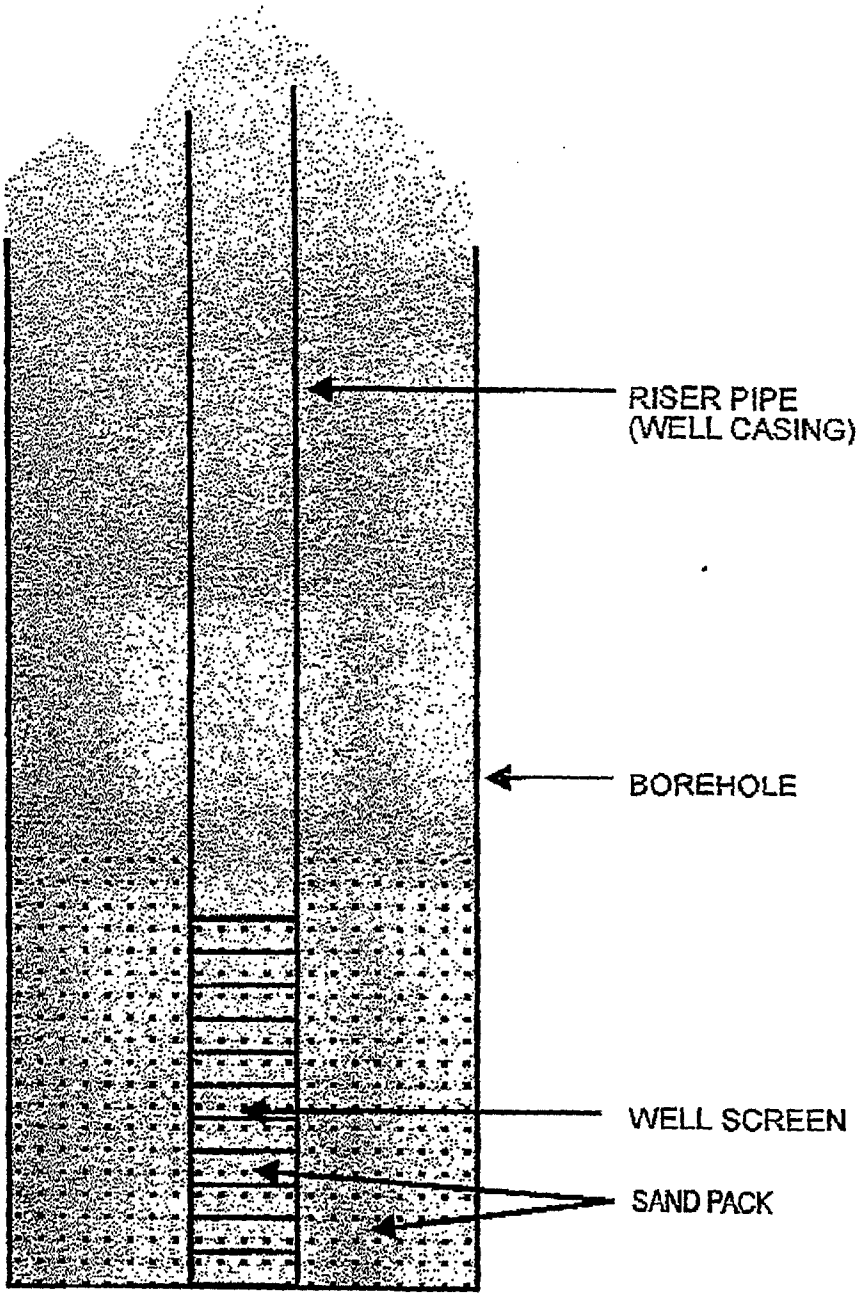
TEMPORARY WELL INSTALLATION
FIGURE 3



DOUBLE SAND PACK

DG1194

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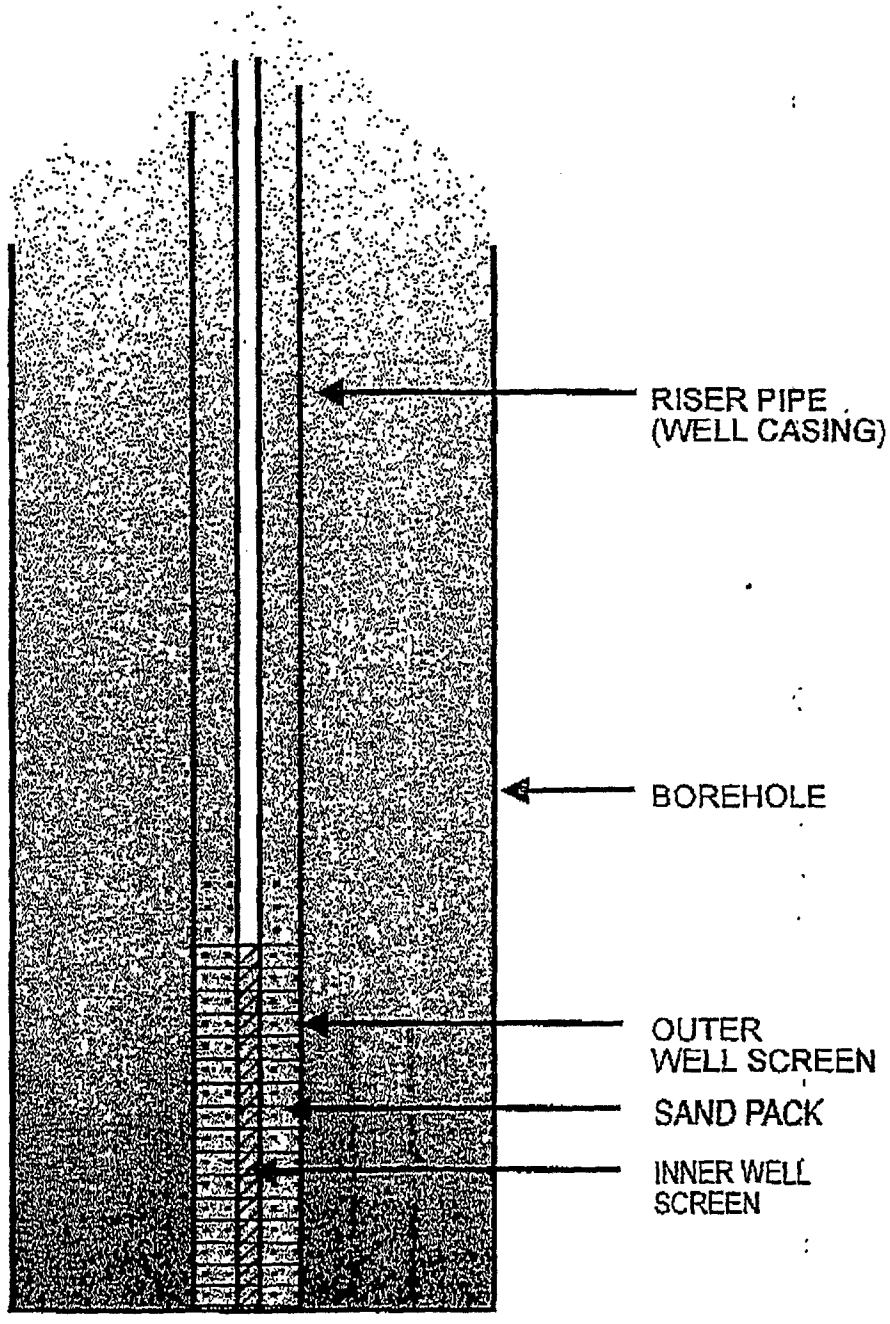
TEMPORARY WELL INSTALLATION
FIGURE 4



WELL-IN-A-WELL
CONSTRUCTION

EPA

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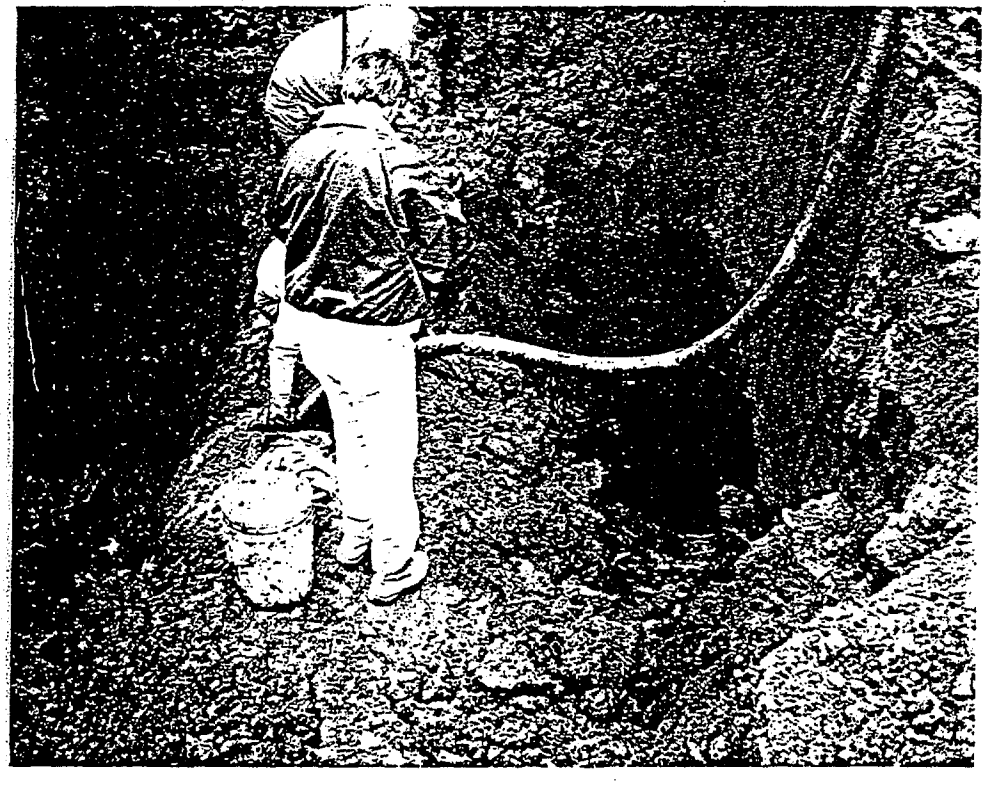
WASTE SAMPLING



235

STUDY PLANNING

- Gather site information.
- Visit site prior to investigation (if possible)
- Develop a site safety plan
- Prepare a study plan
- Prepare an equipment list
- Determine personnel needs
- Arrange for laboratory analyses

SITE RECONNAISSANCE GOALS

- Determine the level of personnel protection
- Determine ambient conditions at the site via air monitoring.
- Select potential sampling locations
- Locate decontamination and support areas
- Prepare a site map

SAMPLE HANDLING CONSIDERATIONS FOR WASTE SAMPLES

- Waste samples are not preserved
- Waste samples should not be collected from environmental samples during collection and transport to the lab.
- A minimum volume of sample should be collected.

DESIGN CRITERIA FOR WASTE SAMPLING EQUIPMENT

- The equipment should be easy to clean.
- Must yield a representative sample
- Must be constructed of materials that will not react with or alter the sample in any way.
- It must be easy to use

CONTAINERIZED WASTE

- Drums, tanks, vats, tanker trucks, railroad tank cars, etc.

NON - CONTAINERIZED WASTE

- Ponds, lagoons, pits, sumps, basins, sewers, waste piles