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16. Abstract <p>In this study, an extensive literature review was done to collect information on case studies on site remediation, environmental site characterization, remedial technologies, regulations and specifications. A total of sixty cases has been documented and analyzed. Popular treatment methods for hazardous wastes and petroleum substances have been identified with cost.</p> <p>A well integrated Hazardous Waste Management Plan (HWMP) has been developed. Four cases representing various stages of construction were identified and flow charts with sequence of actions for contaminated site investigation and remediation have been developed. Methods of environmental site characterization, sampling and waste analyses have been summarized. Federal and state regulations and other specifications related to contaminated sites and underground storage tanks have been discussed. Training requirements for workers have been summarized. This handbook, with a chapter on "Quick Reference," will be a guidance document to TxDOT engineers on procedures for identifying/handling hazardous wastes/petroleum substances at construction/acquisition sites.</p>			
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**Explore State-of-the-Art Techniques in
Identification, Handling, Neutralizing, and
Disposing of Hazardous Materials Encountered
on Construction Projects and Analyze the
Effectiveness of these Techniques Versus their Cost**

Project No. 01719

Final Report

Texas State Department of Transportation

by

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There was no invention or discovery conceived or first actually reduced to practice in the course of or under this contract, including any art, method, process, machine, manufacture, design or composition of matter, or any new and useful improvement thereof, or any variety of plant which is or may be patentable under the patent laws of the United States of America or any foreign country.

PREFACE

This research project was undertaken with the primary objective of developing a Reference Document for handling contamination at acquisition/construction sites. The primary purpose of the Reference Document is to integrate a broad field into a single book that deals with all phases of this important subject. This was accomplished by first doing a literature review to collect information on case studies on remediation, methods of site and waste characterization, environmental site assessment, treatment technologies, regulations and specifications. A total of sixty case histories on remediating contaminated soils and groundwater have been documented and analyzed. Popular remedial methods for hazardous wastes and petroleum substances contaminated soil and groundwater have been identified with cost.

Several state DOTs have developed guidelines for handling contamination on construction sites. While few DOTs have their documents on the internet others have handbooks. Most DOTs have training requirements as recommended by OSHA for workers on hazardous waste contaminated sites. The Hazardous Waste Management Plan with five PHASES has been developed for handling contamination at construction sites. Information collected from various sources (EPA, FHWA, OSHA, TNRCC, State DOTs, ASCE, ASFE and ASTM) have been effectively combined in developing the HWMP. Four cases for handling hazardous waste or petroleum substances representing various stages of construction were identified and flow charts with sequences of actions for contaminated site investigation and remediation have been developed. The four cases are as follows: CASE 1- During Project Development ; CASE 2 - Before Site Acquisition ; CASE 3 - During Construction; and CASE 4 - During Maintenance. Methods of site characterization, soil and groundwater sampling and waste analyses have been summarized for various field conditions and types of contaminants. Federal and state regulations and other specifications related to contaminated sites and Underground storage tanks have been discussed.

This Reference Document with a chapter on "Quick Reference" will be a guidance document to TxDOT engineers on procedures for identifying, investigating and characterizing a site that may be, or is contaminated with hazardous materials or petroleum substances.

ABSTRACT

The discovery of hazardous substances or petroleum products can affect an entire highway project. However, in many instances, these surprises are avoidable through a well planned environmental site investigation and a hazardous waste management plan (HWMP). Remediation of a contaminated site will involve procedures which are acceptable to federal and state regulatory agencies. Hence, several organizations and agencies have formulated technical and procedural approaches regarding the performance of environmental site assessments. Several state DOTs have also developed their own procedures for handling contamination at construction sites.

In this study, an extensive literature review was done to collect information on case studies on remediation, methods of site and waste characterization, environmental site assessment, treatment and containment technologies, regulations and specifications. A total of sixty case histories on remediating contaminated soils and groundwater have been documented and analyzed. Popular treatment methods for hazardous waste and petroleum substances have been identified with cost. The information collected from literature review was synthesized into a well integrated Hazardous Waste Management Plan (HWMP) to address contamination at various stages of construction and a simplified Reference Document (Handbook) for TxDOT designers and project engineers was developed.

The Hazardous Waste Management Plan with five PHASES has been developed for handling contamination in construction sites. Information collected from various sources (EPA, FHWA, OSHA, TNRCC, State DOTs, ASCE, ASFE and ASTM) have been effectively combined in developing the HWMP. Four cases for handling hazardous waste or petroleum substances representing various stages of construction were identified and flow charts with sequence of actions for contaminated site investigation and remediation have been developed. The four cases are as follows: CASE 1- During Project Development ; CASE 2 - For Acquisition ; CASE 3 - During Construction; and CASE 4 - During Maintenance. Methods of environmental site characterization, soil and groundwater sampling and waste analyses have been summarized for various field conditions and types of contaminants. Federal and state regulations and other specifications related to contaminated sites and underground storage tanks have been discussed. Training requirement for workers and guidelines from other state DOTs have been summarized.

This Reference Document with a chapter on "Quick Reference" will be a guidance document to TxDOT engineers on procedures for identifying, investigating and characterizing a site that may be or is contaminated with hazardous materials or petroleum substances.

SUMMARY

Hazardous waste management as a field has grown so rapidly that technology transfer has had difficulty keeping pace with ambitious regulatory programs since the amendments to CERCLA in 1986. The problem of handling hazardous waste or petroleum substance at construction/acquisition sites is very complex. It can present danger to the works and public health; increase liability to TxDOT and increase the cost to the project. Remediation is an environmental challenge because at least one environmental medium has been contaminated by human activities and must be corrected. It is a technical challenge because every site is unique, and every site has many uncertainties; the technology is doubly challenged because remediation (treatment, containment, landfilling) must be completed economically.

In this study, an extensive literature review was done to collect information on case studies on remediation, methods of site and waste characterization, environmental site assessment, treatment technologies, regulations and specifications. A total of sixty case histories on remediating contaminated soils and groundwater have been documented and analyzed. Nearly 70 treatment methods have been grouped into biological, chemical, physical and thermal methods. Popular treatment methods for hazardous wastes and petroleum substances have been identified with cost.

The Hazardous Waste Management Plan with five PHASES has been developed for handling contamination at acquisition/construction sites. Information collected from various sources (EPA, FHWA, OSHA, TNRCC, State DOTs, ASCE, ASFE and ASTM) have been effectively combined in developing the HWMP. Four cases for handling hazardous waste or petroleum substances representing various stages of construction were identified and flow charts with sequence of actions for contaminated site investigation and remediation have been developed. The four cases are as follows: CASE 1- During Project Development ; CASE 2 - Before Site Acquisition ; CASE 3 - During Construction; and CASE 4 - During Maintenance. Methods of site characterization, soil and groundwater sampling and waste analyses have been summarized for various field conditions and types of contaminants. Federal and state regulations and other specifications related to contaminated sites and underground storage tanks have been discussed. Training requirement for workers and guidelines from other state DOTs have been summarized. Based on the information collected from 11 state DOTs following can be concluded: (1) Over 50% of the cases, State Regulatory Agency (SRA) were responsible for the clean-up of contamination. (2) Over 50% of the DOTs have memorandum of understanding (MOU) with the SRA. (3) Only two of the states have a formal employee training program outlined in their

document. (4) Over 70 percent of the states have a section on Underground Storage Tanks (USTs). (5) Only two states have information on asbestos.

This Reference Document will be a guidance document to TxDOT engineers for handling potential contamination at acquisition/construction sites.

IMPLEMENTATION STATEMENT

This Reference Document with a chapter on "Quick Reference" will be a guidance document to TxDOT engineers on procedures for identifying, investigating and characterizing a site that may be or is contaminated with hazardous materials or petroleum substances. Training requirement for workers and guidelines from other state DOTs have been summarized.

The following factors should be considered in the implementation of the Reference Document. (1) Developing a Memorandum of Understanding (MOU) with TNRCC to accelerate the corrective action plan (CAP) approval process. (2) Developing a training program for workers according to OSHA requirements (3) Placing this Reference Document on the internet (World Wide Web) so that information can be rapidly accessed by TxDOT engineers. (4) Updating regularly federal and state regulations and other specifications.

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Chapter 1

INTRODUCTION

The discovery of hazardous substances or petroleum products can affect an entire highway project - from initial planning straight through construction and maintenance. When soil and/or groundwater contamination is found at a construction site, completing the project on time and within the budget is always a challenge. The most difficult situation is when contamination is unexpectedly discovered during construction, which almost always results in work stoppages and cost overruns. However, in many instances, these surprises are avoidable and the delay and cost controlled through well planned environmental site investigation and a hazardous waste management plan (HWMP) [4 - 7].

Remediation of a contaminated site should involve procedures which are acceptable to federal and state regulatory agencies. Hence, several organizations and agencies, including the American Society Testing for Materials (ASTM), the Association of Ground Water Scientists and Engineers (AGES), American Society of Civil Engineers (ASCE), Association of Engineering Firms Practicing in Geosciences (ASFE) and the U.S. Environmental Protection Agency (EPA), have formulated technical and procedural approaches regarding the performance of environmental site assessments [1]. In general, most approaches have been directed toward a limited environmental assessment (commonly referred to as initial site assessment or file review and site walkover) to satisfy potential liability issues under the CERCLA legislation and to provide protection under the SARA provisions. The ASCE guidelines detail additional processes to conduct a subsurface investigation, and provides preliminary summaries on remedial investigation and remedial planning, design, and implementation [1]. Several State DOTs have also developed their own procedures for handling contamination in construction sites.

In this study, an extensive literature review was done to collect information on case studies, methods of site and waste characterization, environmental site assessment, treatment technologies, regulations and specifications. The information was then synthesized into a well integrated Hazardous Waste Management Plan to address contamination at various stages of construction and a simplified Reference Document (Handbook) for TxDOT designers and project engineers was developed.

Early detection before the construction begins is the best defense against added costs and delays, especially at sites where hazardous substances and petroleum products may be

present, this makes it possible to negotiate with regulators the best approach and integrate it into the planned or ongoing construction. The presence of contamination does not automatically require expensive treatment strategies. TNRCC may agree to a "no-further-action" determination, often with appropriate land-use restrictions, when it can be demonstrated that there is little or no risk to human health or the environment, this must be substantiated by a site risk assessment coupled with a thorough understanding of site geologic and hydrogeologic parameters [1-3]. Risk-assessment data may also be used to negotiate for less stringent cleanup targets. If remediation is called for, it may take place prior to, after or during construction, depending on site conditions and project objectives.

1.1 OBJECTIVES

The overall objective of this study is to develop a reference document to handle contamination in construction sites. The specific objectives are as follows:

- (1) To conduct extensive literature review in handling and disposing of waste and hazardous materials. Survey other State DOT's, FHWA, other governmental entities and private sector owners for additional information. Survey environmental consultants for new technologies for site characterization and treatment processes.
- (2) Evaluate the available information and identify equipment, materials and treatment procedures that appear to be effective strategies for handling the most commonly encountered hazardous or waste materials. The acceptability of these strategies will be verified with the TNRCC or other regulatory agencies. Approximate cost information with advantages and disadvantages of each treatment method will be developed. Special training requirements for worker safety will be identified.
- (3) Develop a ***Reference Document*** that contains the information gathered in this study. Step by step instructions will be presented to handle contamination at sites during design/construction/maintenance of a project. Explanations and example situations that will provide for a general understanding of the processes and equipment will be included in the ***Reference Document***.

This Reference Document will be a guidance document to TxDOT Engineers on procedures for identifying, investigating and characterizing a site that may be or is contaminated with hazardous materials.

1.2 ORGANIZATION

In Chapter 2, methods to solve contamination problems at various stages of construction have been presented with flow charts and a brief discussion on the HWMP. This chapter is structured as a quick reference for the TxDOT Engineer. In Chapter 3, various phases of hazardous waste management plan are discussed in more detail. Site characterization, sampling and waste analysis methods are included in Chapter 4. Chapter 5 includes the remedial methods used for groundwater and contaminated soils below and above groundwater table. Chapter 6 discusses the relevant federal and state regulations and specifications. Also federal and state regulations for Underground Storage Tanks are discussed separately. Other DOT experiences and information on their handbooks are summarized in Chapter 7. Each Chapter has a separate conclusions and references. Additional information relevant to this project is placed in the Appendix.

1.3 REFERENCES

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Chapter 2

Quick Reference For Contamiated Sites

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2. 1. INTRODUCTION

Investigations after preliminary site visit are site specific and time consuming since no two contaminated sites are alike. Hence a phased approach is effective because the scope of each phase builds on information gathered in the previous phase, allowing the engineers conducting the investigation to better identify and characterize potential contamination problems at the site [1, 4, 5 - 9]. Other advantages of the phased approach include: prevention of costly "over-investigation," better control of information flow (more information is not always better if there is no strategy or plan to use them), and completion of a more meaningful and directed investigation tailored to the property and the need of the TxDOT.

In this chapter a Hazardous Waste Management Plan (HWMP) has been developed and the sequence of actions for contaminated site investigation and remediation is discussed briefly with the details are in Chapter 3. Four cases representing various stages of construction are identified and flow charts have been developed with step by step procedure for each case.

Hazardous Waste Management Plan (HWMP)

Hazardous waste management plan should follow a systematic approach consisting of information and data gathering, planning, remedial action and post monitoring [1, 11]. A Flow chart with the overall hazardous waste management plan is given in Fig. 2.1. HWMP has five Phases as follows:

- Phase I : Preliminary Site Assessment (PSA)
- Phase II : Environmental Site Investigation (ESI)
- Phase III : (a) Remedial Investigation (RI), and Feasibility Studies (FS)
(b) Correction Action Plan (CAP)
(c) Permits and Contracting
- Phase IV : Site Clean Up
- Phase V : Post Site Monitoring

Each Phase is developed fully in Chapter 3.

Phase I: Preliminary Site Assessment (PSA)

This phase of work involves the nonintrusive data search, review of site-specific information, a site walkover, and interviews with people familiar with the site operations and with TNRCC/RRC/EPA personnel knowledgeable of the facility's compliance with

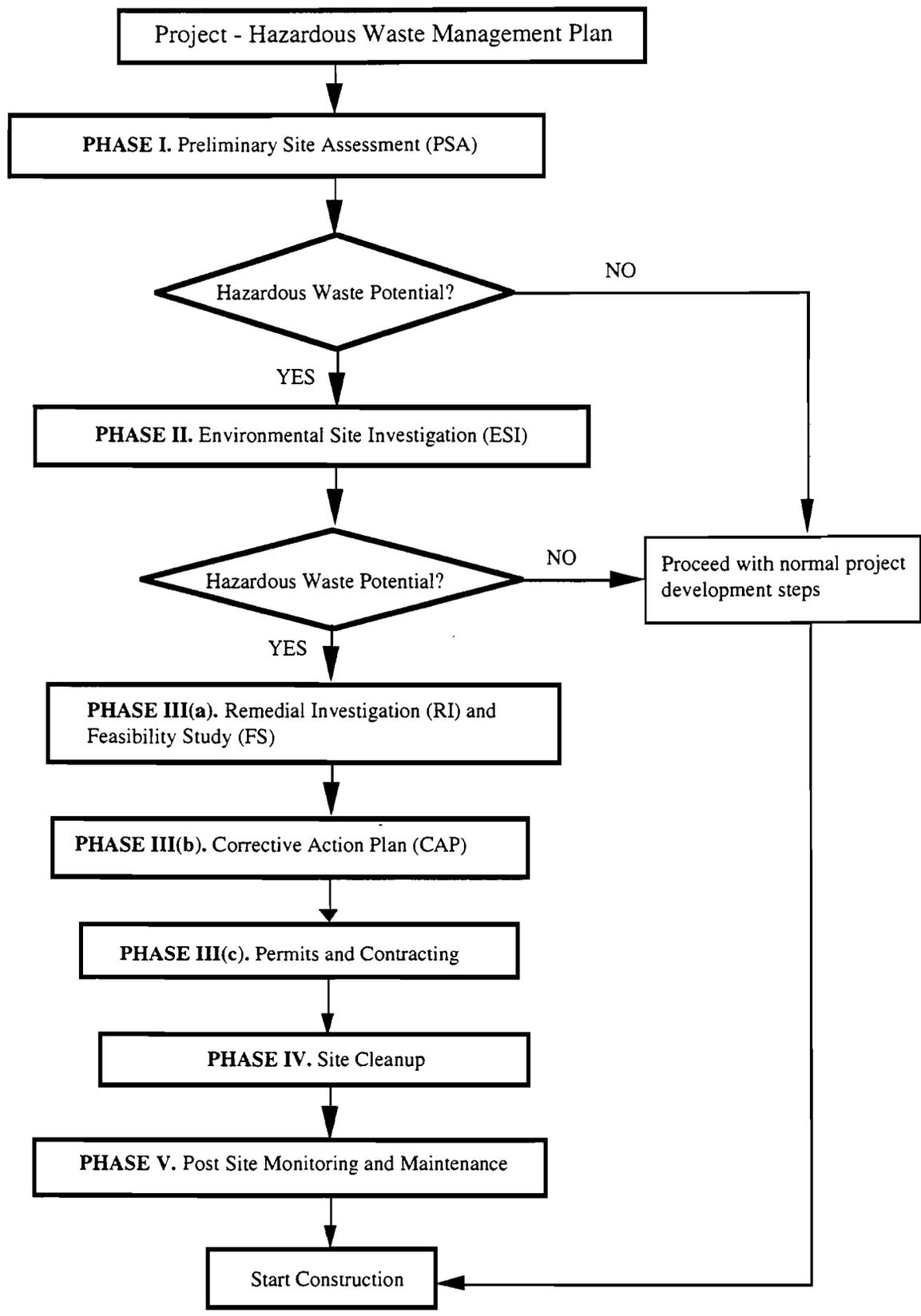


Figure 2.1. Flow Chart for Hazardous Waste Management Plan (HWMP)

environmental regulations. This phase may also include initial contact with the owner. The step by step procedure to be adopted in Preliminary Site Assessment is discussed in Chapter 3.

Phase II : Environmental Site Investigation (ESA)

Phase II work generally involves invasive or intrusive testing coupled with laboratory analysis. The media tested will depend on site specific conditions identified in Phase I. Media to be considered for testing include, but are not limited to, soil, groundwater, surface water, and substances at the property that require identification for purposes of proper management. Phase II also involves pre-planning for site investigation, collection and interpretation of data, and preparing the report.

Phase III (a): Remedial Investigation (RI) and Correction Action Plan (CAP)

Phase III (a) consists of the remedial investigation as defined by EPA and CERCLA guidelines. This phase is generally an extension of the Phase II tasks. This phase involves the collection of data defining the real extent of contamination, its mobility, and potential risk to human health and the environment. Information to be used in the latter remedial planning and design phase is generated during Phase III. It also involves remedial planning such as evaluating treatment alternatives based on their feasibility for implementation and development of design and other documents for approval. The different steps in this phase include evaluation of data, risk assessment, treatability studies, development of alternative remedial actions, screening and evaluation of these alternatives, cost effective analysis and preparation of remedial investigation report.

Phase III (b): Approval of Correction Action Plan (CAP)

Depending on the extent of the contamination problem, the CAP must be reviewed and approved by the TNRCC.

Phase IV : Remediation and Site Clean Up

Phase IV involves implementation of the corrective action plan. Phase IV also presents protocols for verifying the effectiveness of cleanup and developing a site closure

report. The report should include the site clean-up procedure, verification methods and preliminary plan for post monitoring.

Phase V: Post Site Monitoring

Once the site clean up has been completed the site should be monitored on a timely basis for a certain period of time to assess the effectiveness of the cleanup and compliance with the regulatory requirements.

SPECIAL CASES

The four most frequently encountered cases related to contamination in construction sites are considered in this section. The different cases identified are based when contamination is discovered in the construction site. The cases are as follows:

CASE 1: DURING PROJECT DEVELOPMENT

CASE 2: SITE ACQUISITION

CASE 3: DURING CONSTRUCTION

CASE 4: DURING MAINTENANCE

The HWMP is modified for each case.

2. 2. CASE 1: DURING PROJECT DEVELOPMENT

During highway project development or expansion, sites both within and outside TxDOT right-of-way are considered. Hence it is important to verify whether contamination will be a problem at these sites. A Flow Chart (Fig. 2.2) has been developed for this case by modifying Phase I of the HWMP. Two major steps have been identified for this case and are discussed below.

2. 2. 1. STEP 1 : Site Visit / Field Survey

The purpose of the site visit is to evaluate current land use and environmental conditions at the site. Also it is important to determine the potential for contamination in the site soil and groundwater due to current on-site and adjacent site uses.

Specific information/data to be collected during a site reconnaissance can be divided into two distinct categories. The first category is to characterize land uses of the site and the second is to characterize environmental conditions at the site.

(a) Land Use Characterization

It is important to note at least the presence of the following features at the site.

(1) What are the physical features and surface conditions?

(Information on parking lots, roads and trails, fences and gates, erosion, rock outcroppings, land filling, drainage, waterbodies and wetlands).

(2) What are the utilities on site?

(Power poles and transformers, water lines, sewer lines, outfalls, catch basins, septic systems and wells).

(3) Any buildings and other structures on site?

(Name and nature of business, age and size of structure, use of asbestos, type of insulation, lead paint, floor drains, sumps).

(b) Environmental Characterization

(1) Any evidence of contamination?

(Abandoned drums and barrels, discolored surface water, stained soil, vegetative distress, distinguishable odor).

(2) What are the waste management practices (mainly for industrial sites)?

CASE 1: During Project Development

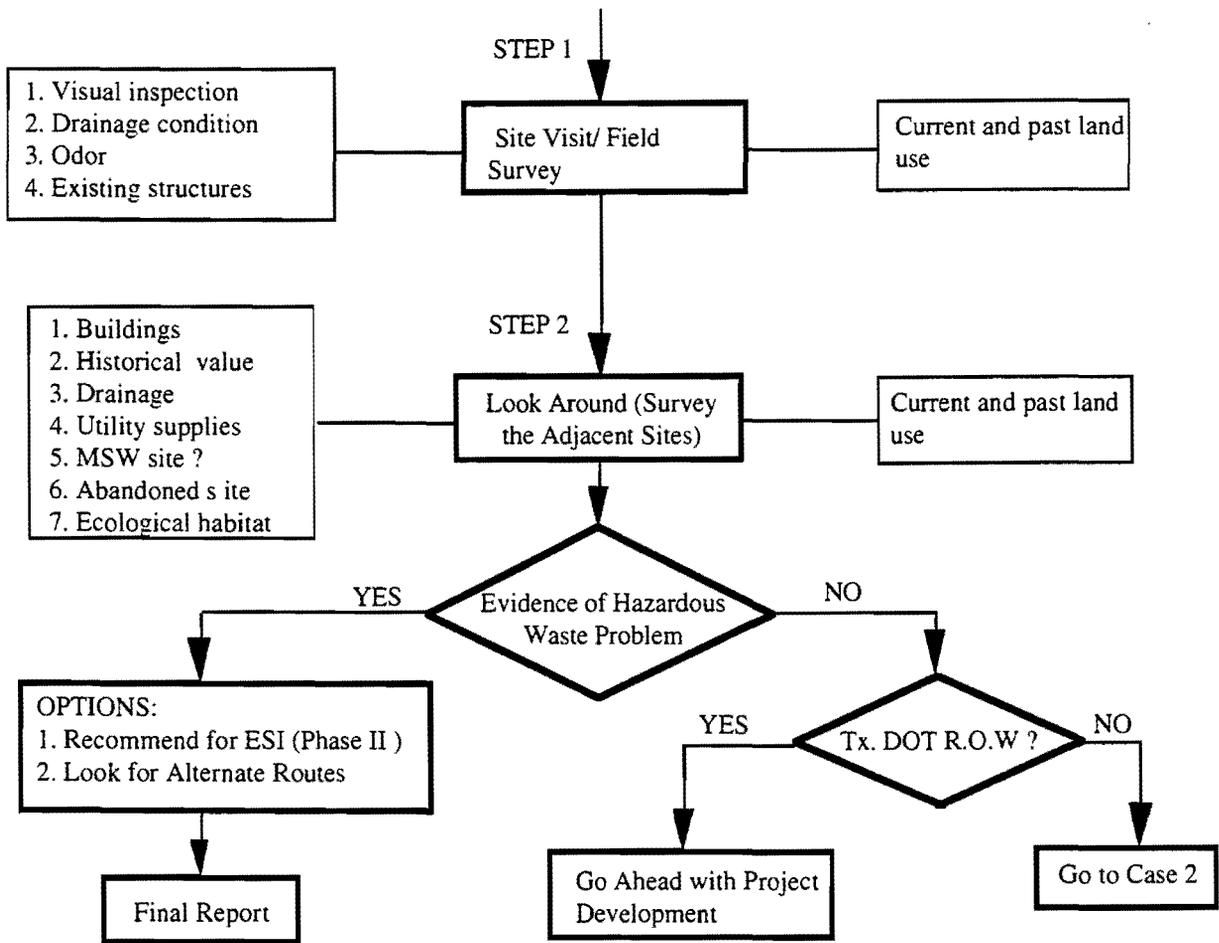


Figure 2.2. Flow Chart for Verifying Contamination During Project Development

(Regulatory compliance, chemical inventory, spill reports, material safety data sheets (MSDS)).

(3) What are the waste disposal methods?

(Storage location, burial location, signs of spills or leaks, types and quantity of waste generated, processing operation, recycling methods).

(4) Any underground (UST) and aboveground storage tanks (AST)?

(Type and quantity of liquids, location and capacity of tanks, age of tanks, type of tank materials, abandoned tanks, leaks).

2. 2. 2. STEP 2: LOOK AROUND

As part of the field survey, it is important to observe, to the extent possible, environmental conditions of immediately adjacent properties. This is important because of the potential for migration of contaminants. In observing adjacent properties, information previously described (STEP 1) should be collected including the following:

1. Any evidence of hazardous waste contamination?

(Municipal solid waste landfills, Superfund sites, leaking UST/AST, abandoned structures).

2. Any historical locations or ecological habitat?

(Location, historical buildings and monuments, type of endangered species, responsible state agencies).

A comprehensive investigation of past and current uses of the adjacent sites can help to determine the source, extent, and constituents of contaminants that may be present in a site's soil and groundwater or in buildings and structures.

2. 2. 3. STEP 3: RECOMMENDATION AND FINAL REPORT

When the data collection is completed, information should be analyzed to identify hazardous waste problems in the sites of interest. Based on the information available, a decision can be made on the potential for contamination.

- (1) **No, there is no contamination problem** with the site and hence project development can proceed and the site could be recommended for acquisition with further investigation (CASE 2).

- (2) **Yes, there is contamination problem** and hence recommend for ESI (Phase 2, HWMP plan) or look for alternative route for the highway project.

After the investigation is completed a final report should be developed with the recommendations. Findings must be provided in a clear and concise manner. The report should also include some of the following subheadings.

Scope of Work

Study Area Boundaries

Site Description and Setting

Site History Evaluation

Regulatory Information Review

Site Reconnaissance

Regulatory Issues

Summary of Findings and Opinions

Recommendations

Limitations of the Report

References

Appendices

2.3. CASE 2: BEFORE SITE ACQUISITION

This involves Phase I (HWMP) which is a nonintrusive data search and review combined with an on-site inspection. The work involves the review of site-specific information, site walk over, and interviews with people familiar with the site operations and with agency personnel knowledgeable of the facility's compliance with environmental regulations. The Flow chart for this case is in Fig. 2. 3. The different steps are explained below.

STEP 1: INITIAL CONTACT WITH THE OWNER

Some of the information that must be collected during the initial contact with the owner and the questions can be grouped as follows:

(1) Site specific information

(a) What is the physical address of the site?

(Plot number, street, city, county, zip code).

(b) What are the site boundaries and property value?

(Site maps, aerial map, land value).

(c) Current and past use of property?

(House, farm, industry, repair shop).

(d) Who are the neighbors/adjacent properties?

(Land use, owners).

(2) Information on site history

(a) What were the known past uses of the site and surrounding areas?

(Homes, industry, service station, repair garage, metal workshop, vacant land).

(b) Are there previous geotechnical or environmental studies of the site available?

(Name of company, reports).

(c) Are there any known past environmental problems?

(Chemical spills, contaminated soil, UST).

(d) Are there any known past or present health or safety concerns or violations?

(Waste disposal, storage of chemicals).

CASE 2: Before Site Acquisition

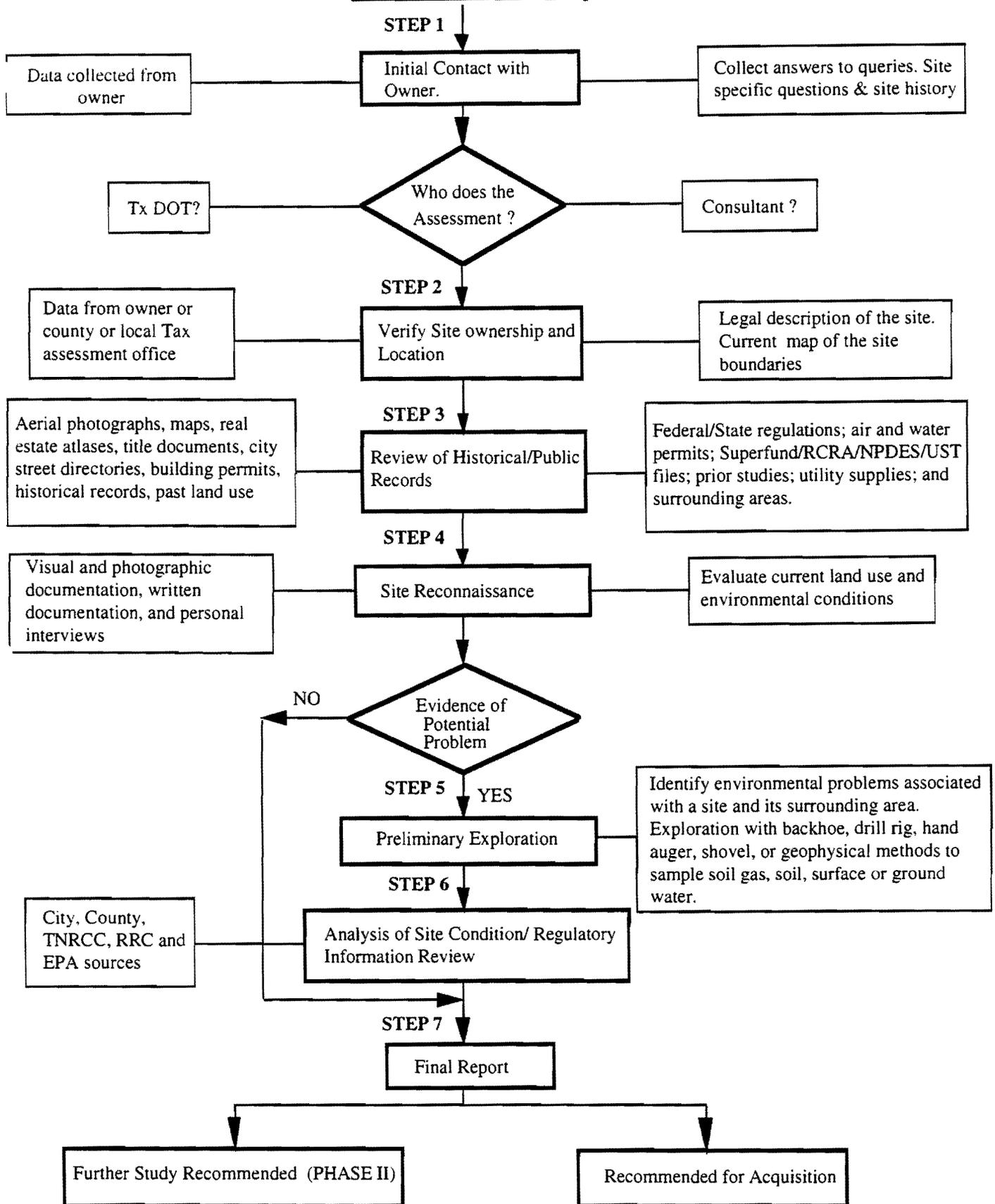


Figure 2.3. Flow Chart for Before Site Acquisition

2. 3. 2. STEP 2: VERIFICATION OF SITE OWNERSHIP AND LOCATION

It is important that the ownership and location of the site under study be identified and verified. Proper identification assures the client that the correct site is being investigated. Street addresses cannot be relied upon as the sole site location identifier. While the address may be accurate, there is no way of knowing the true boundaries of the site. Accordingly, the current legal description of the site should be obtained. This can usually be obtained from the owner a title company, or other sources if the tax number for the site has been identified. Also, a current plat map of the site boundaries should be obtained. This too is often available from the owner or from the county or local tax assessment office. The plat should be confirmed as recorded and not in the approval process. The legal description obtained will be based on one of two methods: metes and bounds or plats and platting. Some of the information that must be collected during this step is as follows:

- (a) **Who is the current site owner/past owners?**
(Name, address, duration of ownership, title company).
- (b) **Who is the current site occupant?**
(Name, phone, type of business, rental documents)
- (c) **What law firm, if any, represents the owner?**
(Liability, lean on property, loans).

2. 3. 3. STEP 3 : REVIEW OF HISTORICAL/ PUBLIC RECORDS

Evaluating the site history is an important element in the site characterization process. A comprehensive investigation of past and current uses of a site can help to determine the source, extent, and constituents of contaminants that may be present in a site's soil and groundwater or in buildings and structures.

Data Sources

To accomplish a good site history evaluation, a wide variety of data sources needs to be reviewed [1, 3, 6-9]]. The extent to which these data sources can be reviewed depends in part on the project budget and schedule. There are a variety of data sources that contain information relating to past and current site uses. These include aerial photographs, maps, real estate atlases, title documents, city street directories, textual

records, building permits, and historical records. The sources for obtaining some of this information are as follows:

(a) Federal Government Sources

Agricultural Stabilization's Conservation Service (ASCS)
U.S. Geological Survey (USGS)
National Oceanic & Atmospheric Administration (NOAA)
Soil Conservation Service (SCS)
National Archives & Records Administration (NARA)

(b) State and Local Government Sources

Texas Natural Resources Conservation Commission (TNRCC), Austin
Department of Transportation
City and County Engineering Departments

(c) Other Sources

Commercial Vendor Sources

(d) Maps

The following classes of maps are useful in determining past and current uses of a site:

- (a) topographic,
- (b) thematic (geologic, hydrologic, soil, climatologic, railroad, highway, forestry, and land use),
- (c) historic, and
- (d) planimetric.

(e) Real Estate Atlas

Real estate atlases can be considered a type of thematic map and are generally published for use in recording property ownership at the city and county level generally published for use in recording property ownership at the city and county level. The best known real estate atlas makers are the Metsker Map and Kroll Map companies, both located in the state of Washington. However, there are similar companies in the midwest and on the east coast.

(f) Title Searches and Documents

A traditional chain of title search examines the title of the owner of real estate to determine whether it is free and clear of encumbrances, and consists of an examination of such public records relating to or affecting real estate as established and maintained under authority of law.

(g) City Street Directories

Street directories exist for most first, second, and third class cities in the United States. R.L. Polk & Company based in Kansas City, Missouri is the best known publisher of such directories.

(h) Building Permits and Plans

An excellent source of historic site use information are building permit generally available from city or county building departments. Building permits and plans can provide land use information on a property over time. Building plans often accompany building permits. These plans may have information on construction materials of concern.

(i) Textual Records

Textual records of value for site history evaluation purposes include books, reports, monographs, dissertations, theses, newspapers, and periodicals (magazines and journals). Textual records are available in city, county, regional, university, state, and federal agency libraries.

(j) Archival Records and Manuscripts

Manuscripts consist of business records and personal papers collected by museums, historical societies, and university libraries for the purpose of research. For site history evaluation purposes, business records will prove the most valuable because they contain records relating to business operations and administration. Archival records and manuscripts can be found at the local, state, and federal level.

Some of the frequently asked questions to determine the history of the site is as follows:

- (a) Are there any documentations available on the site?**
(Museums, historical societies, libraries).
- (b) What were the known past history of the site and its surrounding areas ?**
(Monuments, historic sites, cemetery, old/historic buildings).

2. 3. 4. STEP 4: SITE RECONNAISSANCE

The purpose of the site reconnaissance is to evaluate current land use and environmental conditions to determine the potential for contaminants to exist in the property's soil and groundwater based on current on-site and adjacent site uses. This is

achieved through a combination of visual and photographic documentation, written documentation, and personal interviews.

Personal Interviews

Available on-site and adjacent land occupants or owner/operators should be interviewed regarding their knowledge of past and contemporary uses of the site and surrounding areas.

Site and Environmental Characterization

Details are in CASE 1 (section 2.2.1).

Adjacent Properties: As part of the site reconnaissance, it is important to observe, to the extent possible, environmental conditions of immediately adjacent properties. This is important because of the potential for migratory contamination. In observing adjacent properties, the items previously described should be evaluated and include the following: (a) evidence of hazardous substances, (b) waste management practices, (c) waste disposal methods, (d) processing operations, and (e) UST/AST.

Some of the frequently asked questions during the site reconnaissance are as follows:

- (a) **What is the current use of the site and its surrounding areas?**
(Homes, industry, service station, repair garage, metal workshop, vacant land, land fill, storage tanks).
- (b) **Is there any environmental monitoring at the site?**
(Monitoring wells).
- (c) **Were there any environmental problems?**
(Chemical spills, contaminated soil, UST).
- (d) **Are there any health or safety concerns or violations?**
(Waste disposal, storage of chemicals, odor).

2.3.5. STEP 5: PRELIMINARY EXPLORATION

This step consist of identifying the environmental problems associated with a site and its surrounding area [2, 17]. Exploration is done with backhoe, drill rig, hand auger, shovel, or geophysical methods to sample soil gas, soil, surface water or groundwater. This helps to know the extent of contaminant present and to make a decision on acquisition.

Some of the frequently asked questions during the preliminary exploration of the site are as follows:

- (a) **What are the methods for site exploration?**
(Geophysical methods, sampling methods (CHAPTER 4)).
- (b) **How many samples to collect and test?**
(Depends on anticipated level of contamination).
- (c) **Depth of groundwater and direction of flow?**
- (d) **Any wells, buried tanks or sumps ?**
(UST, waste disposal, storage of chemicals).

Soil samples must be analyzed to determine whether the site is contaminated. If the site is contaminated detailed analyses must be performed on the soil samples.

2.3.6. STEP 6: ANALYSIS AND REGULATORY INFORMATION REVIEW

Analysis of the information collected from STEPS 1 through 5 will give a better understanding of the condition of the site. Reviewing the local, state (TNRCC [12 -16], RRC), and federal (EPA) regulatory information [5 -7] will accomplish the following:

- (i) Could identify known environmental problems associated with a site and its surrounding area.
- (ii) Could describe available documented information related to a site and surrounding area, relative to the potential for contaminants to exist on the site due to past practices or to have migrated to the site due to past practices at other sites.
- (iii) Utility department will have information on utilities on and adjacent to the property under study. Perhaps most important will be their records pertaining to the status of PCB oils in electrical power pole transformers

Analysis of the data collected on the site and regulatory information will determine whether the site is contaminated.

2.3.7. STEP 7: FINAL REPORT

When the investigation is completed, a final report on the findings must be submitted. It should recommend to the TxDOT one of the following (1) acquisition of the

property, (2) further study (ESI, HWMP Phase II) before acquisition or (3) not to acquire the property based on documented evidence. The report should at least include the following subheadings.

Scope of Services

Study Area Boundaries

Site Description and Setting

Site History Evaluation

Regulatory Information Review

Site Reconnaissance

Regulatory Issues

Summary of Findings and Opinions

Recommendations

Limitations of the Report

References

Appendices

2. 4. CASE 3: DURING CONSTRUCTION

The objective of CASE 3 can be achieved by effectively combining HWMP Phase II, Phase III, Phase IV and Phase V. The Flow chart for this case is in Fig. 2. 4. If contamination is detected during construction the following steps are to be executed.

2. 4. 1. STEP 1: STOP CONSTRUCTION

If contamination is discovered in the construction phase of a project the contractor should stop the work on that portion of the project and immediately notify the TxDOT engineer in charge of the discovery. Depending on the type and extent of contamination, site may have to be cleared of construction equipments, materials and workers. The TxDOT engineer must also contact the TNRCC about the situation and file the necessary papers to document the incident.

2. 4. 2. STEP 2: WASTE ANALYSIS AND IDENTIFICATION

Identify the type of waste, medium and the extent of contamination (details are in Chapter 4) must be determined. When the contaminants are identified, data on their intrinsic toxicity and the health risks must be determined. Once the nature and extent of contamination have been determined, the potential impacts to public health and the environment must be evaluated. The magnitude of the health risks is generally screened by comparing waste concentrations in soil and groundwater to regulatory limits set by EPA or TNRCC for drinking water or Maximum Contaminant Levels (MCL's) standards or guidelines.

Notify the TNRCC about the type and extent of contamination.

2. 4. 3. STEP 3: REVIEW GEOTECHNICAL AND HYDROGEOLOGICAL REPORTS

The data collected during previous site investigation must be reviewed. The reasons for missing the contamination must be investigated. Frequently asked questions are as follows:

- (a) **What are the methods that were used in site investigation?**
(Geophysical methods, sampling methods (CHAPTER 4)).
- (b) **How was the contamination missed during past investigation?**
(Recent contamination, leaking neighbourhood tanks, past investigation didn't include environmental site assessment).

CASE 3: During Construction

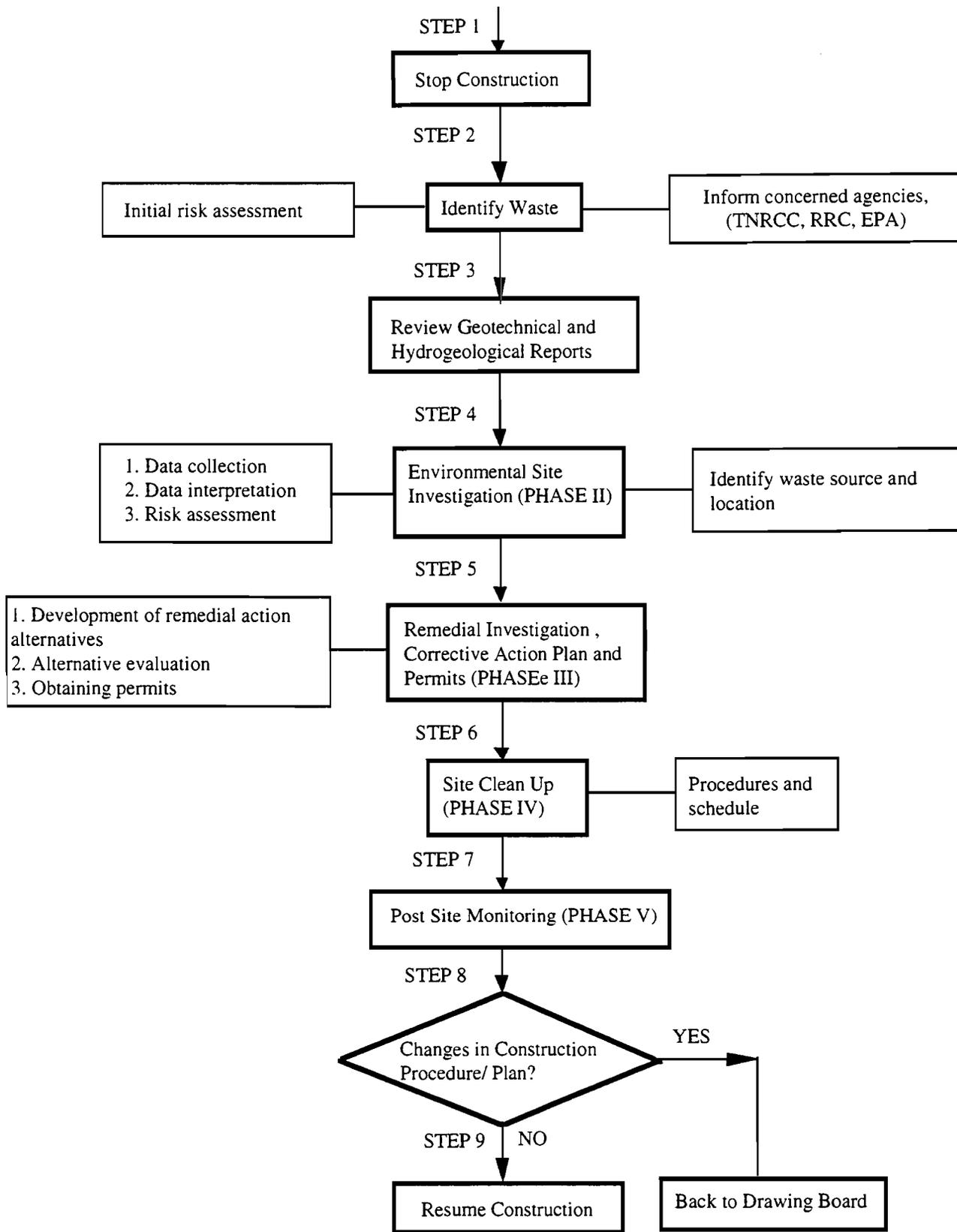


Figure 2.4. Flow Chart for Decontaminating a Site During Construction

- (c) **Cause of contamination (i) existing condition or (ii) due to an accident during construction?**
(Missed during past investigation, groundwater contamination from neighbours, damaging utility pipes during construction).
- (d) **Depth of groundwater and direction of flow?**

Based on the information available on the site, additional investigations must be planned for part or the entire construction site.

2. 4. 4. STEP 4: ENVIRONMENTAL SITE INVESTIGATION (PHASE II-HWMP)

ESI work involves field studies coupled with laboratory analysis [2]. The media to be tested will depend on site specific conditions identified when contaminants were encountered on the site during construction. Detail procedures for PHASE II-HWMP are in Chapter 3.

2. 4. 5. STEP 5: REMEDIAL INVESTIGATION, CORRECTIVE ACTION PLAN AND PERMITS (PHASE III-HWMP)

This involves treatability studies, work plan for remedial action, and obtaining necessary approval from TNRCC [15]. Detail procedures for PHASE III-HWMP are covered in Chapter 3.

2. 4. 6. STEP 6: SITE CLEAN UP (PHASE IV-HWMP)

Based on the approval and CAP, remediation of contaminated region will be done. Other elements important for implementation of PHASE IV-HWMP are detailed in Chapter 3.

2. 4. 7. STEP 7: POST SITE MONITORING (PHASE V-HWMP)

Once the clean up has been completed the site should be monitored on a timely basis for a certain period of time to assess the effectiveness of Clean up. For details refer to Chapter 3.

2. 4. 8. STEP 8: CHANGES IN CONSTRUCTION PROCEDURE/ PLAN

Construction procedures can be reevaluated and if necessary changes must be incorporated. Accidents with buried utility lines (gas, phone, electricity) and sewer pipes,

especially during excavation must be avoided. If changes are made these must be approved by appropriate TxDOT officials.

Some of the frequently asked questions are as follows:

- (a) **How can further contamination on site be avoided?**
- (b) **Is there any risk involved for the construction workers on site?**
- (c) **Is there any additional cost and time involved in changes in construction procedure?**

2. 4. 9. STEP 9 : RESUME CONSTRUCTION

Construction can proceed with caution, but without any further delay.

2. 5. CASE 4: DURING MAINTENANCE

During the maintenance of TxDOT facilities contamination might be encountered due to migration of contamination from adjoining facilities or onsite accidents. If contamination is encountered the following steps must be taken to overcome the problem and the Flow chart for this case is in Fig. 2. 5.

2. 5. 1. STEP 1: IDENTIFY WASTE

The type and amount of contaminant present must be identified. Also the extent of contamination (details are in Chapter 4) must be determined. When the contaminants are identified, data on their intrinsic toxicity and the health risks must be determined. Once the nature and extent of contamination have been determined, the potential impacts to public health and the environment must be evaluated. The magnitude of the health risks is generally screened by comparing waste concentrations in soil and groundwater to regulatory limits set by EPA or TNRCC for drinking water or Maximum Contaminant Levels (MCL's) standards or guidelines.

Notify the TNRCC about the type and extent of contamination.

2. 5. 2. STEP 2: REVIEW GEOTECHNICAL AND HYDROGEOLOGICAL REPORTS

The data collected during previous site investigation must be reviewed. The reasons for missing the contamination must be investigated. Frequently asked questions are as follows:

- (a) **What are the methods that were used in site investigation?**
(Geophysical methods, sampling methods (CHAPTER 4)).
- (b) **How was the contamination missed during past investigation?**
(Recent contamination, leaking neighbourhood tanks, past investigation didn't include environmental site assessment).
- (c) **Cause of contamination (i) existing condition or (ii) due to an accident during construction?**
(Missed during past investigation, ground water contamination from neighbours, damaging utility pipes during construction).
- (d) **Depth of groundwater and direction of flow ?**

Based on the information available on the site, additional investigations must be planned for part or the entire construction site.

CASE 4: During Maintenance

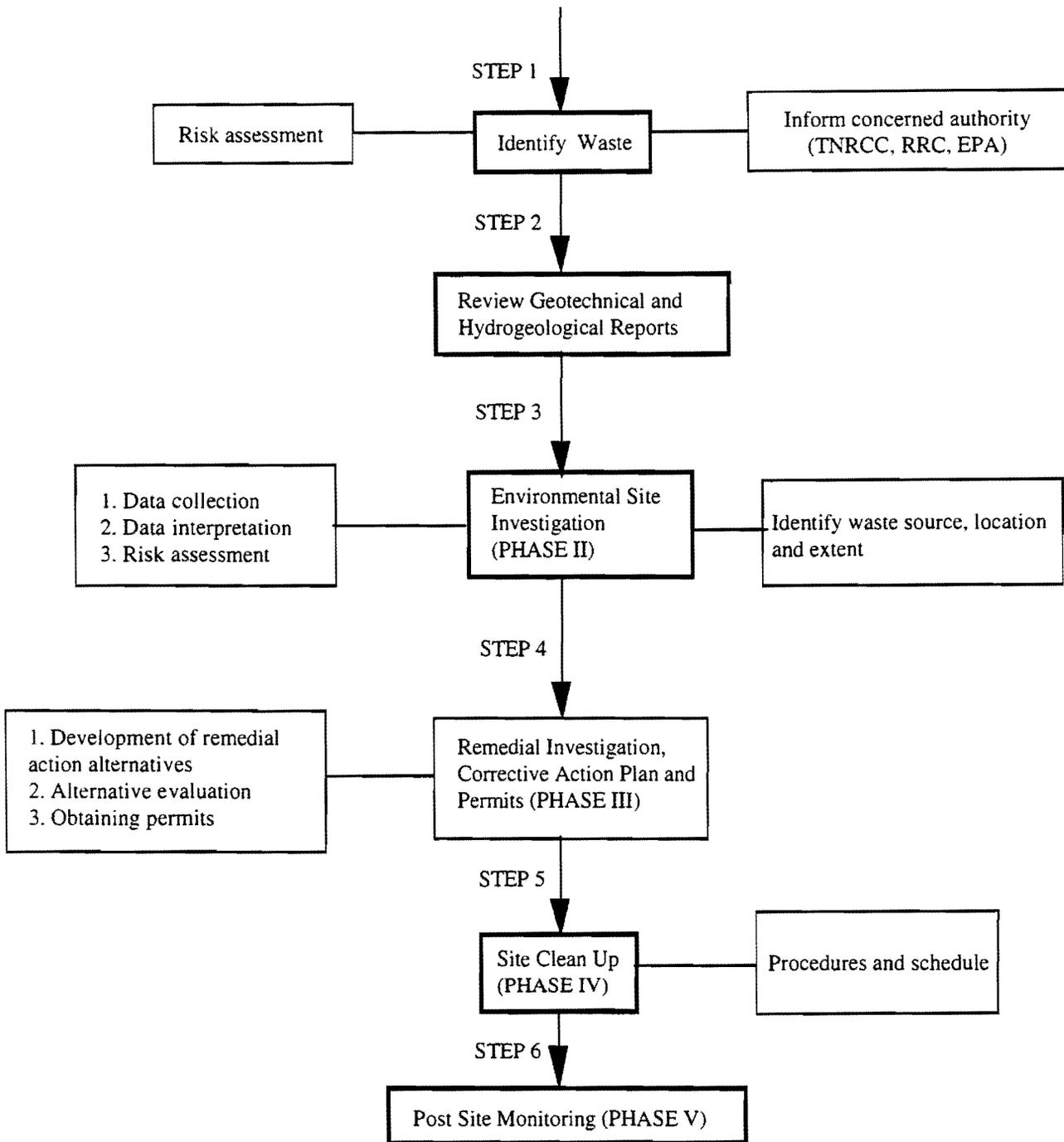


Figure 2.5. Flow Chart for Decontaminating the Site during Maintenance

2. 5. 3. STEP 3: ENVIRONMENTAL SITE INVESTIGATION (PHASE II-HWMP)

ESI work involves field studies coupled with laboratory analysis. The media to be tested will depend on site specific conditions identified when contaminants were encountered on the site during construction. Detail procedures for PHASE II-HWMP are in Chapter 3.

2. 5. 4. STEP 4: REMEDIAL INVESTIGATION, CORRECTIVE ACTION PLAN AND PERMITS (PHASE III- HWMP)

This involves treatability studies, work plan for remedial action, and obtaining necessary approval from TNRCC. Detail procedures for PHASE III-HWMP are covered in Chapter 3.

2. 5. 5. STEP 5: SITE CLEAN UP (PHASE IV-HWMP)

Based on the approval and CAP, remediation of contaminated region will be done. Other elements important for implementation of PHASE IV-HWMP are detailed in Chapter 3.

2. 5. 6. STEP 6: POST SITE MONITORING

Once the clean up has been completed the site should be monitored on a timely basis for a certain period of time to assess the effectiveness of clean up. For details refer to Chapter 3.

2.6. CONCLUSIONS

Four cases representing various stages of construction were identified and flow charts with sequence of actions for contaminated site investigation and remediation have been developed. The four cases are for handling hazardous waste or petroleum substances during development (CASE 1), for acquisition (CASE 2), during construction (CASE 3) and during maintenance (CASE 4).

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Chapter 3

Hazardous Waste Management Plan (HWMP)

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3. 0. INTRODUCTION

Hazardous Waste Management Plan (HWMP) has become an integral part of the process when acquiring right-of-way properties or when contamination is found at construction sites, regardless of the size of the property [2-6, 9-19]. A systematic approach emphasizing thorough planning, project management, coordination, and standardization of all elements of work should be utilized when developing and executing a HWMP. Many problems develop through inadequate communication and insufficient attention to project management and coordination. By using a systematic approach to project management and coordination, many of the problems that could arise in meeting project commitments would not occur or would be quickly recognized allowing action to be taken before affecting the planned construction [18-20].

There are many skills that must be drawn upon to properly conduct the various activities of the HWMP. As the HWMP process (broken into five phases) moves from the limited assessment through invasive subsurface investigation techniques, and in some cases to remedial design and cleanup, the shift in skills required will be from the scientific and engineering disciplines to the engineering and construction disciplines. The engineer must play an active role in all phases of work to provide for the gathering of applicable data for use in the selection, design, and implementation of corrective measures. This Handbook will discuss the expertise required in the five phases of work and the means by which a team is selected to best address environmental conditions that are discovered. The review of information and reports generated during the HWMP by qualified staff is an integral part of the process providing for quality control and quality assurance at each and every step of the process.

3. 1. PHASE I: PRELIMINARY SITE ASSESSMENT (PSA)

Phase I PSA is a combination of data search and review with an on-site inspection. This phase of work involves the review of site-specific information, a site walkover, and interviews with people familiar with site operations and with agency personnel knowledgeable of the facility's compliance with environmental regulations [2 - 6].

Objective: The purpose of PHASE I PSA is to identify, to the extent possible, recognized environmental conditions with the property. Recognized environmental conditions are as follows: the presence or likely presence of any hazardous substances or petroleum products on a property under conditions that indicate an existing release, a past release, or a material threat of a release of any hazardous substances or petroleum products into structures on the property or into the ground, groundwater, or surface water of the property.

The flow chart in Fig. 3.1 summarizes the various stages in successfully completing PHASE I PSA and was developed by effectively combining the approaches suggested by ASTM, ASCE and ASFE. Also, ASTM E 1527-94 is a Standard Guide for PHASE I PSA.

3. 1. 1. STEP 1: SITE OWNERSHIP AND LOCATION

The success of Phase I PSA is dependent on good planning and execution. The planning process begins with the initial client contact and consists of, but is not limited to, the following basic questions to be answered.

(a) Site Specific Questions

- (1) What is the physical address of the site?
- (2) Is it located within a city or is it within an unincorporated jurisdiction?
- (3) What are the site boundaries—is a site map available?
- (4) Is a legal description of the property available?
- (5) Who are the neighbors/adjacent properties—to get a cursory understanding of adjacent land use?

(b) Players

- (1) Who is the client for billing purposes?
(Name of the owner, agency, mailing address, phone)
- (2) Who is the current site owner?

PHASE I: Preliminary Site Assessment (PSA)

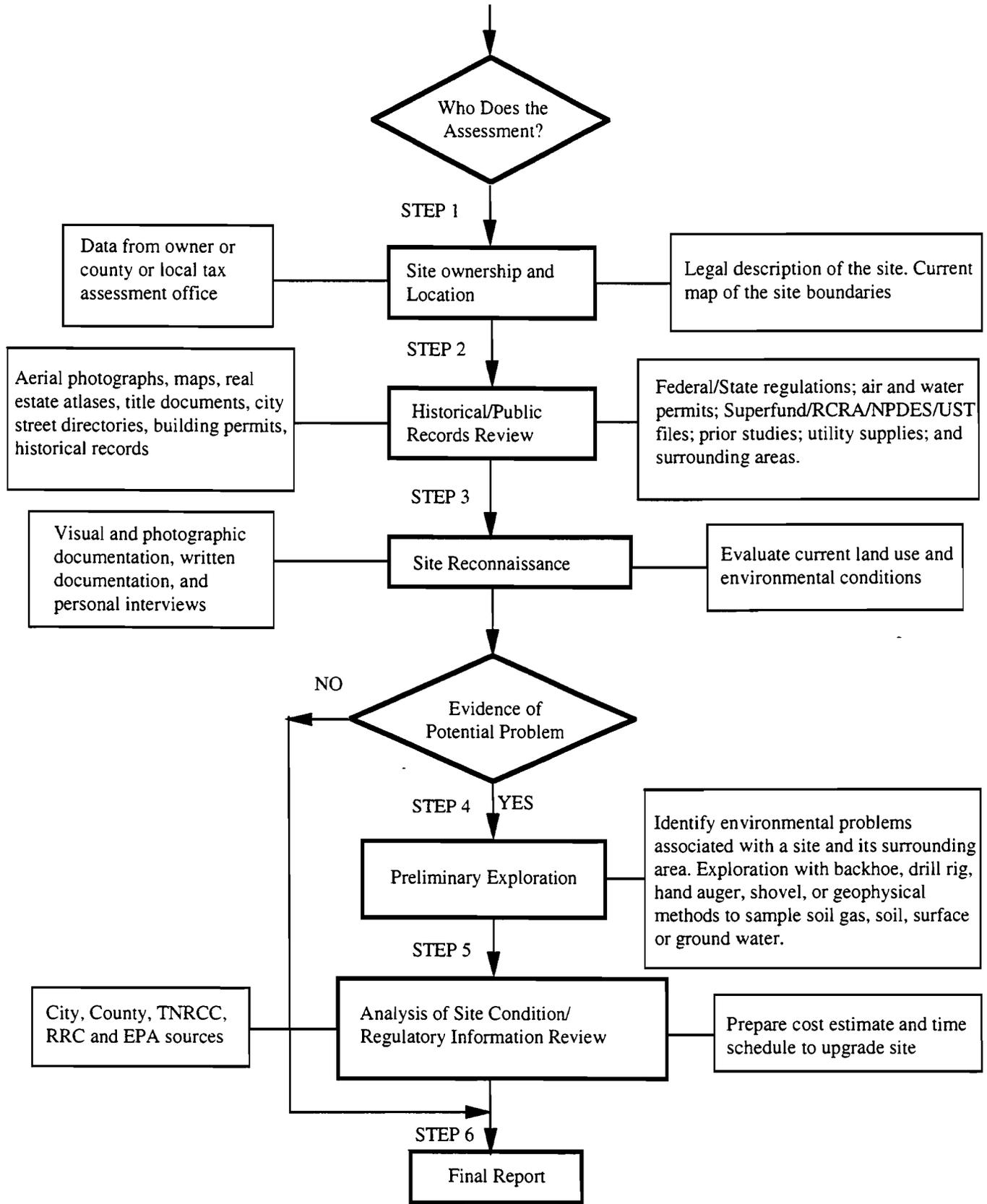


Figure 3.1. Flow Chart for Preliminary Site Assessment

- (3) Who is the current site occupant?
- (4) What law firm, if any, represents the client?
- (5) Who is the TXDOT representative?
(TXDOT Engineer, consultant)

(c) Site History

- (1) What are the known past uses of the site and surrounding area?
- (2) Are there previous geotechnical or environmental studies of the site available?
- (3) Are there any known past environmental problems?
- (4) Are there any known past or present health or safety concerns or violations?

It is important that the ownership and the location of the site under study be identified before the PSA begins. Street addresses cannot be relied upon as the sole site location identifier. While the address may be accurate, there is no way of knowing the true boundaries of the site. Accordingly, the current legal description of the site should be obtained. This can usually be obtained from the client, a title company, or other sources if the tax number for the site has been identified. Also, a current plat map of the site boundaries should be obtained. This too is often available from the client or from the county or local tax assessment office.

In rural and undeveloped areas a survey consists of a walking tour of a property and identifying an intersection of a government survey line. From that point, the survey describes boundary lines, giving directions in compass degrees and the distance before reaching the next corner of the property. This description continues around the property boundary until the survey starting point is reached. It is also common for rural properties to be described by natural features such as streams and outcroppings, as long as the objects and boundaries are adequately described.

3.1.2. STEP 2: HISTORICAL/PUBLIC RECORDS REVIEW

The objective of consulting historical sources is to develop a history of the previous uses of the property and surrounding area, in order to help identify the likelihood of past uses having leads to recognized environmental conditions in connection with the property.

The site history evaluation is the first and most important element of the PHASE I PSA. A comprehensive investigation of past and current uses of a site can help to determine the source, extent, and constituents of contaminants that may be present in a site's soil and groundwater or in buildings and structures. A good site history evaluation helps characterize

known activity on and adjacent to a site from its undeveloped to its present condition, identify past and current land uses, identify potential contaminants released to the environment, assist engineers, geologists, and other related technical professionals in determining where to place soil borings and install monitoring wells for chemical sampling and analysis based on the location of historic activities of concern on a site, to fulfill all the appropriate inquiry requirements of CERCLA and SARA and identify possible adjacent properties that may have had releases that could migrate to the site.

The data sources that contain information relating to past and current land uses include aerial photographs, maps, real estate atlases, title documents, city street directories, building permits, textual records, historical records, and oral information.

Some of the questions related to this step are as follows:

1. Where can aerial photographs and maps be obtained?

(Federal government sources, state government).

2. What can you see in these maps?

(Screen site for contamination, locate UST/AST, landfill, seasonal changes, rivers).

3. Any accessibility limitations?

(slopes, depressions).

4. Was previous site reports reviewed?

(Locate hot spots, type of contaminants, contaminated medium).

5. What types of investigations are planned?

(Geophysical methods, soil sampling, groundwater sampling, waste analysis
(CHAPTER 4))

3. 1. 3. STEP 3: SITE RECONNAISSANCE

The purpose of the site reconnaissance is to evaluate current land use and environmental conditions to determine the potential for contaminants to exist in the property's soil and groundwater based on current on-site and adjacent site uses [2, 3, 28-33]. This is achieved through a combination of visual and photographic documentation, written documentation, and personal interviews. Information must be collected on current land uses and environmental conditions.

3. 1. 4. STEP 4: PRELIMINARY EXPLORATION

Soil and groundwater samples must be collected from locations at the site which are identified as the most probable chance of contamination. Soil samples can be collected using hand augers or split spoon samplers [3-6]. Sampling wells should be set up to collect groundwater samples. Preliminary exploration should be limited to a few days [2].

3. 1. 5. STEP 5: ANALYSIS OF SITE CONDITION/REGULATORY INFORMATION REVIEW

The acquisition and analysis of available local (city, county, regional governments), state, and federal information related to known environmental conditions of a site and other sites of concern within a designated radius of the site is a critical step in determining the potential for contaminants of concern to exist on a site. Information obtained in this review may also be valuable to the site history evaluation because local, state, and federal data sources often include historic site use information. A thorough local, state, and federal regulatory information review accomplishes identification of known environmental problems associated with a site and its surrounding area and describes available documented information related to a site and surrounding area relative to the potential for contaminants to exist on the site due to past practices or to have migrated to the site due to past practices at other sites.

It is recommended that a checklist be developed to assist the consultant in ensuring that all appropriate local, state, and federal agencies are contacted for information on the site and surrounding area. To perform a thorough local, state, and federal information review, a wide variety of data sources need to be reviewed. These data sources are available in the form of reports, lists, databases, and original agency files.

Before commencing the regulatory information review, some thought should be given to the size of the area around a site for which other sites of concern should be researched. The ASTM E 1527 standard for Phase I PSAs established a set radii (called the approximate minimum search distance) for certain types of regulatory information (called the standard environmental record source).

Approximate Minimum Search Distance

The recommended search distances to Federal, State and Other facilities are as follows (ASTM E 1527):

	Approximate min. search distance kilometers (miles)
Federal NPL site	1.6 (1.0)
Federal CERCLIS	0.8 (0.5)
Federal RCRA TSD facilities	1.6 (1.0)
Federal RCRA generators	property and adjoining property
Federal ERNS	property only
State Hazardous sites	1.6 (1.0)
State Landfills	0.8 (0.5)
State Leaking UST	0.8 (0.5)
State Registered UST	0.8 (0.5)

(ERNS - Emergency Response Notification System, EPA)

Factors to consider in reducing the approximate minimum search distance include (1) the location (urban, rural or suburban) of the property; and (2) the distance that the hazardous substances or petroleum products are likely to migrate based on local geologic or hydrogeologic conditions. Except for Federal NPL site and Federal RCRA TSD facility the minimum search distance to other locations may be reduced on a case by case basis.

3. 1. 6. STEP 6: FINAL REPORT FORMAT

When the PHASE I PSA investigation is completed, the findings must be documented in a clear and concise manner. The report should have sections at least on the following subheadings.

1. Scope of Services
2. Study Area Boundaries
3. Site Description and Setting
4. Site History Evaluation
5. Site Reconnaissance and Preliminary Investigation
6. Regulatory Information Review
7. Summary of Findings and Opinions
8. Recommendations
9. Limitations of the Report
10. References

3. 2. PHASE II: ENVIRONMENTAL SITE INVESTIGATION (ESI)

Simply stated, a Phase II Investigation is an environmental site assessment that includes a subsurface investigation and/or sampling component whose major purpose is to characterize and confirm the presence of on-site contamination. In general, it includes invasive and non-invasive subsurface investigation, chemical analysis of air, soil, source material, surface water, and/or groundwater samples collected on-site, evaluation of the analytical and hydrogeological data, and frequently, some form of risk assessment. PHASE II investigation is an investigation that builds on and confirms information identified during the PHASE I assessment. The need for a PHASE II investigation is recommended if contamination is suspected on site.

Objective: The primary objectives of conducting a PHASE II ESI are to evaluate the recognized environmental conditions identified in PHASE I PSA and to provide sufficient information regarding the nature and extent of contamination to assist in determining the need for remedial investigation for the site.

The scope of PHASE II can be broken down into four basic stages: Pre-investigation planning, site exploration, data interpretation, and reporting. The flow chart in Fig. 3.2. summarizes the various stages in successfully completing PHASE II. Also, ASTM E 1903-97 is a Standard Guide for PHASE II ESI [6].

3. 2. 1. STEP 1: PRE-INVESTIGATION PLANNING

The key to providing for a technically well-run project and effective cost controls lies in good up-front planning. The primary end-product resulting from this planning stage is the written scope of work, proposal, and work plan for PHASE II ESI.

Some of the questions related to this step are as follows:

- 1. What is the objective of this investigation?**
(Screen site for contamination, locate UST)
- 2. What are the scheduling requirements and constraints?**
(Deadline for project, seasonal changes)
- 3. Any accessibility limitations?**
(Slope, depression, fence, river)
- 4. What are the regulatory requirements?**

PHASE II: Environmental Site Investigation (ESI)

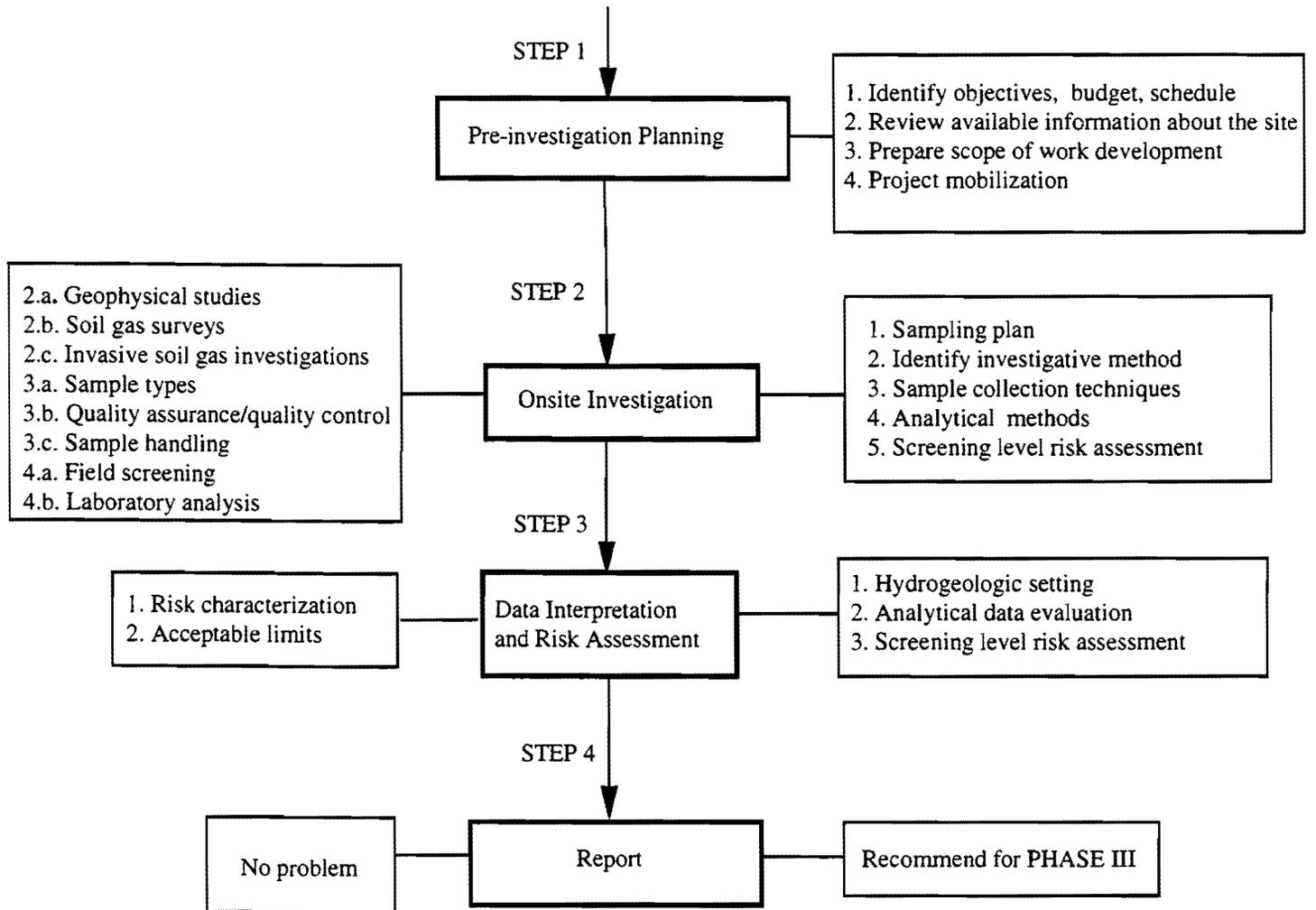


Figure 3.2. Flow Chart for Environmental Site Investigation

(OSHA for workers, TNRCC)

5. Was PHASE I report reviewed?

(Locate hot spots, type of contaminants, contaminated medium)

6. What types of investigations are planned ?

(Geophysical methods, soil sampling, groundwater sampling, waste analysis)

3. 2. 2. STEP 2: ON-SITE INVESTIGATION

The on-site data collection of the PHASE II investigation represents the heart of the study. This investigation usually focuses on obtaining quantitative or semi-quantitative data from chemical analyses of selected media. Qualitative physical data such as groundwater pumping test results, soil grain size analyses, and dye tracer tests are performed as required to obtain the necessary site conditions.

Some of the questions related to this step are as follows:

1. What kind of information is required?

(Extent of contamination, type of contamination).

2. What are the investigative methods?

(Geophysical study, soil gas survey, soil and groundwater sampling, monitoring wells)

3. What are other investigative methods?

(Cone penetrometer, test pits, pump test (Chapter 4)).

4. What are the drilling methods?

(Chapter 4, hollow-stem auger, rotary auger).

5. What are the sampling methods?

(Chapter 4, split-barrel, thin wall tub, piston sampler).

6. What are the analytical methods ?

(Chapter 4, field screen, laboratory analysis).

3. 2. 3. STEP 3 : DATA INTERPRETATION & RISK ASSESSMENT

The challenge of the PHASE II ESI investigation is that it requires that the data be critically analyzed to determine whether or not the site is contaminated, and if contaminated the

extent of contamination. Information collected on the geotechnical and environmental properties of the site should be effectively combined and analyzed in this STEP.

The aim of data evaluation is to address several major questions such as:

- (1) Does the data confirm or disprove the presence of oil or a hazardous material? If confirmed, what is the nature and magnitude of the release, and is it from an on-site source or from off-site property? What media are impacted?
- (2) If the data confirms the presence of petroleum product or a hazardous substance, what is the public health significance? Is there potential for human contact?
- (3) If release of a petroleum product or a hazardous material is present, what level of risk is involved? Are there migration mechanisms and pathways for petroleum product or hazardous materials to migrate readily from an on-site release point to a sensitive receptor, such as a drinking water supply well or a sensitive wetland?
- (4) Is further data collection warranted for selecting remedial methods?

These are some of the frequently asked questions and it focuses not only on the answers but also on understanding the uncertainties inherent in interpretations and conclusions.

3 . 2 . 4 . STEP 4 : FINAL REPORT

At the completion of a PHASE II ESI, it should be possible to conclude, at a minimum, that either (a) the ESI has provided sufficient information to render a professional opinion that there is no reasonable basis to suspect the presence of hazardous substance or petroleum products on the property, or (b) the ESI has confirmed the presence of hazardous substance or petroleum products on the property. Final report for Phase II ESI investigation must be prepared. Following subheadings must be included in the the Phase II ESI report:

1. Site Conditions
2. Scope of Current Activities
3. Results of Field Study
4. Findings, Opinions, and Recommendations

3. 3. a. PHASE III (a) : REMEDIAL INVESTIGATION & FEASIBILITY STUDY (RI/FS)

Objective: The purpose of the RI/FS is to develop the data necessary to plan the site remediation and to use that data to determine the feasibility of various remediation alternatives.

The EPA has developed guidelines for the performance of the RI/FS entitled, Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, report number EPA540 G49004. A flow chart for RI/FS, with modification to the EPA version, is in Figure 3.3a.

The PHASE III(a), or Remedial Investigation/Feasibility study, is the subject of this section. Data developed by the site and remedial investigations are used to begin screening of remedial alternatives as PHASE III (a) proceeds. Under Superfund requirements, community involvement through a formal community relations plan is required. For complex sites, several iterations of investigation, sampling, and analysis may be necessary to fully define acceptable alternatives.

a. Site Remediation

Before a remedial action can be undertaken at a site, a number of questions must be answered:

- 1. What are the types of contaminants and the levels of contamination?**
(Metal, organic, petroleum, inorganic, UST, brown field site)
- 2. What is the extent of contamination?**
(Area, depth)
- 3. What is the size of the contaminated groundwater plume?**
(Volume, depth)
- 4. Where is the contamination located and in what direction is the groundwater flow?**
- 5. Based on the available remedial alternatives, how to select the best method ?**
(Treatment, containment, landfill, established/innovative technology)
- 6. What is the best way to clean up the site?**
(Contractor, TxDOT)
- 7. How long will it take to complete the clean up, and what will it cost?**
- 8. What level of protection is adequate: how clean is clean?**

PHASE III(a): Remedial Investigation and Corrective Action Plan (RI/FS)

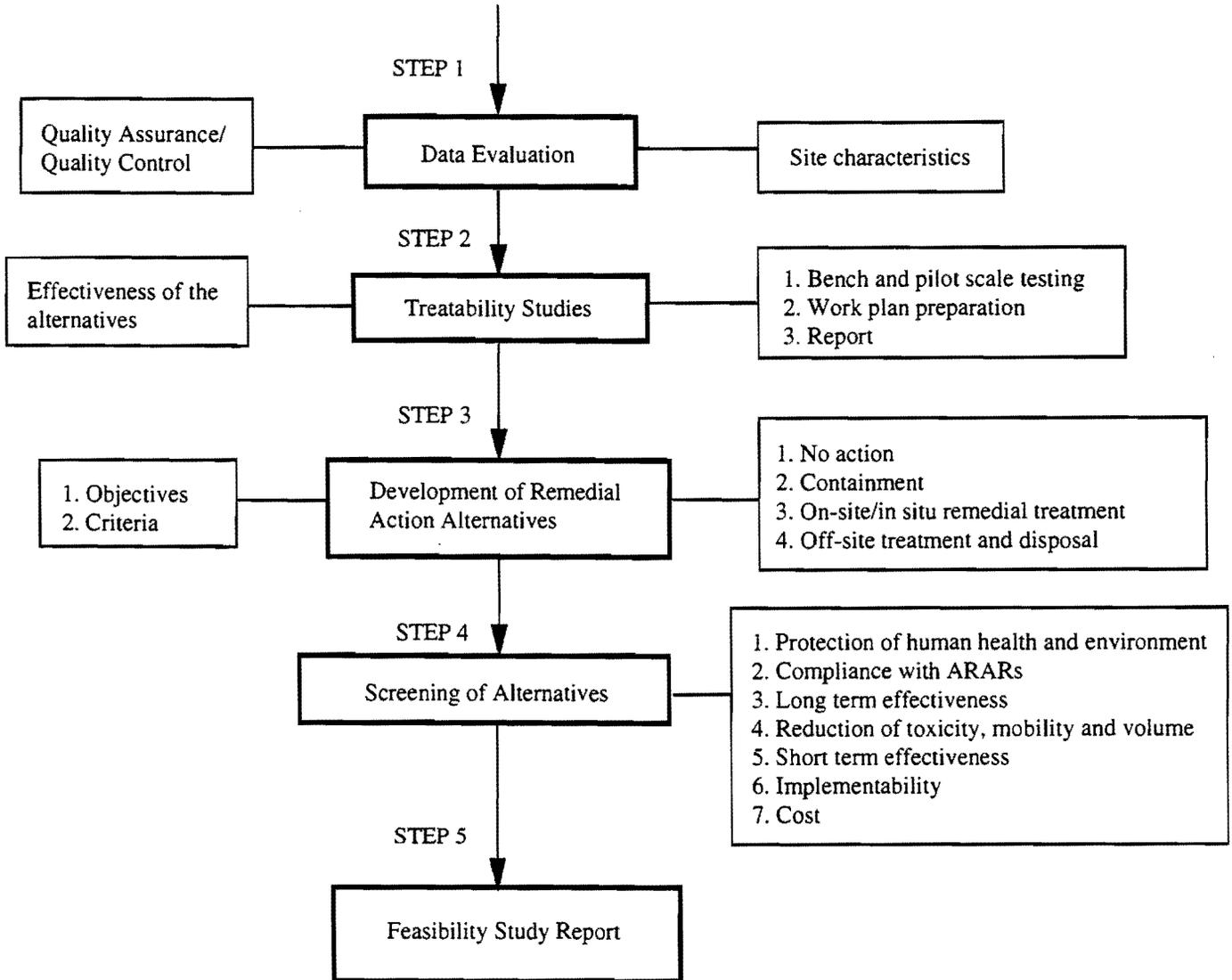


Figure 3.3a. Flow Chart for Remedial Investigation and Feasibility Study

Answers to these questions will help in developing an effective remedial procedure for the contaminated site. The last question is based on TNRCC and EPA limits on contaminants. There is simply not enough technical and health-related information available to know the precise level of cleanup needed at any specific site. The selection of appropriate cleanup technologies and the ultimate evaluation of cleanup performance remains a challenge.

The EPA has established a procedure for discovering releases, evaluating remedies, determining the appropriate extent of response, and ensuring that remedies selected are cost-effective. This procedure, commonly called the remedial investigation/ feasibility study (RI/FS) process, is outlined in the revised National Contingency Plan (NCP) in 29 CFR 300 [].

3. 1. 1. STEP 1: DATA EVALUATION

The first step in the feasibility study is to identify existing site problems using preliminary remedial investigation data (site background, previous studies, initial remedial investigation activities) and determine the remedial technologies that are most applicable. Review of the data collected on the site is an important continuous process during the Phase III investigation [2]. The objective is to develop knowledge necessary to guide the ongoing investigation. The data evaluation should include a description of the sources of contamination and ultimately create a picture of the nature and extent of the contamination. This is necessary to plan the cleanup and to determine the cost of various remedial alternatives. It will also guide the assessment of risks. Knowing the present distribution of the contaminants is also the first step in analyzing possible transport pathways (wind, groundwater) and future contaminant distribution.

a. Site Characteristics

The data provided by the PHASE I and II investigations must be compiled and summarized to create as complete a picture as possible, based on available data, of the physical characteristics of the site. The topography, geology, and ecology of the contaminated area will be of prime concern. Site data should be reviewed to identify conditions that may limit certain remedial technologies.

Some of the questions related to this step are as follows:

- (1) **Is there any limitation on accessibility?**
(Depressions, built in areas, gates, fences, trails, roads).
- (2) **What is the topography and native vegetation?**
(Rolling hills, flat land, rock out crops, steep or rugged terrain, lakes, trees, bushes).

- (3) **What is the site geology?**
(depth of bedrock, bedrock type, bedrock properties (strength, permeability)).
- (4) **What is the soil characteristics?**
(type of soil, soil profile, engineering properties).
- (5) **What is the groundwater characteristics?**
(Depth of ground water, aquifer profile, seasonal fluctuations).
- (6) **What is the surface water characteristics?**
(Proximity of nearest lake, river and bayou, floodplain or coastal storm surge boundaries, rainfall runoff, drainage for storm and wastewater).
- (7) **What is the climatic characteristics?**
(evapotranspiration parameters, wind speed and direction, temperature parameters, precipitation, local air quality, regional air quality).

b. Waste Characteristics

Knowledge of contaminant source characteristics will be of prime value in further investigation and action, and must be described in the greatest detail possible [3, 22, 28, 32, 33]. If an underground storage tank has leaked, it is necessary to know what compounds the tank contained and to determine how much product was lost, in order for the investigators to determine whether an investigation is complete. The nature and extent of the contamination is perhaps the most obvious site characteristic to be developed. Remedial alternatives will be constrained according to the identity of the contaminants. The costs of cleanup will rise with the amount of soil or water that is contaminated. The fate and transport of the contaminants will vary with the type of contaminant (and therefore its solubility, vapor pressure, and other physical characteristics) and the type of media (soil or water) contaminated.

Some of the questions related to waste characterization are as follows:

- (1) **What is the physical state?**
(Solid waste, UST, contaminated soil and/or ground water)
- (2) **What is the chemical composition of waste?**
(Metal, organics, salts, petroleum)
- (3) **Hazardous or non-hazardous?**
(Toxicity, ignitability, reactivity, corrosivity)
- (4) **What is the physical composition of waste?**
(Solubility, volatility, density)

3.3.a.2. STEP 2 : TREATABILITY STUDIES

The next step in the remedial study is to identify and screen potentially applicable technologies to eliminate those that are difficult to implement and rely on unproven technologies, or may not achieve the remedial objectives within a reasonable time period [23, 24, 26, 28]. This screening process focuses on eliminating the technologies that have severe limitations for site-specific conditions. Site and waste characteristics are used to screen the remedial technologies.

Treatability studies are part of the iterative process that moves back and forth between ESI (PHASE II) and remedial alternative development. ESI provides the description of the problem and based on past experience several alternative remedial methods can be selected for evaluation. Remedial methods are greatly affected by the composition of the soils and hence, the treatment efficiency is difficult to predict and can only be evaluated by testing. Bench scale treatability tests are proposed at this stage which employs the proposed remedy on small samples of site soils and groundwater.

3.3.a.3: STEP 3: DEVELOPMENT OF REMEDIAL ACTION ALTERNATIVES

Technologies that have passed the initial screening process then form the overall remedial action alternatives that appear to address all site problems. Each alternative may consist of an individual technology or a combination of technologies. These alternatives are screened to eliminate those that are more costly, provide inadequate health protection, or have adverse environmental impacts. Select the lowest-cost alternative that effectively mitigates and minimizes damages and provides adequate protection of public health and the environment.

Development and selection of the site remedial action is dependent on the type of TxDOT project, workers and public health, surface water quality, groundwater quality, and air quality. When these objectives are determined, candidate remedial action alternatives can be developed and measured against criteria such as reliability and effectiveness, implementability, operation and maintenance requirements, and costs.

The first step is to establish remedial action objectives based on reducing the level of contamination to acceptable levels. The treatment should be typified by performance specifications if possible so that, when achieved, assure that the TxDOT objectives are met. The remedial action alternatives developed must be appropriate to the site for each pathway and

contaminated environmental medium. The identified remedial alternatives must also be consistent with the objectives and criteria developed above.

At any site, the generic remedial action alternatives can be categorized as follows: (1) no action, (2) containment, (3) on-site/in-situ remedial treatment, and (4) off-site treatment and disposal. The final list of generic remedial alternatives can then be expanded from general concepts to specific remedial action alternatives for comparative screening.

3.3.a.4. STEP 4: SCREENING OF ALTERNATIVE REMEDIAL METHODS

The alternative remedies should be evaluated in detail. Several evaluation criteria are considered:

- (1) What is the overall protection to human health and the environment?**
(RG-36)
- (2) Is it an established or emerging treatment technology, containment technology or land disposal?**
(Chapter 5, EPA documents)
- (3) Does it comply with federal and state regulations (ARARs) and standard specifications ?**
(Chapter 6, EPA, TNRCC, RRC, ASTM)
- (4) What is the short and long term cost effectiveness?**
(Partial or total stoppage of construction work, protection to workers, modification to construction project, post monitoring requirements)
- (5) What is the reduction in toxicity, mobility, and volume?**
(Eliminate toxicity, permanency of treatment, immobilization, change in volume)
- (6) What is the cost?**
(Chapter 6)
- (7) How many remedial technologies should be selected?**
(No more than three)
- (8) Are these technologies acceptable to the community?**

All these factors must be considered and the potential technologies should be ranked based on the above mentioned criteria.

3.3.a.5. STEP 5: REMEDIAL INVESTIGATION /FEASIBILITY STUDY (RI/FS) REPORT
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A feasibility study report must be prepared using the data and information collected from Steps 1 through 4. It should indicate how various remedial technologies were evaluated and selected. No more than three remedial technologies must be selected. A preliminary design report on implementing remediation technologies for the site will a part of the feasibility report. The design report will include the following sections:

- (1) Necessary qualifications of the contractor to perform the remedial work
- (2) Conceptual design criteria for remedial process
- (3) Important steps in the remedial process and methods to ensure quality control if possible
- (4) Implementation of the remedial process
- (5) Methods of monitoring of the remedial work during the process
- (6) Any special conditions/requirements for the site
- (7) Time needed for remedial work

3. 3. b. PHASE III (b): CORRECTIVE ACTION PLAN (CAP)

It is important to develop a corrective action plan (CAP) to handle the contamination on the site. TNRCC may or may not require a CAP depending on the level of contamination and the intended use of the site. Should TxDOT have any questions regarding the need for CAP, the TNRCC coordinator for the Remediation Section in Austin, Texas must be contacted. If a CAP is required by TNRCC the following procedure can be used to develop a comprehensive CAP for the site [TNRCC, RG-36]. The identification and quantification of risks to human health and the environment from uncontrolled and highly complex hazardous waste sites is difficult. Risk assessment and site cleanup usually has to proceed on the basis of very limited knowledge. Even if a CAP is not required, it is in the best interest of TxDOT to develop a comprehensive CAP for the site.

3. 3. b. 1. STEP 1: RISK ASSESSMENT

The first step in the CAP process is to establish risk-based target concentrations. The PST Division of TNRCC has established two risk-based evaluations, Plan A and Plan B [RG-36]. The Plan A evaluation is a comparison of the maximum contaminant levels at a site to a table of conservative target cleanup goals based upon the appropriately selected beneficial ground water use category and land use (example: residential, commercial or industrial). The site should first be screened under Plan A for possible site closure, to set target cleanup goals, or to determine the need for further evaluation under Plan B.

a. How to determine target cleanup goals?

Plan B evaluation involves the determination of site-specific target cleanup goals based upon site specific information. In most cases, a Plan B evaluation will result in more appropriate (often, less stringent) target cleanup levels than those that would have been established under Plan A. Remediating a site to a less stringent target cleanup levels usually results in substantial cost and time savings; therefore, the TNRCC highly recommends the use of the Plan B evaluation in establishing target cleanup levels for all LPST sites.

PHASE III (b): Corrective Action Plan (CAP)

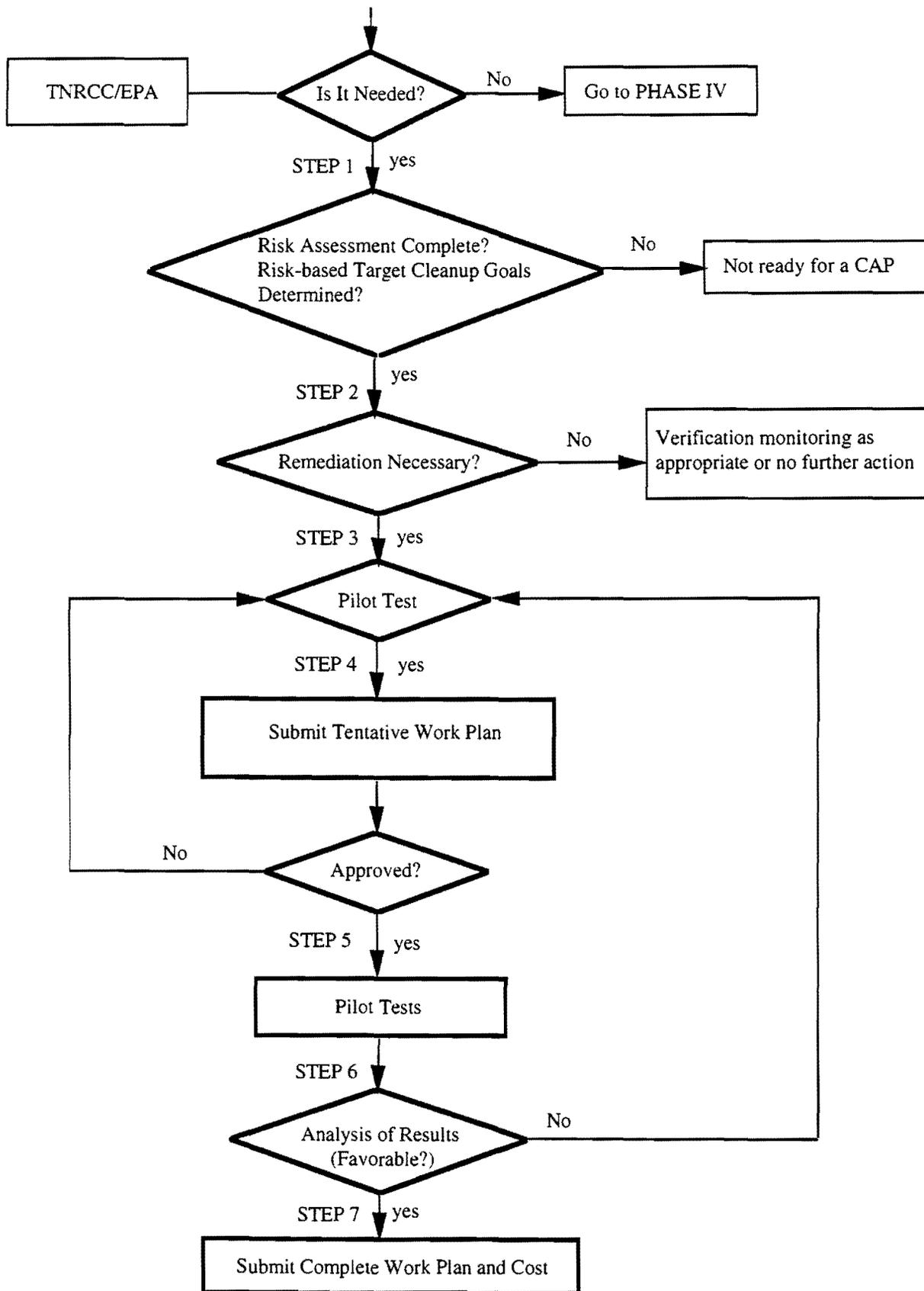


Figure 3.3 b. Flow Chart for Corrective Action Plan

3. 3. b. 2. STEP 2: IS REMEDIATION NECESSARY ?

Following evaluation under Plan A or Plan B procedures, one can determine whether remediation is necessary at the site. If remediation is necessary, the target cleanup goals that must be met at the site are those that were determined in the Plan A or Plan B evaluation.

3. 3. b. 3. STEP 3: IS PILOT TEST NECESSARY?

Once the need for remediation and the target cleanup goals have been established, the next step is to determine what type of remedial technologies might be appropriate for the site. Based on the remedial technology for the possible use, identify any pilot or feasibility tests that may be required to demonstrate the feasibility of the selected technology and to collect data essential for system design. Pilot tests are required for most types of remedial technologies, including soil vapor extraction, bioventing, air sparging, and bioremediation. In addition, aquifer pump tests are required for any remedial system involving groundwater extraction.

TxDOT can perform the pilot test or subcontract the work out.

Some of the questions related to this step are as follows:

- (1) **Who will do the PILOT test?**
(Specialty Contractor, TxDOT District Office/Austin)
- (2) **Who will do the monitoring of the test?**
(Specialty Contractor, Consultant, TxDOT)

3. 3. b. 4. STEP 4: SUBMIT WORK PLAN

Once the need for pilot and/or aquifer pump tests are identified, submit a work plan/cost proposal (if eligible for reimbursement) and a brief description of the remedial technologies being considered for the site to the TNRCC coordinator for the proposed activities.

Some of the questions related to this step are as follows:

- (1) **Who will develop the work plan?**
(Specialty Contractor, TxDOT District Office/Austin)

3.3.b.5. STEP 5: COMPLETE PILOT TESTS

Following preapproval of the proposed activities, complete pilot tests on all potential remedial technologies considered for the site.

3.3.b.6. STEP 6: ANALYSIS OF TEST RESULTS

Following preapproval of the proposed activities, complete all necessary remedial technologies considered for the site, re-evaluate the need for additional pilot testing or alternative remedial methods. If the results are favorable, select the appropriate technology and move forward in the CAP process.

3.3.b.7. STEP 7: SUBMIT WORK PLAN

At this point in the CAP process, TxDOT should submit a work plan/cost proposal (if eligible for reimbursement) for the development of a CAP [TNRCC RG-36] using the selected remedial technology for the site. The results of any pilot and/or aquifer pump tests; a discussion of why the selected remedial technology was chosen over other technologies; a brief conceptual discussion of the proposed CAP; and the Remedial Technology Screening (RTS) form must be included with the work plan/cost proposal for the preparation of a CAP.

CAP WORKSHEETS : New CAP worksheets have been developed that are technology-specific and are intended to facilitate TNRCC review of CAPs. Completion of the CAP worksheets will ensure that the minimum criteria necessary for approval of a CAP is submitted and will facilitate TNRCC review by providing the critical information in a concise and consistent manner. The CAP worksheets for the selected remedial technology are required and must be included with the CAP. If two or more remedial technologies will be combined at a site, then all applicable CAP worksheets must be completed. When submitting more than one CAP worksheet, it is not necessary to duplicate some of the supporting documentation. The CAP worksheet, "Ground water Extraction" must be completed whenever ground water extraction is being performed, either by itself or in conjunction with another remedial technology.

All information supplied on the CAP worksheet for the specified technology(ies) must be supported by data and calculations wherever applicable. Include any equipment brochures, contractor information and remedial system component specifications from the contractor.

3. 3. 3. PHASE III (c): PERMITS AND CONTRACTING

3. 3. 3. STEP 1: SUBMIT CAP TO REGULATORY AGENCY

The CAP must be submitted to TNRCC with all the necessary and supporting documents. The time for approval must be verified at this time with the appropriate authorities. After the CAP is approved by the TNRCC, submit a Notice of Remedial System Installation (NRSI) form (TNRCC-0694) to both the appropriate TNRCC Regional Office and the Central Office in Austin.

TxDOT or the designated party must get the CAP approved before proceeding with the rest of the work. The delay in approval can be substantially reduced if the TNRCC officer for the project is identified in time. Having a MOU (memorandum of understanding) between the TxDOT and TNRCC will go a long way in reducing the delay in getting the CAP approved.

Some of the questions related to this step are as follows:

(1) How soon will the CAP be approved?

(Weeks, months)

3. 3. 3. 2. STEP 2: SELECT CONTRACTOR

In order to implement the CAP, TxDOT can hire a specialty contractor or use its trained employees. The majority of the other state DOTs use speciality contractors and some have standby contractors already in place for rapid response to the problem. In fact, several states indicated that a key element of their contracts required that the contractor be on the site within 24 hours of notification. Other DOTs indicated that they were securing contractors on a case-by-case basis, but that they were either considering or moving to a standby contract. In addition, some DOTs use multiple consultants, with one responsible for carrying out the task and another responsible for oversight of that consultant and for verification of the completion and effectiveness of the solution. With the ability to get a rapid response and to have a firm control over the remediation process some DOTs are planning to develop their inhouse expertise to conduct the remediation [NCHRP Report No. 351]. TxDOT should also consult with TNRCC to get information on potential contractors. TNRCC Innovative Technology Program has developed a vendor list for various treatment methods. Some of the typical questions that need to be asked are as follows:

PHASE III (c): Permits & Contracting

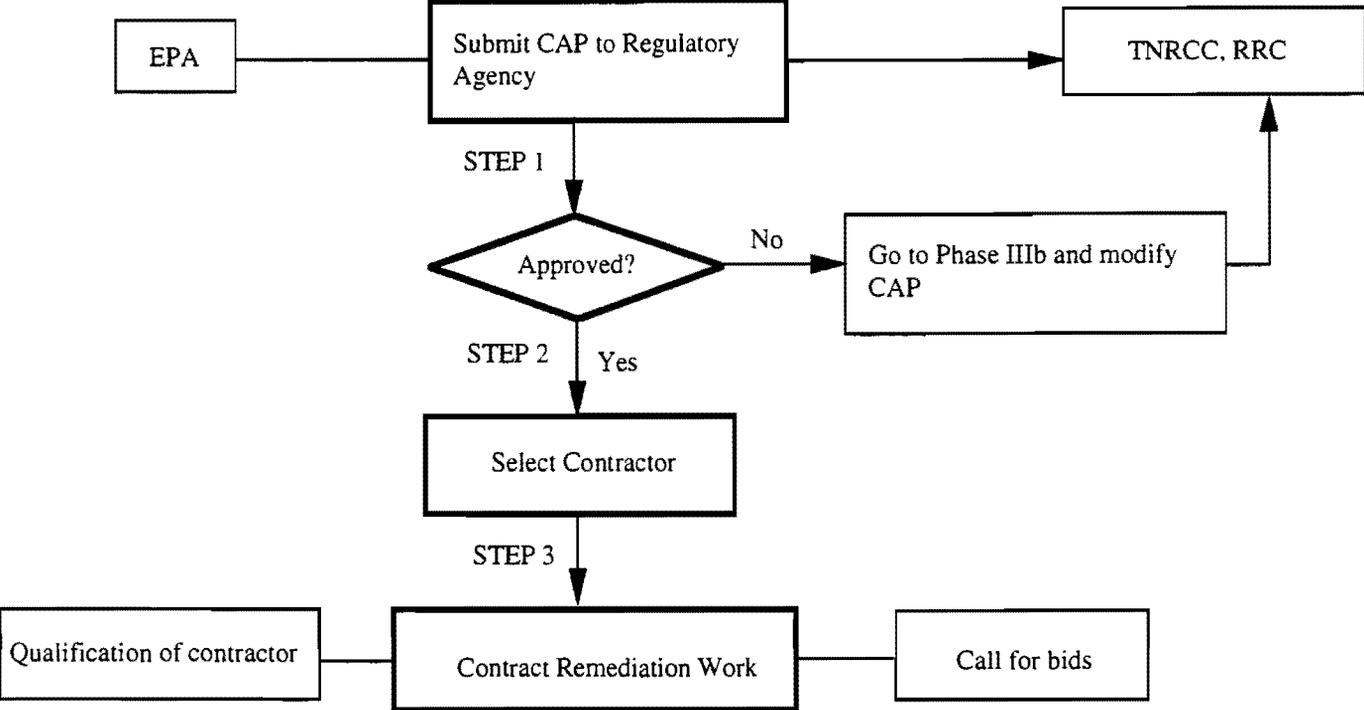


Figure 3.3c. Flow Chart for Permits and Contracting

(1) How is contractor selected?

(TNRCC list, EPA vendor list, World Wide Web)

(2) Is special training and insurance needed?

(OSHA requirements, TNRCC)

3. 3. 3. 3. STEP 3: CONTRACT REMEDIATION WORK

Working with the contractor, the TxDOT engineer must identify the actions to be taken on the site that will lead to achievement of the remedial goals. The contractor shall prepare and submit to the TxDOT engineer for approval a preliminary network analysis of the remediation progress schedule within a specified time (recommened ten (10) days) after award of contract. This method of analysis is generally referred to as the Critical Path Method/CPM). This analysis shall include as a minimum a graphic representation of not less than 50 significant activities and events involved in the construction of the project, and a written statement explanatory thereof if necessary, for a complete understanding of the diagram. The network graphic representation (Arrow Diagram) and statement must clearly depict and describe the sequence of activities planned by the contractor, their interdependence and the times estimated to perform each activity. All time shall be shown in 'working days.' The Contractor shall include with the initial schedule calendar dates for each activity.

a. Health and Safety Plan

Adequate and effective health and safety plans for all workers involved in the remediation work are a key concern for known hazardous waste problems. Health and safety plans are critical elements of any remedial action plan. It should be noted that the contractors are subject to OSHA and EPA hazardous waste site health and safety regulations. Nevertheless, responsible contract oversight dictates that TxDOT project managers have full knowledge of the regulations that apply to construction contractors. In fact, training of TxDOT staff may often be arranged through specialized remediation consultants and contractors.

b. Work Area Security

The drawings should indicate the area requiring fencing to completely isolate the contaminated area from regular traffic and disturbances. The Contractor shall be responsible for all costs associated with relocating existing fences, providing additional fences, maintaining all fences during remediation and removing temporary fencing at the conclusion of remediation. Because each site holds unique health hazards, both known and unknown, it is mandatory that the contractor implement remediation strictly in accordance with the CAP. The contractor must retain the ability to resourcefully react to unforeseen circumstances.

3. 4. PHASE IV: SITE CLEAN-UP

The primary objective is to implement the approved procedures in the shortest possible time. Hence schedules and time sequence of actions must be developed for remedial actions. Other elements important to implementation are management and administrative considerations. The flow chart for PHASE IV is in Figure 3. 4.

3. 4. 1. STEP 1: DEVELOPMENT OF THE PROJECT SCHEDULE

Advance planning avoids unnecessary delays during execution of the project. As an aid to this planning, the contractor should develop a summary sheet listing required actions. The schedule should identify the field and administrative activities in sequential order, and reflects the interdependencies of each.

When developing the schedule, the contractor can use the following guidelines:

1. Description of each major task and responsible party.
2. Starting and ending dates for each major task
3. Remarks about the possible critical nature of each task or potential slack time available.

A graphic schedule of the project will display a detailed listing of tasks with predecessors and successors as well as start dates and duration of the activities.

a. Project Organization

The organization of the parties to a remediation project is a fundamental concern and is critical to the progress of the work. No site undergoing remediation is typical, and none proceeds according to the remediation plan without deviation. Under such circumstances, the plan of the work has to be changed immediately. Representatives of the parties of interest who have decision-making authority must be available and willing to make the necessary decisions expeditiously; and, so that they can reach a consensus, the lines of authority and communication must have been specified in advance.

Two types of organization are delineated and announced prior to the start of work: the internal organization of each party (contractor and TxDOT) and the way the parties interact. Further, within each party, two components are defined:

1. The degree of authority for each individual.
2. The availability of each key decision-maker.

PHASE IV: Site Cleanup/ Remedial Implementation

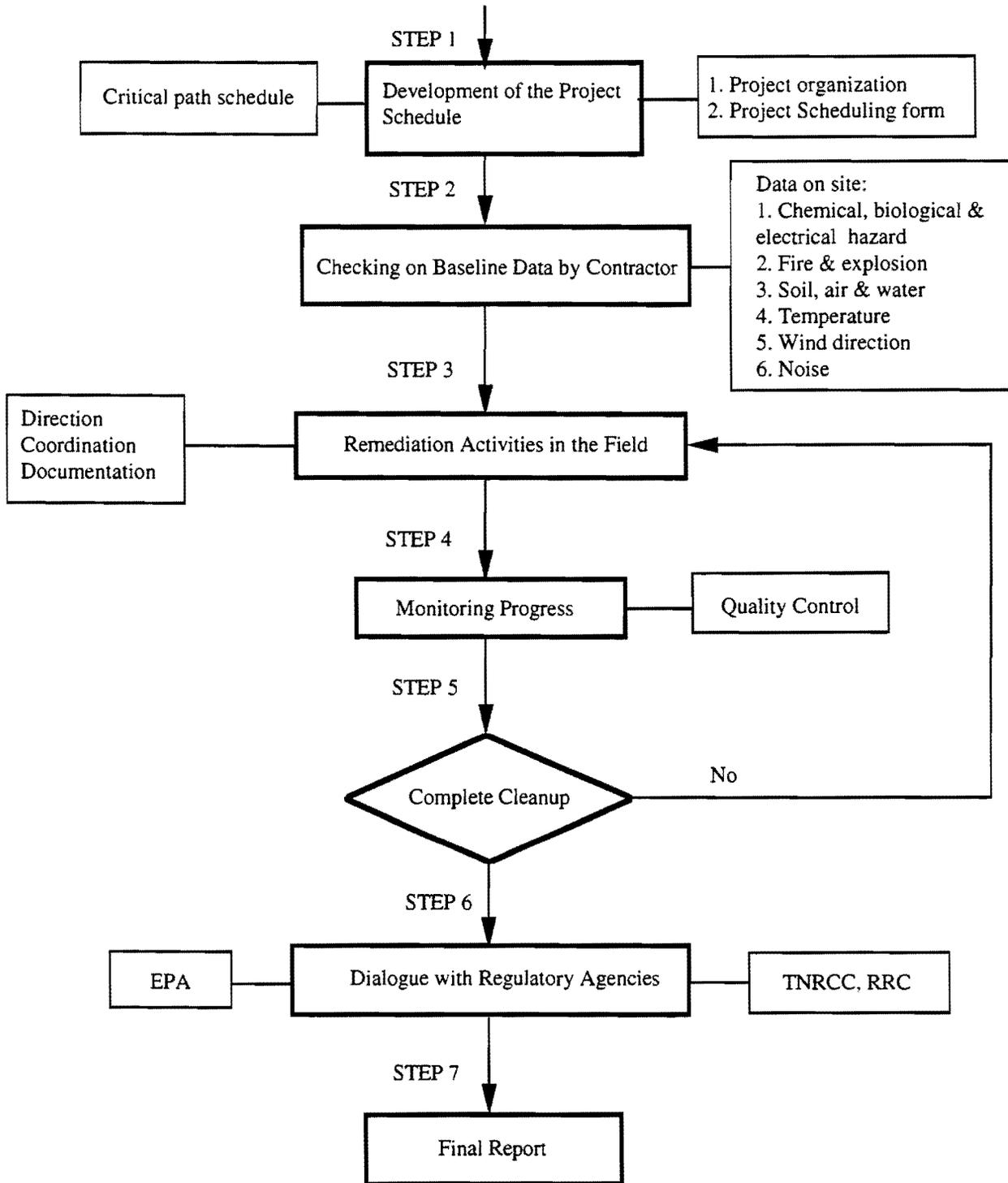


Figure 3.4. Flow Chart for Site Cleanup

As the work on the site progresses, it is important that supervision be provided by individuals with decision-making authority or that responsible individuals be available at all times.

In every case the organization should be designed to maximize communication among decision-makers. The responsible party communicates with the TNRCC on a regular basis or on preselected dates and then advises both the TxDOT engineer and the contractor. Throughout the term of the project, the principal parties confer periodically. These meetings are used to clarify all outstanding issues and questions, and they permit the regular reviews of the progress of the remediation.

b. Work Schedule

TxDOT's engineer can approve or request for modifying the network analysis submitted by the contractor (PHASE IIIc). The Contractor should be required to obtain written approval of the Work Schedule from the TxDOT Engineer prior to initiating the work and shall submit updates of the Work schedule on a monthly basis or as requested by the TxDOT engineer.

Some of the questions related to this step are as follows:

- (1) **Have important tasks and responsible persons been identified?**
(Contractor, TxDOT engineer, TNRCC representative, third party consultant).
- (2) **Has time for each task assigned?**
(Days, weeks, months).
- (3) **Has the chain of command been identified?**
(Contractor, TxDOT).
- (4) **Have the TNRCC contacts been identified?**
(Regional, Headoffice in Austin).
- (5) **Are there any room for changes/modification in the project schedule?**
(Delay due to weather, changes in site condition, equipment breakdown).

3. 4. 2. STEP 2: CHECKING ON BASELINE DATA

Before any work begins on the site, it is important that the contractor collect and record data describing the site and the physical condition of the people who will work on the site. This is done for the contractor's protection. This data is the baseline against which future data will be compared.

Typical categories of data collected about hazards on the site can be summarized as follows:

- (1) Chemical exposure (via any route)
- (2) General safety hazards (treacherous terrain, heavy equipment)
- (3) Fire & explosion
- (4) Biological hazards (infectious wastes or poisonous plants or animals)
- (5) Electrical hazards
- (6) Temperature (heat stress, exposure to cold)
- (7) Noise
- (8) Air pollution
- (9) Water (storm water/wastewater)

The major environmental factors are:

1. Soil : The area where the ground's surface has been contaminated is marked before workers are allowed on the site. During remediation, dust and water erosion can cause contamination to become concentrated or broadcast
2. Presence or absence of explosive conditions
3. Average temperature and humidity, also temperature and humidity extremes
4. Wind direction: The prevailing winds travel across neighboring residences, they might carry smells, or dangerous organic compounds to the inhabitants. It is mandatory that the contractor find ways to prevent the migration of hazardous substances.

All right-to-know laws, regulations of OSHA, and labor laws are followed to the letter, both to protect worker's safety and to preempt any claims of negligence against the contractor and/or TxDOT after the work is complete. Once the remediation has begun, it is necessary to monitor continually the environmental parameters and the health of workers. This data is recorded and maintained. All parameters monitored at the outset are checked periodically during the progress of the remediation, although the individual parameters should be monitored at different frequencies.

Some of the questions related to this step are as follows:

- (1) **Who should collect and document data?**
(Contractor and TxDOT Engineer)

3. 4. 3. STEP 3: REMEDIATION OF SITE

Once the project has been planned, the schedule has been laid out, and all issues have been addressed by the contract documents or consent order, the actual remediation of the site may commence. From the beginning of the project it is essential that the project manager:

1. Direct the progress of the work to ensure that it advances correctly.
2. Coordinate the individual tasks, and communicate with organizations involved in the work.
3. Document all aspects of the work and discussions with TxDOT and TNRCC.

The contractor follows the basic practices of construction management in implementing the remedial alternative. These practices include schedule control, quality control, competitive pricing and purchasing, project cost monitoring, and man power allocation.

Some of the questions related to this step are as follows:

- (1) **Are there any possible delays in starting project?**
(Weather, TNRCC approvals, Equipment problems).

3. 4. 4. STEP 4: MONITORING PROGRESS AND DOCUMENTATION

Site remediation must be monitored and documented. In a hazardous site, such control is necessary because not only must the project proceed according to the accepted plan, but problems must be viewed with as much foresight as possible in order that positive solutions can be prepared. The monitoring also includes quality control.

Throughout the course of a remediation project, it is the role of the project manager to maintain high standards for the work. The quality control data should be prepared in a specifically designed form which then becomes the basis for the documentation of quality control efforts.

a. Documentation

The project manager must determine the amount of record keeping that is sufficient. Documentation is necessary for several reasons, its primary purpose is to permit investigators to reestablish the level of effort that was expended on the site, it also certifies how and when the work was performed, and whether or not the work was done in accordance with the

established remediation requirements (CAP). When a hazardous waste site is corrected, the following records, at a minimum, must be maintained.

A diary records daily events such as conversations, site visits, daily activities, and statistics on the labor and equipment resources expended. Daily reports are taken from the diaries and summarize this data. Prior to the start of the project, photographs are taken of the site to record its condition before remediation. During remediation, photographs are taken to document every phase and aspect of the work. Video equipment is especially useful in this regard. Additional data and documentation may be required if the project poses special problems, if cost information is especially important, or if the public insists upon it.

Some of the questions related to this step are as follows:

- (1) **How often should the remediation operation be monitored?**
(Daily, weekly, monthly)
- (2) **How many photographs are needed?**
(Before, during and after remediation)
- (3) **What are the methods for documentation?**
(Written notes, photographs, video tapes, audio taping interviews)

3.4.5. STEP 5: COMPLETE CLEAN-UP

The TxDOT engineer (or representative) must ensure that the whole site clean-up has been completed according to the CAP. If the cleanup is unsatisfactory the contractor must go back to the site to perform additional remediation and meet the clean-up levels set forth in the CAP document or TNRCC regulations or to the satisfaction of the TxDOT engineer.

Some of the questions for this step are as follows:

- (1) **Who should check clean-up?**
(TxDOT engineer, TNRCC representative, third party consultant)
- (2) **What should be checked?**
(Soil sample, leachability, groundwater samples)
- (3) **If the treatment results are different from CAP, what should be done?**
(Inform TNRCC and contractor, additional treatment at contractors cost)

3.4.6. STEP 6: DIALOGUE WITH REGULATORY AGENCIES (EPA, TNRCC, RRC)

After every aspect of the entire remediation (initiation, planning, implementation, review) is executed according to CAP, TNRCC must be informed. One function of the TNRCC

official responsible for the remediation is to interpret the specific requirements and to explain further the regulations as applied to the specific TxDOT job. Therefore, communication between, on the one hand, the contractor and the responsible party (TxDOT), on the other hand, the TNRCC must be maintained throughout the work effort. It is in the best interest of TxDOT to have continuous dialogue with TNRCC.

Some of the questions for this step are as follows:

- (1) **Who should be contacted?**
(TNRCC, contractor for construction)
- (2) **What information must be presented?**
(Consultant report, TxDOT in-house report, complete TNRCC standard form)
- (3) **Does this require any special training?**
(OSHA, TNRCC/ RG-41)
- (4) **Are there any federal or state requirements?**
(TNRCC/RG-261)
- (5) **How often should the measurement be taken ?**
(Hourly, daily, weekly, monthly, quaterly, semi-annually)

3.4.7. STEP 7: FINAL REPORT

The entire clean-up operation must be dated and documented. Monitoring methods in place must be clearly discribed. The level of treatment achieved must be documented.

Report should address the following questions.

- (1) Was the clean-up done in accordance with the CAP? Any deviation from the original plan?
- (2) Any supprises during the remediation process?

3. 5. PHASE V: POST SITE MONITORING

Once the clean-up has been completed the site should be monitored on a timely basis for a certain period of time to assess the quality of clean-up achieved and to monitor migration of contaminants from adjoining sites. PHASE V can be done by TxDOT engineers or by a consultant. The flow chart for PHASE V is in Figure 3. 5.

3. 5. 1. STEP 1: IDENTIFY MONITORING METHODS

Selection of monitoring methods will depend on the type of contaminant (VOC, petroleum), medium (soil, groundwater, sludge) and type of treatment. TNRCC RG-261 guidance document, Operation, Monitoring and Performance (OMP) of Remedial Systems (1996) can be used as reference to identify the monitoring methods.

Some of the questions for this step are as follows:

- (1) **What needs to be measured?**
(VOC, metal, PAH, groundwater).
- (2) **Can TxDOT do it ?**
(Equipment availability, cost, other alternative, consultants)
- (3) **Does it require any special training?**
(OSHA, TNRCC/ RG-41).
- (4) **Are there any federal or state requirements?**
(TNRCC/RG-261).
- (5) **How often should the measurements be taken ?**
(Hourly, daily, weekly, monthly, quaterly, semi-annually).

3. 5. 2. STEP 2: SELECT LOCATIONS ON SITE

In order to monitor the treatment efficiency, several sampling points should be selected.

- (1) **Any spacing requirement for sampling?**
(Minimum/maximum spacings for monitoring wells; Interference with construction project, accessability)

PHASE V: Post Site Monitoring

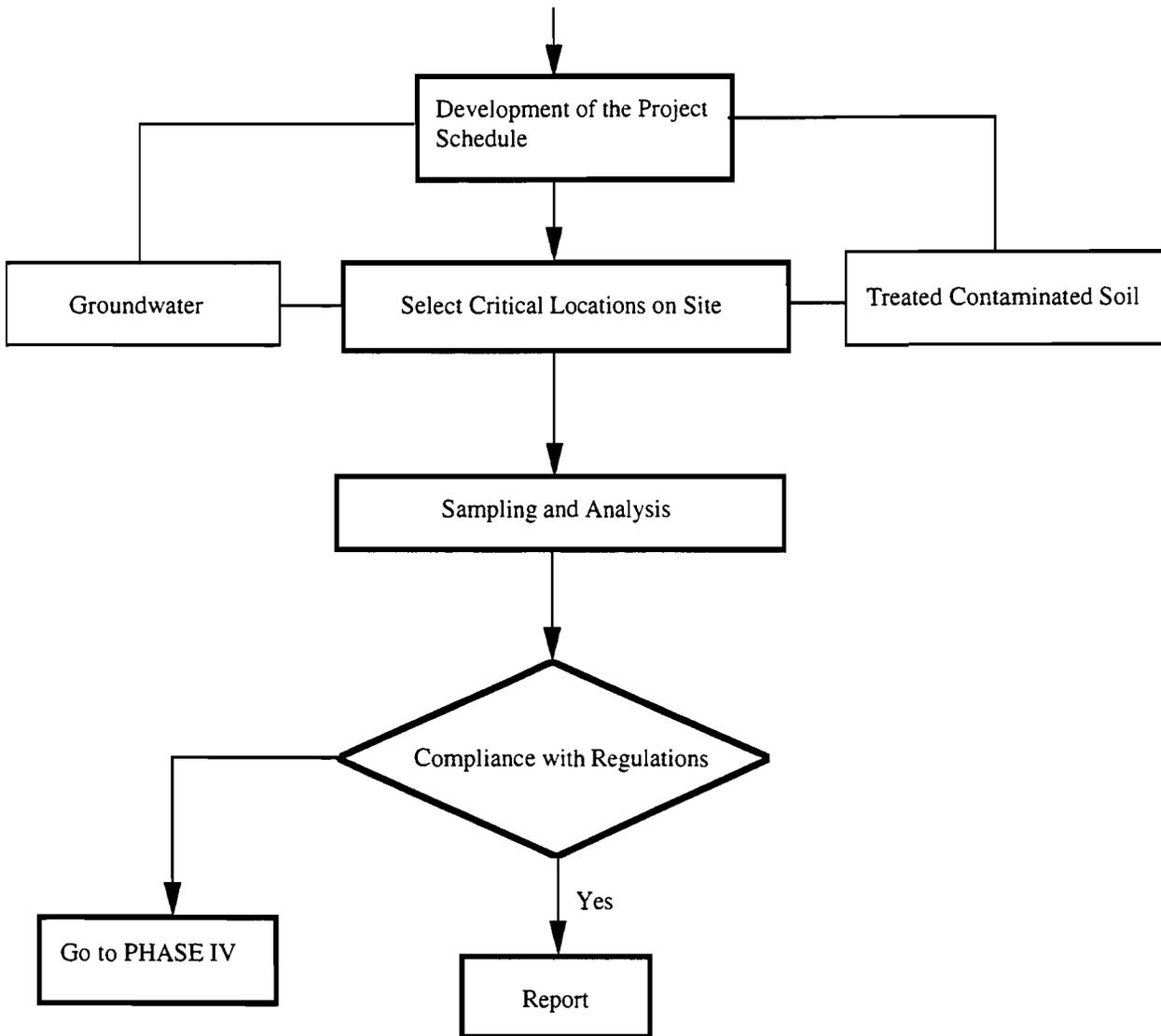


Figure 3.5. Flow Chart for Post Monitoring

3. 5. 3. STEP 3: SAMPLING AND ANALYSIS

Sampling interval, amount and depth of sampling must be established. Adequate samples should be collected. Collected samples can be analyzed in the field or transported to a testing laboratory. Chain of custody of the samples should be maintained.

Some of the questions for this step are as follows:

- (1) **What are the type of tests?**
(Leaching (TCLP, TNRCC), compressive strength, vapor analysis, moisture content)
- (2) **How many samples ?**
(Types of tests, accuracy)
- (3) **How to store specimens?**
(TNRCC/ RG-41)
- (4) **How long tests are planned?**
(TNRCC/RG-261)
- (5) **What type of equipment will be used for waste analysis ?**
(GC, ICP, IC, compressive strength, oven (CHAPTER 4))

3. 5. 4. STEP 4: COMPLIANCE WITH REGULATIONS

Contaminants in the samples should be below the TNRCC and EPA limits.

Some of the questions for this step are as follows:

- (1) **What are the acceptable limits?**
(EPA, TNRCC, see Appendix)

3. 5. 5. STEP 5: REPORT

An annual report must be prepared based on the Post Monitoring test results. If a consultant was used for Post Site Monitoring, the report should be submitted to TxDOT. TxDOT can file this document with the TNRCC to indicate compliance with the CAP and to clear the site of contamination and unlist the site for further monitoring if necessary.

3. 6. CONCLUSIONS

A comprehensive Hazardous Waste Mangement Plan with five PHASES has been developed for handling contamination in construction sites. Information collected from various sources (EPA, FHWA, OSHA, TNRCC, State DOTs, ASCE, ASFE and ASTM) have been effectively combined in developing the HWMP.

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Chapter 4

Environmental Site Characterization

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4. 1. INTRODUCTION

Federal regulations such as RCRA and CERCLA, and State guidelines from TNRCC require environmental site characterization and monitoring to detect contamination and to provide data to develop plans for site remediation [12, 15, 21]. Environmental site characterization is the corner-stone of most projects with contamination problems [1, 6, 7, 14, 18]. By achieving a reasonable level of site characterization, it can assure that the risk assessment (PHASE III (b)) and site clean-up (PHASE IV) of a project can be reasonably successful.

There are three key components to environmental site characterization:

- (1) determining the spatial changes in the site's geology and hydrology;
- (2) defining the spatial distribution of contaminants and predicting their movement; and
- (3) quantifying the engineering properties of soil, rock, groundwater and type of contamination.

Hundreds of methods and techniques exist for characterizing, sampling and performing waste analysis on soils and water in the saturated and unsaturated zones in the contaminated sites [ASTM Vols. 04.08 and 04.09]. The primary factor affecting the accuracy of any environmental site characterization effort is the limited number of sample points or borings, resulting in insufficient spatial sampling to adequately characterize the site. To achieve a reasonable statistical sampling of hydrogeologic site conditions can require borings or other methods of sampling placed in a close-order grid. The number of borings required to detect a burial site, tank, or permeable pathway can be calculated [6, 7]. Such calculations show that it is not uncommon to require 100's to 1,000 of borings to achieve a 90% confidence level for detection. But in practice only a limited number of borings and other methods of sampling to characterize large areas and complex geologic settings are made. Also included in this chapter are soil, groundwater and soil gas sampling methods and waste analysis methods.

4. 2. IN SITU TEST METHODS

4. 2. 1. GEOPHYSICAL METHODS

Each geophysical method responds to some physical, electrical, or chemical parameter of the soil, rock and pore fluids or buried wastes [2-4, 8-10, 19, 20, 26, 28-31]. They respond to either (1) electromagnetic energy, (2) acoustic and seismic energy and (3)

other potential field such as gravity and earth's magnetic field. Therefore, for a geophysical method to detect a change in geologic conditions or contaminants there must be a sufficient contrast in the property being measured. Remote, surface [ASTM PS 78-97] and borehole [ASTM D 5753] geophysical measurements can be made relatively quickly. Continuous data acquisition can be obtained with certain geophysical methods at speeds up to several miles per hour. In some cases, total site coverage is economically possible. Because of the greater sample density using geophysical methods, anomalous conditions are more likely to be detected and background conditions defined, resulting in an accurate characterization of surface and subsurface conditions.

The geophysical methods encompass a wide range of airborne, surface, and borehole methods which can be used to improve the accuracy of site characterization. Geophysical methods, like any other means of measurement, have advantages and limitations. There is no single, universally applicable surface or borehole geophysical method to meet all site characterization needs. There are over 30 remote sensing and surface geophysical methods and hence the user must be able to select the method or methods carefully and understand how they should be applied to specific site conditions to meet project requirements. Radar has the highest resolution (both horizontally and vertically) of any surface geophysical method and can delineate targets as small as reinforced steel bars in concrete. The resolution of all of the surface geophysical methods decreases with increasing depth.

4. 2. 1. 1. Remote Sensing Methods

Eight technologies have been identified in this category [EPA 625/R-93/003a]. Remote sensing is often restricted to the use of airborne sensing methods in the visible and near-visible spectrum. Some of the questions related to remote sensing are as follows:

1. What are some of the remote sensing methods?

(visible photography, infrared photography, ultraviolet photography, thermal infrared scanning, multispectral imaging, active microwave (radar), airborne electromagnetics (AEM) and aeromagnetism [EPA/625/R-93/003a].

2. When will remote sensing be used?

(CASE 2, PHASE I)

3. Can it detect contaminants? what type?

(Yes, if located on the surface.)

4. Can it detect buried objects ?

(No; Only disturbed surfaces due to buried waste can be detected.)

5. Can it detect contamination in the soil/ground water?

(No)

6. Penetration depth and cost?

(Surface only; low cost)

7. Most popular remote sensing method?

(Visible photography)

4. 2. 1. 2. Surface Methods

Twenty four technologies have been identified [EPA/625/R-93/003a]. Some of the questions related to this technology are as follows:

1. What are some of the popular surface methods?

(Ground penetrating radar (GPR), electromagnetic induction, electrical resistivity [ASTM G 57], seismic refraction [D 5777], metal detection and magnetometry [EPA/625/R-93/003a].

2. When will surface methods be used?

(CASE 2; PHASE I & II)

3. What are the applications?

(Details are in Table 4.1)

4. 2. 1. 3. Borehole Logging Methods

There are more than 40 borehole geophysical techniques. This technique most commonly uses probes that are lowered on a cable. Some of the questions related to this technology are as follows:

1. What are some of the types of logging methods?

(Electrical and Electromagnetic Logs, Nuclear Logs, Acoustic and Sonic, and Seismic Logs, and Miscellaneous Logs)

2. What are some of the popular electrical logging methods?

(Resistivity, Fluid conductivity)

3. What is the popular electromagnetic logging method?

(Induction)

4. What are some of the popular nuclear logging methods?

(Neutron, Gamma-Gamma, Natural Gamma)

Table 4. 1. Typical Applications for Surface Geophysical Methods

	Application	Radar	Electro magnetics	Resistivity Sounding	Seismic	Magneto meter
1. Natural Conditions						
a	Layer thickness and depth of soil and rock	1	2	1	1	NA
b	Mapping lateral anomaly locations	1	1	1	1	NA
c	Determining vertical anomaly depths	1	2	1	1	NA
d	Depth to water table	2	2	1	1	NA
2. Sub-Surface Contamination Leachates /Plumes						
a	Existence of conductive contaminants	2*	1	1	NA	NA
b	Mapping contaminant Boundaries	2*	1	1	NA	NA
c	Determining vertical extent of contaminant	2*	2	1	NA	NA
d	Quantify magnitude of contaminants	NA	1	1	NA	NA
e	Determine flow direction	2*	1	1	NA	NA
f	Detect organics floating on water table	2*	2*	2*	NA	NA
g	Detection & mapping of contaminants within unsaturated zone	2	2*	1	NA	NA
3. Location and Boundaries of Buried Wastes:						
a	Bulk Wastes	1	1	1	2	NA
b	Non-metallic containers	1	1	1	2	NA
c	Metallic -ferrous containers	2	1	NA	NA	1
d	Metallic-non-ferrous	2	1	NA	NA	NA
e	Depth of burial	2	2	1	2	2*
4. Others						
a	Location of pipes, cables, tanks	1	1	NA	2	1
b	Identification of permeable pathways due to utility trench fill	1	1	NA	2	1
c	Abandoned well casings	NA	NA	NA	NA	1
5. General Information						
a	Penetration depth (m)	<1-25	0.75-60	0-100	1-30	0-5
b	Cost ³	M	L-M	L-M	L-M	L-M

Note: 1-Denotes primary use; 2- Denotes possible applications, secondary use. In some cases this may be the only effective approach due to circumstances. NA- Not Applicable. *-limited applications; 3- Cost ratings are relative and approximate: L = low, M = moderate, = high

5. What is the popular acoustic and seismic logging methods?

(Acoustic Velocity/Sonic method)

6. Typical bore hole diameter?

(38 to 100 mm diameter)

7. What factors to select in borehole techniques?

(Subsurface characteristics, Casing (cased/uncased), Borehole condition (wet (conductive fluid), dry)

8. Are there any ASTM standard?

(Yes. D 5753)

4. 2. 2. CONE PENETROMETER

The cone penetration test (CPT) involves hydraulically pushing a cone-shaped instrument into the soil and measuring resistance to penetration, pore pressure development and collecting samples of soil, gas and groundwater for analyses [ASTM D 3441, D 4633, D 5778]. Also in situ hydraulic conductivity can be determined. With a variety of in situ physical and chemical sensors, this technology is being increasingly used for environmental site characterization [11, 14]. Some of the questions related to CPT are as follows:

1. When can CPT be used?

(CASE 1, 2, 3 & 4, PHASE I, II & V)

2. What is the maximum depth?

(30 to 100 m depending on geology and push capacity of the system)

3. Can it be pushed through asphalt and concrete?

(Yes for asphalt. No for concrete)

4. Are there any ASTM standard?

(Yes. D 5778)

4. 3. SAMPLING METHODS

The location, type of samples collected, and sampling equipment should be in accordance with the sampling plan developed in the detailed site investigation plan [1, 18]. Sampling equipment and procedures should be appropriate for the medium being sampled (soil, groundwater, gas) and be designed to minimize the introduction of errors into physical and chemical test results. Table 4.2 summarizes the commonly used techniques for sampling.

4. 3. 1. Solids (Soil) Sampling

The primary objectives of soil sampling programs are generally to determine the surface area and vertical extent of soil contamination. Soil sampling can be done with hand operated or power driven equipment. Some of the questions related to soil sampling are as follows:

1. What is the difference between regular and environmental soil sampling?

(Same methods except that precautions must be taken against contaminating adjacent strata/areas; Sampling tubes have to be lined to avoid chemical reactions; Equipment must be decontaminated before next use or leaving site)

2. What are some of the hand operated sampling methods?

(Scoops, spoons, shovels, hole diggers, tubes, and augers (several types))

3. What are the advantages of scoops and spoons?

(Inexpensive, easy to use, readily available, easily decontaminated, easily transportable)

4. What are the advantages of hand operated augers?

(Inexpensive, easy to use, readily available, easily transportable, large volume of samples)

5. To what depth can hand-operated samplers be used?

(2 to 3 meters)

6. What are the types of power-driven sampling devices?

(Split-spoon, split barrel, rotating Core, thin wall open tube (Shelby tube, continuous tube), piston samplers)

7. Are there any ASTM standards?

(Yes. D 1452, D1586, D1587, D 2113, D 3550 and D 5451)

4. 3. 2. Water Sampling

Water state in the subsurface is measured in terms of hydraulic head in the saturated zone, and negative pressure potential or suction in the unsaturated (vadose zone). There are more than 20 types of water sampling devices available. Some of the questions related to water sampling are as follows:

1. What is the difference between regular and environmental water sampling?

(Same methods except that precautions must be taken to prevent (a) volatilization of contaminants and (b) contaminating adjacent strata/areas; sampling tubes have to be lined to avoid chemical reactions; equipment must be decontaminated before next use or leaving site)

Table 4. 2. Summary of Sampling Methods for Environmental Site Investigations [D 5730]

Media	Method	Descriptions	Applications	Remarks [ASTM]
Soil	Scoops, spoons, shovels	Hand operated; Collect surface or shallow soil samples; Yield disturbed samples.	CASE 2; PHASE I	Not for PHASE II or PHASE V; [D 4700, D 6169]
	Augers	Hand or motor operated; Collect soil sample up to 3 m; Yield disturbed and non representative samples;	CASE 2, 3, 4 ; PHASE I & II	Recommended for above ground water; [D 1452, D 6151]
	Split spoon sampler	Power driven; Collect soil samples up to 20 m; Yield disturbed and representative samples	CASE 2, 3 & 4; PHASE I, II & V	[D 1586]
	Thin-walled tube sampler; Piston sampler	Power driven; Collect soil samples up to any depth; Undisturbed samples	PHASE II & V	[D 1587, D 2113, D 3550]
Ground water [D 4448]	Open bailer	Hand or power driven; Collect water samples from well, drains, sumps.	CASE 2; PHASE I	Some loss of volatile compounds [D 420]
	Positive displacement pump	Power driven; submergible pump placed below static water level. Collect water samples at the surface.	CASE 2, 3 & 4; PHASE II & V	[D 3856, D 5358, D 5717, D 5903]
	Suction lift pump	Power driven; pump placed at the surface. Collect water samples at the surface.	CASE 2, 3 & 4; PHASE II & V	Some loss of volatile compounds [D 5717]
Gas	Whole-air methods	Sample a mixture of gases, including contaminants and non-contaminant vapors	CASE 1, 2, 3 & 4; PHASE I, II & V	[D 4696; D 5314]
	Whole air-passive approach	Collect bulk gases near surface through a flux chamber	CASE 2, 3 & 4; PHASE I, II & V	Monitor gas emission from soil [D 5314]
	Sorbed contaminants-active approach	Collect bulk gases through a probe then extract interested contaminants by adsorption	CASE 2, 3 & 4; PHASE I, II & V	Monitor gas emission from soil [D 5314]
	Sorbed contaminants-passive approach	Use the passive movement of contaminants in soil to a sorbent collection device over time	CASE 2, 3 & 4; PHASE I, II & V	Monitor gas emission from soil [D 5314]

2. How are water sampling methods classified?

(Portable samplers and portable in situ sampler)

3. When are portable samplers used?

(Permanently installed and screened monitoring wells)

4. What are the popular portable samplers ?

(Bladder pumps, piston pumps, suction pumps, open bailer, syringe sampler)

5. What is the minimum well diameter ?

(13 to 50 mm)

6. What are the other factors that must be considered ?

(Maximum sampling depth, sampling rate, Table 4. 2)

7. What are the popular portable in situ samplers ?

(CPT samplers, New technologies are being developed [EPA/625/R-93/003a])

8. Are there any ASTM standards ?

(Yes. D4696 for sampling soil pore liquids in the vadose zone and D4448 for groundwater)

4. 3. 3. Gas Sampling

There are a variety of methods for soil gas sampling in the unsaturated zone (vadose zone). Sampling of soil gases (volatile contaminants or gases such as methane and carbon dioxide, which are indicators of increased microbial activity resulting for organic contaminants) has gained rapid acceptance as a method for preliminary mapping of contaminant plumes in groundwater, and monitoring of underground storage tanks. Soil gas surveys are also gaining popularity as an effective screening technique for mapping the extent of VOCs, particularly low molecular weight halogenated compounds (solvents). Some of the questions related to gas sampling are as follows:

1. How many gas sampling systems exist ?

(Six, Few are listed in Table 4.2)

2. What are the major limitations of gas monitoring?

(Soil gas monitoring does not provide repeatable quantitative information over time due primarily to the dynamic nature of phase equilibria. Thus, it can be utilized as a stand alone quantification technique)

3. What precautions need to be taken?

(An experienced personnel technique is needed to perform gas sampling)

4. Are there any ASTM standards?

(Yes. D 5314)

4. 3. 4. Unsaturated Zone (Vadose Zone)

Water movement in the vadose zone is important in determining the migration of contaminants. There are over 20 methods for measuring soil water potential, moisture content, and other soil hydrological characteristics.

(a) Some of the questions related to the Basic Characteristics of unsaturated zone (vadose zone) are as follows:

1. What are the three types of potentials?

((1) Matric potential (the attraction of water to solids in the subsurface); (2) Osmotic potential (the attraction of solute ions to water molecules); (3) gravitational potential (the attraction of gravity forces))

2. What is matric potential?

(The energy required to extract water from a soil against the capillary and adsorptive forces of the soil matrix, [D 3404])

3. What is Osmotic Potential?

(The component of the total soil-water potential associated with dissolved ions)

4. What is the popular method to measure water potential?

(Porous cup tensiometer)

5. What are the emerging techniques to measure moisture content in the field?

(Dielectric or capacitance sensor, time domain reflectometry (TDR))

(b) Some of the questions related to the INFILTRATION, CONDUCTIVITY AND FLUX in the vadose zone are as follows:

1. What is unsaturated hydraulic conductivity, infiltration rate, and flux?

(Hydraulic conductivity of soil at negative pressure potentials and various moisture contents; infiltration rate: the maximum rate at which water enters a soil; flux: the volume of water crossing a unit area of porous material per unit time)

2. How many methods are available to measure unsaturated hydraulic conductivity?

(Nine)

3. What are the popular methods?

(Instantaneous profile, draining profile, tension infiltrometer [EPA/625/R-93/003a])

4. What is water flux in the vadose zone?

(Amount of water that passes through and enters the groundwater)

5. How to measure water flux?

(tracers, soil-water flux meter, lysimeters)

6. Are there any ASTM standards?

(Yes. Hydraulic conductivity [D 5126], Infiltration rate [D 3385 and D 5093])

4.3.5. Soil Solute Sampling

A variety of methods are available for locating and monitoring areas of high soil salinity. There are several methods for monitoring soil solute movement and more than 20 methods for sampling solute solutions.

(a) Some of the questions related to the soil solute sampling in the vadose zone are as follows:

1. What are the popular methods to measure soil salinity?

(Four probe electrical method, porous matrix salinity sensors)

2. What is measured using these two methods?

(Resistivity)

3. Is there any depth limitation in using the two methods?

(Yes, four-probe method is limited to near surface; no depth limitation for the porous sensor)

4. What are the popular methods to sample soil solute ?

(Vacuum type porous cup, lysimeter)

4.4. WASTE ANALYSIS

There are large numbers of techniques for field screening and analysis. Field screening methods provide an indication of presence or absence of waste. Field analytical methods include all chemical analysis methods capable of providing chemical-specific quantitative data in the field. Table 4.3 summarizes the common used techniques for waste analysis.

4.4.1 Field Method

Field methods can be classified as portable and are more rapid and generally less expensive than laboratory methods.

(a) Some of the questions related to the field methods are as follows:

1. What are some of the field methods ?

(pH, alkalinity, acidity, electrical potential (Eh), electrical conductance, ion selective electrode, detector tubes, portable gas chromatography, x-ray fluorescence, radiation detectors, field bioassessment)

Table 4. 3. Summary of Waste Analytical Methods for Environmental Site Investigations

Media	Parameter	Instrument	Field	Lab	Detection Limit	Standard Methods
Soil	pH	pH meter	√	√	0.01 unit	G 51/D 4972
	Alkalinity/Acidity		√	√	0.1 mg/L	D 1067
	Eh	Electrodes	√	√	0.1 mv	D 1498
	Organic	GC, LC,	√	√	1 µg/L	D 3871
	Petroleum	HPLC, TOC	√	√	0.1 mg/L	D 5765
	VOC/SVOC		√	√		D 5241
	Inorganic	AA, ICP	Limited	√	1 µg/L	D 4542/D 5463
	Ion	IC	Limited	√	1 µg/L	D 5738/D 4878
Ground water	pH	pH meter	√	√	0.01 unit	D 1293/D 5464
	Alkalinity/Acidity		√	√	0.1 mg/L	D 1067
	Eh	Electrodes	√	√	0.1 mv	D 1498
	Organic	GC, LC,	√	√	1 µg/L	D 3871
	Petroleum	HPLC, TOC	√	√	0.1 mg/L	D 5765
	VOC/SVOC		√	√		D 5241
	Inorganic	AA, ICP	Limited	√	1 µg/L	D 4542/D 5463
	Ion	IC	Limited	√	1 µg/L	D 5738/D 4878
Gas	VOC, SVOC	GC, TOC	√	√	1 µg/L	D 1292/D 5314

(See also ASTM Vols. 11.01 and 11.02)

2. What are the advantages of the field methods?

(Quick results, generally lower cost per sample)

3. What are the disadvantages of the field methods?

(QA/QC procedure are more difficult, less accurate instruments)

4. 4. 2. Laboratory Method

For detailed and more accurate analysis the samples must be transported to the laboratory for testing.

(a) Some of the questions related to the laboratory methods are as follows:

1. What are some of the laboratory methods ?

(pH, alkalinity, acidity, electrical potential (Eh), electrical conductance, ion selective electrode, gas chromatography, x-ray fluorescence, atomic absorption, ionic coupled plasma, total organic analyzer)

2. What are the advantages of the laboratory methods?

(More accurate and lower detection limit than field methods, QA/QC procedures are better adaptable)

3. What are the disadvantages of the laboratory methods?

(Time consuming, sample handling and storing, cost depends on the number of samples)

4. 5. CONCLUSIONS

This chapter serves as guidance or a starting point for detailed environmental site investigation. Five popular surface geophysical methods have been discussed in relation to their applications. There are several ASTM standards/guide for environmental site characterization and sampling of soil, water and gas. Also a section on waste analyses has been included.

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Chapter 5

Remedial Technologies

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5.1. INTRODUCTION

When a site is contaminated with either hazardous wastes or petroleum products it will require remediation [2, 5, 8, 10, 11, 14, 16]. Remediation will include treatment, land disposal and containment [1, 18, 21, 28, 29, 31, 33]. Based on the type and level of contamination the remedial methods can be selected to comply with the federal and state environmental regulations.

Case studies (Table 5.1) have been analyzed to identify popular methods used in hazardous waste and petroleum products contaminated sites remediation. The results are also compared to remediation methods used in Superfund sites in Texas and other parts of the country for remediating hazardous wastes. Treatment technologies are grouped into biological, chemical, physical and thermal methods.

5.1.1. Media

The nature and concentration of contaminants, their distribution through the site, the affected media influence the preselection of treatment technologies. The summary of treatment methods considering their suitability for different media is presented in Tables 5.2 through 5.5. The media through which contamination occurs can be classified into:

- (1) Soil, Sediment, and Sludge and
- (2) Groundwater, Surfacewater, and Leachate.

5.1.2. Contaminants

Contaminants are generally grouped as follows (EPA/542/B-94/013, 1994) [34]:

- (1) Volatile Organic Compounds (VOCs), which include acetone, dichloroethane (D027-029), BTEX, vinyl acetate, carbontetrachloride, ethylene dibromide, chloroform (D022), dichloromethane.
- (2) Semivolatile Organic Compounds (SVOCs), which include aldrin, anthracene, 4-chloro-3-cresol, 2,4-dinitrophenol, benzyl alcohol, tetrachlorophenol.
- (3) Fuels, which include benzene, cyclohexane, naphthalene, flourene, isobutane, phenol, pyrene.
- (4) Inorganics and metals, which include sulfur, ammonia, asbestos, cyanide, fluorine, lead, cadmium (D006), chromium (D007).
- (5) Explosives, which include TNT, RDX, TNB, Nitroglycerine.

Depending on the type of contaminant and the extent of contamination, various remedial options are available for different site condition [1, 2, 21]. The costs involved in the remediation and the duration of the treatment also governs the selection of a remediation technology [21, 33, 34].

5.1.3. Remedial Technologies

Depending on the type of contaminant and the extent of contamination, various remedial options are available for the application to a particular site. The costs involved in the remediation and the duration of the treatment also govern the selection of a remediation technology.

Three primary strategies are used separately or in conjunction to remedy sites. These are as follows:

- (1) Treatment technologies: Destruction or alteration of contaminants (section 5.3),
- (2) Containment technologies: Isolating the waste by creating barriers (section 5.4), and
- (3) Disposal technologies: Removal of waste from site (section 5.5).

5.1.4. Petroleum Contaminated Soils

Petroleum contamination is exempted from being considered hazardous under RCRA and EPA's final regulations establishing TCLP. The frequency of discovery by DOTs of petroleum contamination is highest of all problem waste by a large margin [NCHRP Report 351]. A survey found that approximately 90 percent of the petroleum contaminated sites being cleaned up by state transportation agencies involve gasoline and/or diesel fuel contaminated soils [NCHRP Synthesis 226]. Information on petroleum contaminated soil is in section 5.6.

5.2. CASE STUDIES

5.2.1. Background

Information on 60 case studies has been collected and documented (Appendix C). The case studies were collected from books, magazines, journals, proceedings, EPA documents and personal contacts. The case studies include DOT, DOE, DOD, Superfund and RCRA projects.

Case studies are summarized in Table 5.1. The yearly distribution and type of contaminants are shown in Figs. 5.1 and 5.2 respectively. The case studies collected to date in this study are analyzed and compared to the EPA reported Superfund case studies (total of 697 cases) in Figs. 5.3 and 5.4 to identify the popular remediation technologies. The analyses show that physical technologies are the most popular technologies among all the available methods followed by biological and thermal technologies.

Table 5.1 Summary of Case Studies: Remediation of Contaminated Sites

No / Year	State / Country	Location	Major Contaminants/ Concentrations	Contaminated Area/ volume of Site	Remedial Technologies Considered/Adopted	Cost of Remediation	Duration of Remediation	Remarks	Case No.
1/82	Ontario / Canada	Local road, Lake clear	PCB /50 to 700 µg/g	6260 cubic meters	Solidification and Stabilization	\$850,000	Not available	Contaminated soil. Large project. Non-petroleum. Regulations as per Ontario regulation 309. Average PCB concentration after treatment was 21.5 µg/g.	9
1/84	Washington	Tacoma Spur Freeway (SR 705), Tacoma	Polycyclic aromatic hydrocarbons (PAHs)	Not known	Excavation and Removal	\$6 million	Not known	Contaminated soil. Large project. Non-petroleum. Regulations as per Washington state dangerous waste regulations.	47
1/86	Florida	Superfund* Site, Maine	Chlorinated Aliphatics, BTEX , PAHs / 3,310 mg/kg TCE, 130 mg/kg Ethyl benzene, and 35 mg/kg Toluene	8,800 cubic meters	Thermal Desorption	\$290,000	10 months	A disposal pit, Depth of water table and contamination not available. 11,500 tons of soil was treated.	26
1/87	Michigan	Superfund* Site, Battle Creek	BTEX, PCE, TCE / 22,000 kg in soil and 19,000 mg/L in ground water.	1 acre	Air Stripping for Ground water and Soil Vapor Extraction for Soil treatment	Not available	4 years	Contaminated soil and ground water. No regulations. Water table was 6.1 m below the grade.	37
1/88	Michigan	Superfund* Site, Verona	Chlorinated and nonchlorinated aliphatics / 3,900 lb. in groundwater and 1,700 lb. in soil	Not available	Soil Vapor Extraction	\$1, 600,000	4 years	Contaminated soil. Large project. Regulations as per 1991 Record of Decision (ROD).	11
2/88	Michigan	Grayling	BTEX, and total petroleum hydrocarbons (TPHC)	8,400 cubic meters	Bioremediation using Bioreactors	\$39 to \$ 59 per cubic meter	One and a half year	Contaminated soil. Small project. Cleanup goal for TPHC was 10 ppm. Depth of groundwater at 3.0 to 4.6 m.	45

* Superfund Sites

Table 5.1 Summary of Case Studies: Remediation of Contaminated Sites (Continued)

No / Year	State / Country	Location	Major Contaminants/ Concentrations	Contaminated Area/ volume of Site	Remedial Technologies Considered/Adopted	Cost of Remediation	Duration of Remediation	Remarks	Case No.
3/88	New Jersey	I-287 in northern New Jersey	Petroleum hydrocarbons	4-ha	Excavation and Disposal	Not available	Not available	Contaminated soil. Large project. Regulations as per New Jersey Department of Environmental Protection and Energy.	49
1/89	Ontario / Canada	Agricultural land, Southern Ontario	Arsenic, Lead, Cadmium, Zinc Copper and Molybdenum	28.5 acres	Excavation and Landfilling of soil	Not available	Not available	Contaminated soil. Small project. Depth contamination not available. No regulations. Over 43,000 tons of soil was trucked.	7
2/89	California	Superfund Site, * San Jose	Chlorinated and Non-Chlorinated Aliphatics	Not available	Soil vapor extraction	\$2,100,000	15 months	Contaminated soil. Medium project. Non-petroleum. Had regulations.	15
3/89	Missouri	Lumber Company Superfund* Site , Alton	PAHs	Not available	Bioremediation	\$4,047,000	2 years	Contaminated soil. No Regulations. Non Petroleum.	17
4/89	Florida	Wood Preserving Superfund* site, Live Oak	PAHs	Not available	Bioremediation	\$565,400	One and a half years	Contaminated soil. Depth of contamination and Depth of water table not known. Regulations adopted.	18
5/89	Florida	Wood Preserving Superfund* site, Live Oak	PAHs / 100 to 208 mg/kg.	250 cubic meters of soil was excavated	Onsite Incineration and Offsite Incineration were considered / Land Treatment adopted	\$565,410	18 months	Contaminated soil and groundwater. Regulations as per TCIC levels- Cleanup goal of 100 mg/kg of TCIC was established based on risk assessment.	35

* Superfund Sites

Table 5.1 Summary of Case Studies: Remediation of Contaminated Sites (Continued)

No / Year	State / Country	Location	Major Contaminants/ Concentrations	Contaminated Area/ volume of Site	Remedial Technologies Considered/Adopted	Cost of Remediation	Duration of Remediation	Remarks	Case No.
6/89	New Jersey	At a warehouse	Total Petroleum Hydrocarbons (TPH) and Metals	920 cubic meters of soil and 32,000 L (8,400 gal) of diesel fuel	Biological Land Treatment	Not available	1 year	Contaminated soil. Insitu. based on the New Jersey Pollutant Discharge Elimination System- Discharge to Groundwater (NJPDES-DGW) regulations.	44
7/89	Michigan	Detroit	Lead	40,500 cubic meters of soil	Containment using slurry walls	\$8,000,000	Not available	Contaminated soil. Regulations based on Michigan Department of Natural Resources. Depth of contamination up to 6m.	46
8/89	Michigan	Detroit	Lead	5,570 sq.m	In-situ Containment Cell for encapsulation	\$80,000	Not available	Contaminated soil. ESA, RI and site cleanup [PHASE II, III & IV]	55
1/90	Nebraska	Large diesel spill site, Railroad Facility	BTEX , #2 Diesel oil and Other petroleum hydrocarbons	Not available	Insitu Bioventing	\$10 per cubic meter	Two years	Contaminated soil. Medium project. Petroleum contaminants.	12
2/90	New York	WideBeach Development Superfund Site*, New York	PCBs	Not available	Thermal Desorption and Dehalogenation	\$11,600,000	One year	Contaminated soil. Large project. Non Petroleum. Had regulations.	21
3/90	Utah	Air force base, Ogden	TPHs / 20 to 20,000 mg/kg	1250 sq. m	Bioventing preceded by Soil Vapor Extraction	\$335,000	2 years	Contaminated soil. Insitu. Regulatory cleanup level was 38 mg/kg.	25
4/90	South Carolina	At a U.S. Department of Energy Site, Aiken	Chlorinated Aliphatics	1200 acres	Insitu Air Stripping	\$400,000	3 years	Contaminated soil. Depth of Water table and Contamination not available.	32

* Superfund Sites

Table 5.1 Summary of Case Studies: Remediation of Contaminated Sites (Continued)

No / Year	State / Country	Location	Major Contaminants/ Concentrations	Contaminated Area/ volume of Site	Remedial Technologies Considered/Adopted	Cost of Remediation	Duration of Remediation	Remarks	Case No.
1/91	Texas	Highway expansion project	Petroleum Products	2 acres	Onsite thermal desorption	Not available	4.5 months	Contaminated soil. 500,000 gallons of contaminated water was bioremediated and 27,500 tons of soil was treated.	2
2/91	NE United States	Residential sites	Lead, Mercury, Zinc, Copper, Barium (660 ppm), Selenium (1 ppm)	20 acres	Excavation and Landfilling of soil	Tens of millions of dollars	6 to 12 weeks	Contaminated soil. Restoration of 150 properties in the flood plain. Depth of contamination was 1.52 m, depth of Water Table not known.	3
3/91	California	IBM facility, San Jose	Volatile Organic Compounds	Not available	Dual system of air stripping and steam stripping	\$5.75 million	Not available	Contaminated groundwater. Depth of contamination and water table are not known.	5
4/91	Oklahoma	Air force base, Oklahoma City	Chromium ⁶⁺ (80,000 µg/L) and Trichloroethylene(330,000 µg/L)	61.8 acres / Groundwater plume 220 acres	Air or steam stripping of VOCs and precipitation of chromium	\$13 million	2 years	Contaminated groundwater. Depth of contamination was 15-25 m below the surface; Depth of water table was 4.5-9 m. Treated water was used for industrial applications.	6
5/91	Alaska	Air force base, Fairbanks	PAH and BTEX	Not available	Bioventing	\$758,077	3 years	Contaminated soil. Depth of contamination was at 6.1 m. Depth of water table not known.	23
6/91	Arizona	Luke Air Force Base	TPHs, BTEX, and Methyl ethyl ketone (MEK)	Not available	Soil Vapor Extraction	\$507,185	14 months	Contaminated soil. Treatment had reduced TPH and BTEX to 100 and 412 mg/kg respectively.	29

* Superfund

Table 5.1 Summary of Case Studies: Remediation of Contaminated Sites (Continued)

No / Year	State / Country	Location	Major Contaminants/ Concentrations	Contaminated Area/ volume of Site	Remedial Technologies Considered/Adopted	Cost of Remediation	Duration of Remediation	Remarks	Case No.
7/91	Florida	I-595, Broward County	Benzene (D018) and Volatile Organic Aromatics	Not available	Groundwater treatment with filtration, clarification, and carbon adsorption treatment	\$750,000	5 months	Groundwater treatment. 99% of Benzene and 95% of Volatile organic aromatics were removed. Regulation levels were 1 ppb for benzene and 50 ppb for VOCs	38
8/91	Michigan	Adrain, Lewanee County	Halogenated and nonhalogenated VOCs , PAHs, and Metals	12.5 acres	Thermal Desorption	\$190-\$340 per ton of soil treated	18 months	Contaminated soil. Depth of contamination and Depth of water table not known. Clean up of 5,100 tons of soil was completed.	36
9/91	Mississippi	Superfund Site,* Canton	Polynuclear aromatic hydrocarbons (PAHs) / 4,000 mg/kg	10,500 cubic yards	Slurry-phase bioremediation	\$230 per cubic yard	3 years	Contaminated soil and slurry. 14,140 tons of soil need treatment.	51
1/92	New York	SMS Instruments Superfund* site, Deer Park	Chlorinated and Non-Chlorinated Aliphatics (1,500 g/kg) and Semivolatile Organic Compounds (1,200 mg/kg)	Not available	Soil Vapor Extraction system that used horizontal vapor extraction wells	\$450,420	1.5 years	Contaminated soil. Cleanup levels ranged from 3.5 to 5.5 mg/kg. Depth of water table and contamination not known.	13
2/92	Washington	Commencement Bay, Tacoma	Chlorinated aliphatics which includes dichloroethane (DCE), PCA, PCE, TCE	Not available	Soil vapor extraction	\$5,313,973	2 years	Contaminated soil. Depth of contamination was 12 m. Depth of water table not known.	14
3/92	Colorado	Lowry Air Force Base in Denver	BTEX and TPHs	Not available	Bio-remediation	\$104,257	1.5 years	Contaminated soil. Depth of water table and contamination not known.	16
4/92	Michigan	Superfund Site in Adrian*	Chlorinated Aliphatics, PAHs, Other organics and Metals	Not available	Thermal desorption (Residence time 90 minutes; temperature was 500-530°F)	Not available	One and a half year	Contaminated soil. The regulations for methylene chloroaniline in soil was 1.68 mg/kg.	19

* Superfund

Table 5.1 Summary of Case Studies: Remediation of Contaminated Sites (Continued)

No / Year	State / Country	Location	Major Contaminants/ Concentrations	Contaminated Area/ volume of Site	Remedial Technologies Considered/Adopted	Cost of Remediation	Duration of Remediation	Remarks	Case No.
5/92	Texas	French Limited Superfund* Site, Crosby	PAHs, Chlorinated Aliphatics (5,000 mg/kg), PCBs, Metals (500 mg/kg).	30,000 tons	Slurry phase Bioremediation	\$49,000,000	22 months	Contaminated soil. Maximum allowable limits for contaminants were established. Depth of the water table and contamination were not available.	24
6/92	California	Gasoline spill site, California	BTEX	800 acres	Dynamic underground stripping	\$5,400,000	1 year	Contaminated soil. Petroleum Contamination. No regulations.	31
7/92	Oregon	CERCLA soils operable unit, Hermiston	Explosives	187 cubic meters	Composting	\$1,840,000	6 months	Contaminated soil. Depth of water table and contamination was not known.	33
8/92	Nebraska	Hastings groundwater contamination site	Chlorinated aliphatics	141,450 cubic meters	Soil Vapor Extraction	\$370,000	1 year	Contaminated soil. Depth of water table and contamination was not known.	34
9/92	Colorado	Lowry Air Force Base, Denver	BTEX and heating oil	3,000 cubic yards of soil	Land Farming	\$17 per ton of soil excavated and treated.	1 year, 3 months	Contaminated soil and groundwater. Regulations as per Colorado Department of Health and specifications as per American Petroleum Institute Recommended Practice 1604 and the National Fire Protection Association Code 30.	43
10/92	Florida	Interstate I-595, Fort Lauderdale, Broward County	Petroleum based contaminants	Not available	Horizontal drains and vertical wells for recovery	\$750,000	3 months	Groundwater. Depth of GW at 5 ft while the contamination extended to 50 ft. Regulations as per FDEP.	48

* Superfund

Table 5.1 Summary of Case Studies: Remediation of Contaminated Sites (Continued)

No / Year	State / Country	Location	Major Contaminants/ Concentrations	Contaminated Area/ volume of Site	Remedial Technologies Considered/Adopted	Cost of Remediation	Duration of Remediation	Remarks	Case No.
11/92	New York	Fuel dispensing area, Watertown	BTEX / Not Available	Not available	Air stripping and granular activated carbon	\$958, 780	One and half years	Contaminated soil and groundwater. Leaks from UST. Site cleanup (PHASE IV).	56
12/92	Georgia	Superfund Site	Halogenated volatile organic compounds	1,600 cubic yards of soil	Soil Vapor Extraction	\$413 per cubic yard	6 months	Contaminated soil. Before construction. Illegal disposal of wastes. Site cleanup (PHASE IV).	58
1/93	Ohio	Nuclear fuel processing plant, Southern Ohio	VOCs	2418 sq. m.	Shallow soil mixing with hot air injection and vacuum extraction	\$131 per cubic meter	The treatment of 680 columns was completed in 10 weeks.	Contaminated soil. After construction. Contamination was due to past land farming activity. Depth of water table was 4 m. Depth of contamination was 6.7 m.	1
3/93	New Jersey	Piney Hollow Road, Winslow Township	Chromium, Copper, Nickel and Volatile organic compounds	10 acres	Soil washing	Not available	3.5 months	Contaminated soil and ground water. 19,507 tons of soil was treated. Depth of contamination was not known.	8
2/93	Colorado	Oil sump at a truck maintenance facility, Denver	BTEX, TPHs, Total organic compounds	Not available	Insitu Bioremediation	Not available	2.5 years	Contaminated soil and ground water. Expansion project. Monitoring wells were used for site investigation. Depth of water table was 4 m.	4
4/93	New Jersey	Superfund Site* , Winslow Township	Beryllium, Chromium, Copper, Nickel, Zinc, Lead, Mercury	19,200 tons of soil	Soil Washing and Offsite disposal of sludge	\$7,700,000	Four months	Contaminated soil. Waste recycling facility. Soil cleanup levels were established. 19,200 tons of soil was treated.	20

* Superfund

Table 5.1 Summary of Case Studies: Remediation of Contaminated Sites (Continued)

No / Year	State / Country	Location	Major Contaminants/ Concentrations	Contaminated Area/ volume of Site	Remedial Technologies Considered/Adopted	Cost of Remediation	Duration of Remediation	Remarks	Case No.
5/93	Georgia	Agriculture, Nutrition Company Superfund* Site, Albany	Halogenated Organic Pesticides like dieldrin, toxaphene, DDT, lindane	4,300 tons of soil	Thermal Desorption	\$849,996 (operating temperatures 833-1080°F)	3 months	Contaminated soil. Soil cleanup levels were established. (Pesticides < 100 mg/kg; and 90% reduction). Depth of ground water and contamination are not known.	22
6/93	Michigan	Parsons/ ETM Enterprises Superfund* Site	Pesticides, Heavy Metals, Phthalates, PAHs, and Dioxins	2,290 cubic meters	Insitu Vitrification	\$1,763,000	1 year	Contaminated soil. Soil cleanup standards were chosen. Depth of ground water and contamination are not known.	27
7/93	California	Air force base Superfund* site	Chlorinated aliphatics	Not available	In situ soil vapor extraction	\$3.8 million	1 year	Contaminated soil. A 25% reduction in VOCs was selected as soil cleanup standards.	28
8/93	Ohio	Superfund Site* , Reading	VOCs, SVOCs, PAHs, Metals	12,800 tons of soil	Thermal Desorption	Not available	5 months	Contaminated soil. Soil cleanup standards were established. 62% cleanup was achieved.	39
9/93	Michigan	Superfund Site* , Grand Ledge	Metals, Dioxins, Pesticides	3,000 cubic yards of soil	Insitu Vitrification	Not available	1 year	Contaminated soil. Depth of ground water and contamination are not known. Soil cleanup standards were established.	40
10/93	Colorado	Commerce City *	Halogenated volatile organic compounds	684 pounds of soil	Soil vapor extraction (SVE)	\$2,140,000	6 months	Contaminated soil and groundwater. RI and site cleanup (PHASES III & IV]	52
11/93	Oklahoma	Federal Aviation Administration Facility	BTEX / Benzene 3.8 mg/L	67, 500 square meters	Pneumatic Fracturing	Not available	3 months	Contaminated soil and groundwater. Site Cleanup (PHASE IV]	54

* Superfund

Table 5.1 Summary of Case Studies: Remediation of Contaminated Sites (Continued)

No / Year	State / Country	Location	Major Contaminants/ Concentrations	Contaminated Area/ volume of Site	Remedial Technologies Considered/Adopted	Cost of Remediation	Duration of Remediation	Remarks	Case No.
12/93	Florida	Superfund site,* in Cantonment	Polynuclear aromatic hydrocarbons / 0.578 to 367 mg/kg	19,705 tons	Composting	\$266 per ton of soil	6 months	Contaminated soil and groundwater. RI and site cleanup (PHASES III & IV)	59
1/94	California	Petroleum storage tank in Southern California	#6 Fuel oil	Not available	Excavation and Backfilling. Thermal treatment of excavated soil at 1400°F.	\$1,270,000	Not available	Contaminated soil. Depth of contamination was 1 to 2.4 m, depth of water table 4.5 m.	10
2/94	Michigan	Bofors-Nobel Superfund Site *	Benzene, Chlorobenzene, TCE and Toluene	85 acres	Ultraviolet oxidation with Ammonia stripping	\$12.4 millions	10 months	Contaminated soil. Soil cleanup standards were established.	30
1/95	New Jersey	Northern New Jersey	Polychlorinated biphenyl / Above 50 ppm.	1148 square meters	Excavation and Landfill	\$3.8 million	Not available	Contaminated soil. Geophysical methods. During construction [CASE 3].	50
1/96	New Mexico	At Kirtland air force base Albuquerque	Semi volatiles	80 kg of diesel range organics	Enhanced SVE using radio frequency heating	Not available	Not available	Contaminated soil. Depth of contamination extended to 0 to 13 m.	41
2/96	Minnesota	Blaine	Gasoline Constituents	Not available	Radio frequency heating enhanced SVE and air sparging	Not available	3 weeks	Contaminated soil and groundwater. Site cleanup [PHASE IV].	53
3/96	New York	Superfund Site *	PCBs / 5,000 ppm	446 square meters	In situ thermal desorption	Not available	4 months	Contaminated soil. Site cleanup [PHASE IV].	57
4/96	California	Southern California	Halogenated hydrocarbons	up to 2.5 m.	In situ soil aeration and biopulsing.	Not available	Not available	Contaminated soil and groundwater. ESA and site cleanup (PHASES II & IV)	42
5/96	New York	At an industrial site	Cadmium / 130 mg/kg in soil		Stabilization using jet grouting	Not available	Not available	Contaminated soil and groundwater. RI and site cleanup (PHASES III & IV)	60

Superfund site *

Yearly Distribution of Case Studies

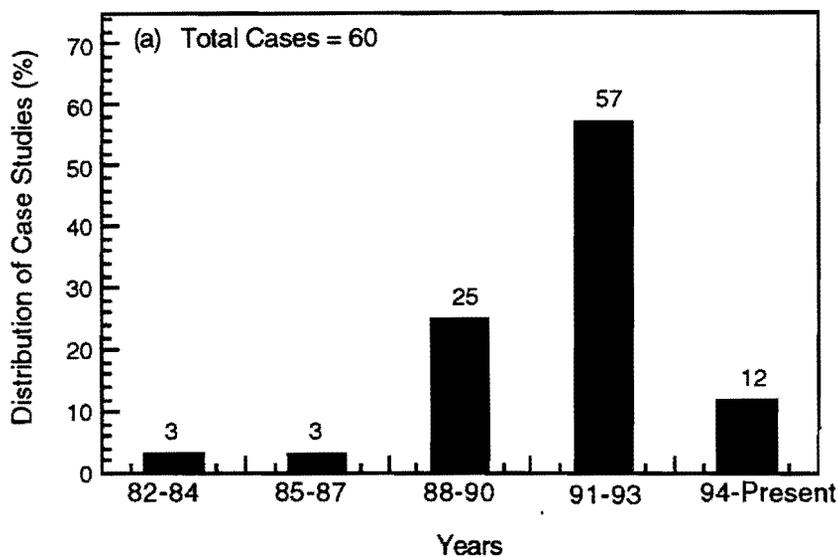


Figure 5.1. Distribution of Case Studies with 2-year interval

Case Studies Based on the Contaminant

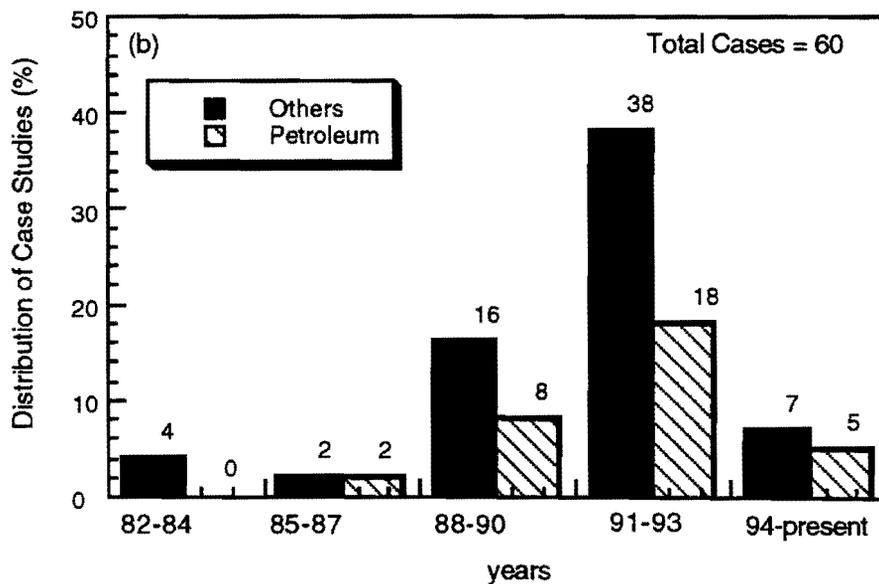


Figure: Distribution of Case Studies
(a) 2 year interval (b) Type of Contaminated Site

Figure 5.2. Distribution of Case Studies Based on Type of Contaminants

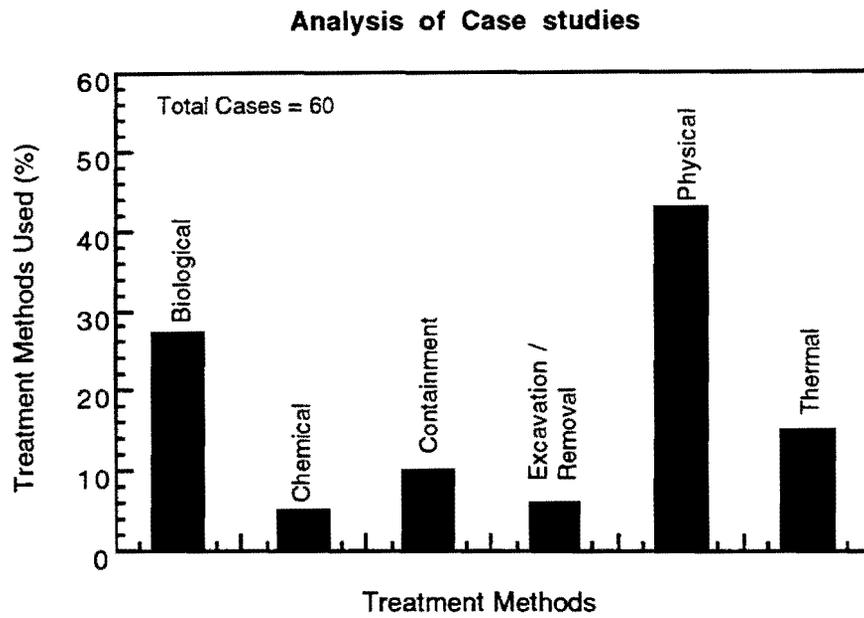


Figure 5.3. Distribution of Remedial Technology from the Case Studies

Analysis of Superfund Treatment Methods (EPA)
(Established and Innovative Technologies)

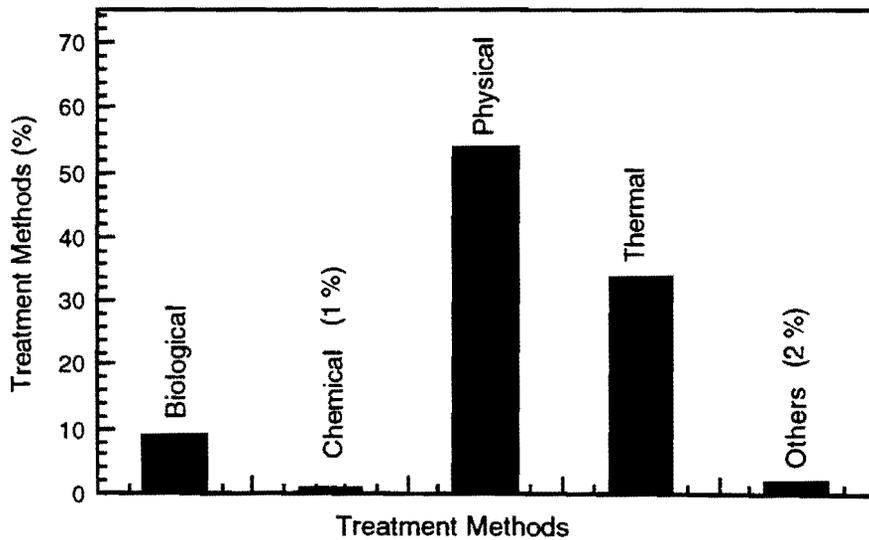


Figure 5.4. Distribution of EPA Superfund Case Studies based on Treatment Technology (EPA/542/R/96/010)

5.2.2. Analysis of the Case studies

(a) Distribution of Case Studies [Figure 5.1]:

Information on a total of 60 case studies has been collected and documented in this study for the period 1982 - 1996. The distribution of case studies with time (2 years interval) is shown in Figure 5.1. Fifty-seven percent of the case studies (34 out of 60 case studies) were reported during the period 1991-1993. Lower number of cases for the final period is due to the fact that information on recent cases has not been published yet.

(b) Type of Contaminant [Figure 5.2]:

Thirty three percent of the case studies were related to petroleum contamination. Other sites documented were contaminated with other organic compounds (86%), inorganic (3%) and/or metals (33%). NCHRP Report 226 had reported over 76 projects on petroleum contaminated soils.

(c) Remedial Technologies [Figure 5.3]:

The analysis of case studies indicates that physical methods were used in 43% of the total cases documented. Biological and thermal treatment technologies were in 27% and 15% of the cases (respectively) of the treatment technologies. The chemical method was the least popular. Containment and disposal technologies were 10% and 6% respectively.

5.2.3. EPA Superfund Projects

The analysis for EPA Superfund sites where established and innovative treatment technologies were used is shown in Fig. 5.4. The trends in treatment methods for case studies is similar to the distribution of EPA Superfund sites. Analysis of EPA data shows that physical treatment methods were selected in remediating 54% of the sites. Physical methods were followed by thermal (32%) and biological (10%) treatment methods.

Distribution of treatment technologies (EPA Superfund sites) in the established and innovative categories are shown in Figs. 5.5 and 5.6. In the established treatment methods category, 50% of the projects adopted the solidification/stabilization (physical) method which was the most popular method. The second popular method in the established category was the thermal method, accounting for 46% of the projects. In the innovative treatment methods category (Figure 5.6) physical, biological and thermal methods were used in 58%, 22% and 18% of the cases (respectively).

Superfund Projects

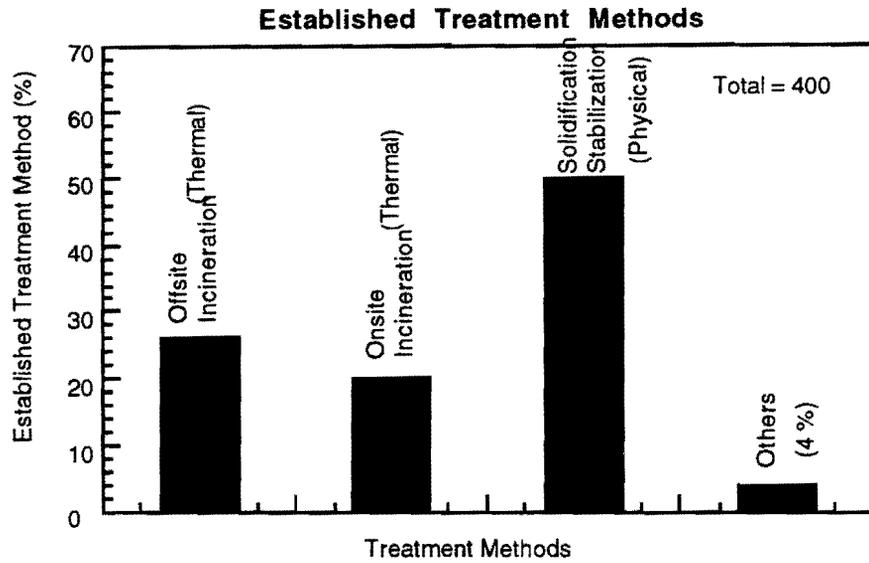


Figure 5.5. Distribution of Superfund - Established Technologies

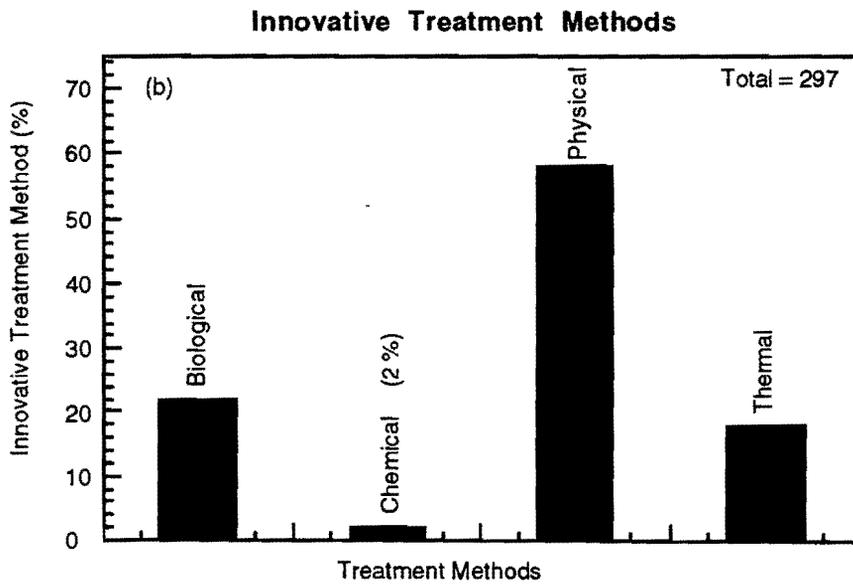


Figure: Distribution of Treatment Methods in Superfund Project
(a) Established Technology (b) Innovative Technology

Figure 5.6. Distribution of Superfund - Innovative Technologies

5.2.4. Texas Projects

Distribution of established and innovative treatment methods adopted in Texas are shown in Figs. 5.7 and 5.8. In the established treatment methods, thermal treatment method (54%) was the most popular method. Solidification/stabilization was adopted in 40% of the projects. In the innovative category, physical (50%) and biological (50%) were the popular methods.

5.2.5. Other Projects (DOD, DOE, and RCRA)

Physical methods were adopted in 58% of the projects, biological methods were used in 36% of the projects.

5.2.6. Cost Analysis

Several factors such as type of contaminant, type of soil, depth of treatment can significantly affect the cost of treatment. Figure 5.10 shows the treatment cost for different treatment technologies. The soil vapor extraction treatment, which is a physical method, costs the least and was in the range of \$10 to \$50 per cubic meter of soil. While the chemical reduction treatment, which is a chemical treatment method, costs \$200 to \$600 per cubic meter of soil. The cost of biological treatment varied from \$10 to \$80 per cubic meter of contaminated soil. Solidification/stabilization treatment cost was in the range of \$50 to \$80 per cubic meter of soil. Thermal treatment varied from \$30 to \$130 per cubic meter of soil.

5.2.7. Summary

A total of 60 case studies were collected and documented in this study. The case studies were analyzed for the most popular remedial technologies and the treatment technologies were compared to EPA Superfund projects and other projects. Of the 60 case studies collected, 35% were related to petroleum contamination. The analysis showed that the physical treatment technologies were the most popular technologies. The cost of physical treatment varied from \$10 to \$80 per cubic meter of soil. Biological and thermal methods also have been used in many projects.

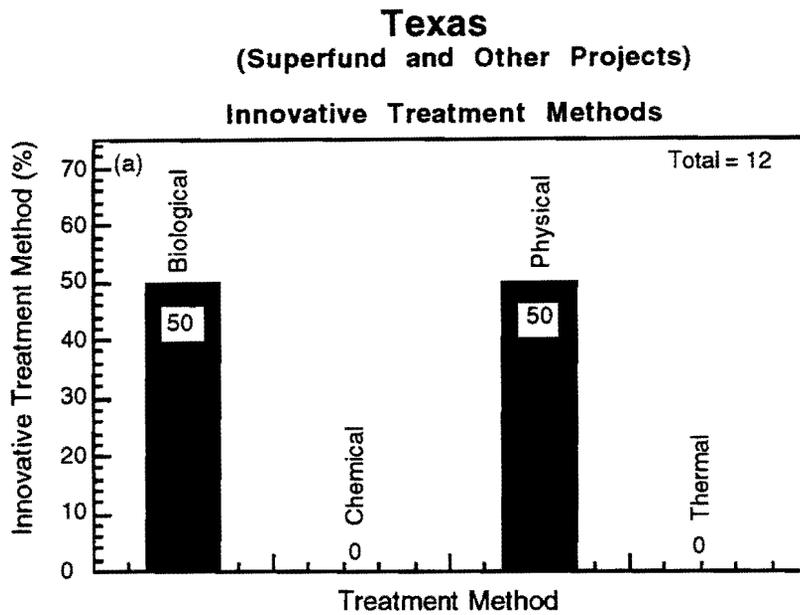


Figure 5.7. Distribution of Established Technologies Used in Superfund Sites in Texas

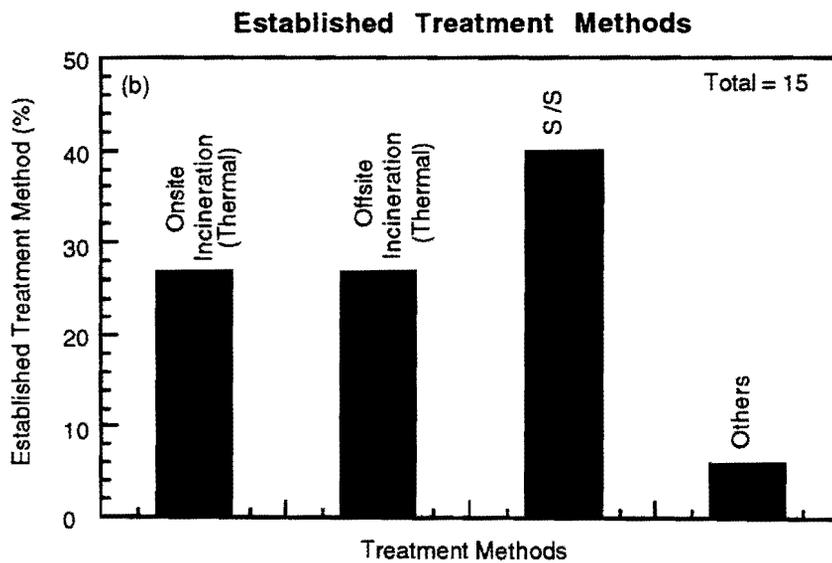


Figure: Projects in Texas
(a) Innovative Methods (b) Established Methods

Figure 5.8. Distribution of Innovative Technologies Used in Superfund Sites in Texas

Other Federal (DOD, DOE)
and RCRA Projects

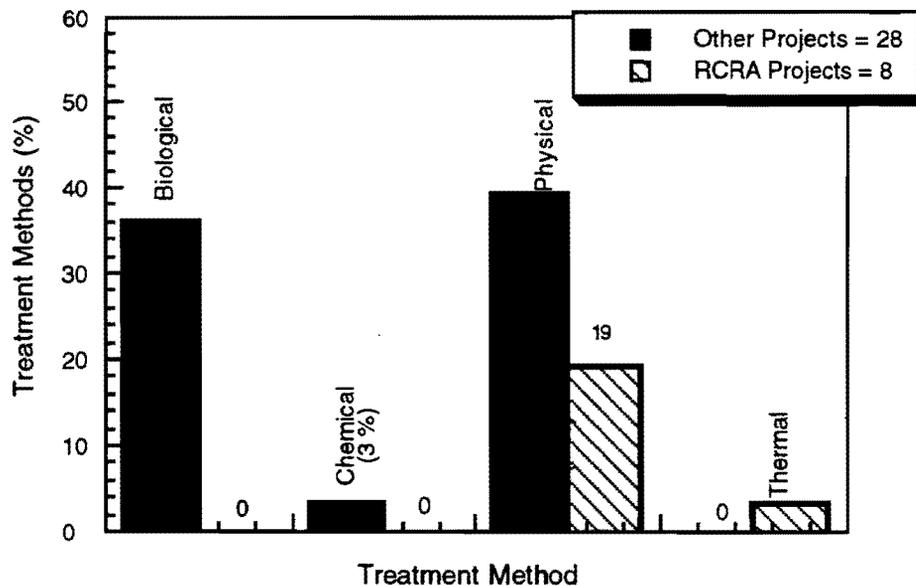
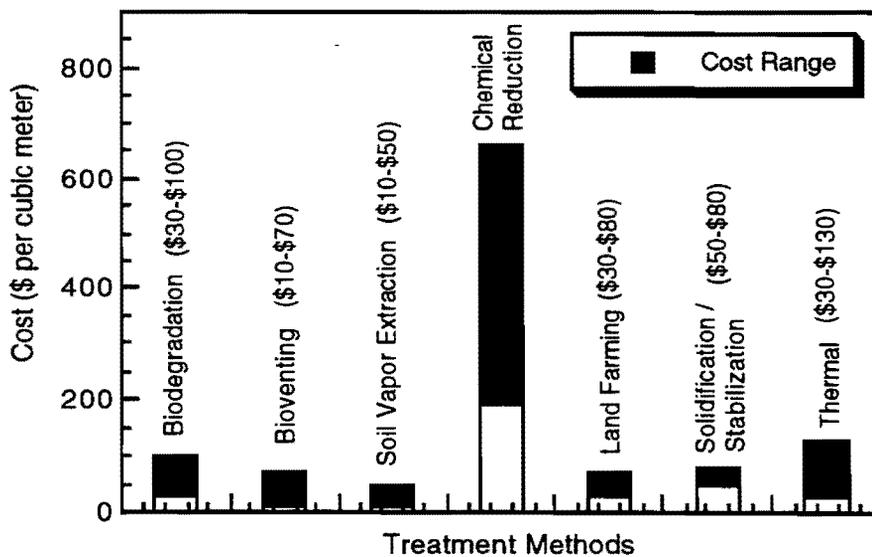


Figure 5.9. Distribution of Other Federal and RCRA projects (EPA/542/R/96/010)

Comparison of Cost



Reference: PB95-104782

Figure 5.10. Costs of Various Technologies

5.3. TREATMENT TECHNOLOGIES

5.3.1. Background

Treatment methods comprise of biological, physical, chemical, and thermal treatment technologies and a combination of two or more of these technologies. The EPA has separated treatment technologies into established technologies and innovative technologies. The treatment technologies can be mainly classified into biological, chemical, physical and thermal technologies. The treatment technologies can be applied both in situ and ex situ.

a) In situ Treatment:

The main advantage of in situ treatment is that it allows soil to be treated without being excavated and transported, resulting in potentially significant cost savings. However, in situ treatment technologies require longer time for remediation, and there is less certainty about the uniformity of the treatment because of the variability in soil characteristics.

b) Ex situ Treatment:

The main advantage of ex situ treatment is that it generally requires shorter time periods than in situ treatment, and there is more certainty about the uniformity of treatment. However, ex situ treatment requires excavation of soils, leading to increased costs and engineering for equipment, possible permitting, and material handling and worker exposure conditions.

Table 5.2 through Table 5.5 list all the treatment technologies identified so far and summarizes their applicability to different media and contaminants. Sixty seven treatment technologies have been identified in the study. Of the 67 technologies identified, biological, chemical, physical and thermal technologies had 18, 14, 18 and 17 respectively.

5.3.2. Biological Technologies

Biological treatment refers to the application of natural microbial metabolic processes to remedy contaminated soils and other wastes. The process requires more time and it is difficult to determine whether contaminants have been destroyed. Nutrients can be

added to enhance the system thereby sustaining the bacterial growth. This method is effective in treating soils contaminated with organics like petroleum hydrocarbons and chlorinated solvents [EPA/542/B-94/013]. The rate at which microorganisms degrade contaminants is influenced by the specific contaminants present, oxygen supply, moisture, temperature, pH, nutrient supply, bioaugmentation, and cometabolism. The biological technologies can be applied both in situ and ex situ.

a) In situ Biological Treatment:

Most commonly used in situ biological treatment technologies include biodegradation, and bioventing [EPA/542/B-94/013].

b) Ex situ Biological Treatment:

Most commonly used ex situ biological treatment technologies include composting, controlled solid phase biological treatment, land farming, and slurry phase biological treatment [EPA/542/B-94/013].

A total of 18 biological treatment methods have been identified (Table 5.2). The biological methods are most commonly used for treating organic wastes in all the three possible media such as unsaturated zone, saturated zone and groundwater.

5.3.3. Chemical Technologies

Chemical methods use the contaminated medium to destroy or chemically convert, separate or contain the contamination; these may either destroy contaminants or make them less hazardous. Surfactants can be added to the flushing solution to chemically increase the solubility of the contaminant. There are a wide variety of these treatments such as neutralization, oxidation, ion exchange, ozonization, and electrolysis.

The disadvantage of these treatments is that they generate byproducts that are as hazardous as, or even more hazardous than, the original contaminants. The residuals from the treatment technology require further treatment which will add to the cost of the treatment method. These can be applied in situ or ex situ.

a) In situ Chemical Treatment:

The most commonly used in situ chemical treatment methods include soil flushing, vacuum extraction and hot gas injection [EPA/542/B-94/013].

Table 5.2. Biological Treatment Technologies

No.	Treatment Technology	Type of Waste												EPA Classification	Cost	Case Studies	Reference
		Soil								GroundWater							
		Unsaturated				Saturated											
		O	P	I	M	O	P	I	M	O	P	I	M				
B	Biological																
B1	Activated Carbon Treatment									x	x			-	Not available	None	15
B2	Air injection	x	x			x	x			x	x			-	Not available	None	26
B3	Biofiltration									x	x			-	Not available	None	7, 29
B4	Biopiles	x	x			x	x							-	\$60 to \$165 per cubic meter	None	25
B5	Bioreactors	x	x			x	x			x	x			-	Not available	45	3, 6
B6	Bioreclamation	x	x			x	x			x	x			-	Not available	None	27
B7	Bioslurry Reactors	x	x			x	x				x			-	Not available	None	14, 35, 38, 39
B8	Bioventing	x	x							x	x			Innovative	\$10 to \$70 per cubic meter	12, 25, 23	6, 24
B9	Composting	x	x			x	x							-	\$200 per cubic meter	33	6
B10	Fixed Bed Reactors									x	x			-	Not available	None	25
B11	Fluidized Bed Reactors	x	x			x	x			x	x			-	Not available	None	11, 13, 25
B12	In situ Bioremediation	x	x			x	x			x	x			Innovative	\$30 to \$100 per cubic meter	4, 16, 17, 18	26
B13	Landfarming	x	x			x	x							Established	\$30 to \$70 per cubic meter	43	6
B14	Nitrate Enhancement	x	x			x	x			x	x			Innovative	Not available	None	6
B15	Oxygen Enhancement	x	x			x	x			x	x			Innovative	Not available	None	6
B16	Sequencing Batch Reactors									x	x			-	Not available	None	25
B17	Solid Phase Biological Treatment	x	x			x	x							Innovative	Not available	None	6
B18	Trickling Filters									x	x			-	Not available	None	7

x - recommended treatment methods; O - Organic; P - Petroleum; I - Inorganic; M - Metal

b) Ex situ Chemical Treatment:

The most commonly used ex situ chemical treatment technologies include chemical oxidation and reduction, dehalogenation and solvent extraction [EPA/542/B-94/013].

A total of 14 chemical methods were identified in the study (Table 5. 3). Most of the technologies may be applied in all the media on all types of contaminants.

5.3.4. Physical Technologies

Physical treatments generally change the volume of wastes or render hazardous constituents inert. These treatments are either separation techniques or immobilization techniques. In separation processes, hazardous constituents are removed from a larger body of waste which is often done by separation of phases, such as solids or gases from liquid waste. Physical treatment is cost effective and can be completed in short time periods but sometimes the treatment of the residuals produced will add to the cost. This can be applied ex situ and in situ.

a) In situ Physical Treatment:

Most commonly used in situ physical treatment methods include soil vapor extraction, solidification/stabilization, air stripping and soil venting [EPA/542/B-94/013].

b) Ex situ Physical Treatment:

Most commonly used ex situ physical treatment technologies include vacuum extraction, physical separation, soil washing and solidification/stabilization [EPA/542/B-94/013].

A total of 18 technologies have been identified among the physical methods (Table 5.4). The most popular methods among these are soil vapor extraction, solidification/stabilization treatment, vitrification and air sparging. Few technologies such as steam stripping, in situ adsorption, vitrification, supercritical extraction are applied only in the soil; they are not suitable for treating groundwater. Some technologies such as carbon adsorption, flocculation/precipitation, catalytic oxidation are applied only in the groundwater. Hence the selection of a remediation technology depends mostly on the media to be treated.

Table 5.3: Chemical Treatment Technologies

No.	Treatment Technology	Type of Waste												EPA Classification	Cost	Case Studies	Reference
		Soil								GroundWater							
		Unsaturated				Saturated											
		O	P	I	M	O	P	I	M	O	P	I	M				
C	Chemical																
C1	Catalytic Oxidation	x	x	x		x	x	x			x			Innovative	Not available	None	6
C2	Dechlorination	x				x								Innovative	Not available	None	25
C3	Dehalogenation	x	x			x	x				x			Innovative	\$200 to \$500 per ton of soil	None	6
C4	ElectroChemical Method			x	x			x	x			x	x	Innovative	Not available	None	19
C5	Hydrolysis									x		x		Innovative	Not available	None	24
C6	Ion Exchange											x	x	Innovative	Not available	None	6
C7	Neutralization			x	x			x	x			x	x	Established	Not available	None	25
C8	Oxidation / Hydrogen Peroxide	x	x	x		x	x	x		x	x			Innovative	\$190 to \$660	None	6, 30
C9	Polymerization	x			x	x								Innovative	Not available	None	25
C10	Precipitation							x	x			x	x	Innovative	Not available	6	6
C11	Reduction	x		x		x		x						Innovative	Not available	None	6
C12	Soil Flushing	x	x	x	x	x	x	x	x					Innovative	Not available	None	6, 24
C13	Soil Washing	x	x	x	x	x	x	x	x					Innovative	\$130 to \$220 per ton of soil	8, 20	6, 17
C14	Ultraviolet Oxidation									x				Innovative	\$0.01 to \$1.5 per 1000 gallons of water	None	6, 33

x - recommended methods; O - Organic; P - Petroleum; I - Inorganic; M - Metal

Table 5.4: Physical Treatment Technologies

No.	Treatment Technology	Type of Waste												EPA Classification	Cost	Case Studies	Reference
		Soil								GroundWater							
		Unsaturated				Saturated											
		O	P	I	M	O	P	I	M	O	P	I	M				
P	Physical																
P1	Air sparging					x	x			x	x			Innovative	Not available	None	1, 6
P2	Air stripping	x	x			x	x			x	x			Innovative	\$0.01 to \$0.04 per cubic meter	37, 32, 5, 6, 31, 1	15, 23, 25
P3	Ammonia stripping					x				x				Innovative	Not available	30	12
P4	Carbon Adsorption									x	x	x		Innovative	Not available	None	6, 25
P5	Catalytic Oxidation									x				Innovative	Not available	None	15
P6	Directional Wells									x		x	x	Innovative	\$60 to \$250 per cubic meter	48	6
P7	Evaporation	x	x			x	x			x	x			Innovative	Not available	None	25
P8	Filtration									x	x			Innovative	Not available	None	25
P9	Flocculation / Precipitation									x			x	Established	Not available	None	25
P10	In situ Adsorption	x	x			x	x				x			Innovative	Not available	None	25
P11	In situ Soil Venting	x	x				x				x			Innovative	\$20 to \$295 per cubic meter	None	23
P12	In situ Steam Extraction Treatment	x	x			x	x			x	x			Innovative	Not available	None	
P13	Molten Glass	x	x			x	x				x			Innovative	Not available	None	25
P14	Particle Radiation									x				Innovative	Not available	None	25
P15	Soil Vapor Extraction	x	x			x	x			x	x			Innovative	\$10 to \$50 per cubic meter	11, 13, 14, 15, 25, 28, 29, 34, 37, 41,	2, 6, 29
P16	Solidification/Stabilization	x	x	x	x	x	x	x	x					Established	\$30 to \$200 per ton of soil	9	6, 36, 39
P17	Solvent extraction	x	x			x	x			x	x			Innovative	\$110 to \$440 per metric ton	None	6
P18	Vitrification	x	x	x		x	x	x		x	x	x	x	Innovative	\$1,300 - \$1,570	40, 27	6

x - recommended methods; O - Organic; P - Petroleum; I - Inorganic; M - Metal

5.3.5. Thermal Technologies

Thermal treatments are in the forefront of current techniques because of their efficiency in destroying a variety of contaminants in a variety of media. Thermal treatments use combustion to induce chemical reactions that destroy contaminants. These treatments can be performed either in the presence of oxygen (incineration) or in the absence of oxygen (pyrolysis). Incineration can treat a potentially wide variety of wastes. Thermal treatment offers quick clean up times but involves a higher cost.

A total of 17 thermal technologies have been identified in the study (Table 5. 5). Incineration, thermal desorption and pyrolysis are the commonly used thermal methods.

5.3.6. Summary

The available treatment technologies are identified and are listed in Tables 5.2 - 5.5 with their suitability for the different media such as unsaturated, saturated and groundwater zones. Biological technologies are mostly suitable for treating organics in the soil and groundwater and are not suitable for metals and inorganics treatment.

Chemical technologies may be applied for all the of contaminants in all the media. But they are less frequently used because of the high costs. Physical technologies are widely used and may be applied to all media for all the contaminants. Soil vapor extraction and solidification/ stabilization techniques are the most commonly used methods among the physical technologies. Thermal technologies are used for all the contaminants other than metals in all the media. Thermal treatment is not favorable because of the high expenses involved.

Table 5.2 through 5.5 summarizes the cost ranges for the most commonly used treatment technologies. Figure 5.5 shows the cost ranges for some of the popular treatment technologies. The plots and the table suggests that the popularity of the physical methods is reflected by the low costs involved in employing these technologies. Chemical technologies are the most expensive technologies.

Table 5.5: Thermal Treatment Technologies

No.	Treatment Technology	Type of Waste												EPA Classification	Cost	Case Studies	Reference		
		Soil								GroundWater									
		Unsaturated				Saturated													
		O	P	I	M	O	P	I	M	O	P	I	M						
T	Thermal																		
T1	Electric Reactors	x	x			x	x						x			Innovative	Not available	None	25
T2	Fluidized Bed Reactors	x	x			x	x						x	x		Innovative	Not available	None	11, 13, 25
T3	Fuel Blending	x	x			x	x									Innovative	Not available	None	25
T4	High Temperature Fluid Wall	x	x			x	x						x			Innovative	Not available	None	31
T5	Incineration	x	x			x	x						x			Established	\$220 to \$1,100 per metric ton	35	6
T6	Industrial Boilers	x	x	x		x	x	x					x	x		Innovative	Not available	None	25
T7	Infrared Incineration	x	x	x		x	x	x					x	x		Innovative	Not available	None	25
T8	In situ Steam Enhanced Extraction	x	x	x		x	x	x					x	x		Innovative	Not available	None	27
T9	In situ Thermal Destruction	x	x	x		x	x	x								Innovative	Not available	None	25
T10	Molten Salt			x	x			x	x							Innovative	Not available	None	25
T11	Pyrolysis	x	x			x	x									Innovative	\$330 per metric ton		6
T12	Radio Frequency Ground Heating	x	x			x	x									Innovative	Not available	None	22, 27
T13	Rotary Kiln Incineration	x	x			x	x									Established	Not available	None	24
T14	Supercritical Water Oxidation	x	x	x		x	x	x					x	x	x	Innovative	Not available	None	25
T15	Thermal Desorption	x	x			x	x									Innovative	\$60-98 per cubic meter	2, 10, 19, 21, 22, 26, 39	6, 26
T16	Thermal Plasma Reduction	x	x	x		x	x	x								Innovative	Not available	None	28
T17	Thermally Enhanced SVE	x	x			x	x									Innovative	\$30 to \$130 per cubic meter	None	6

x - recommended method; O - Organic; P - Petroleum; I - Inorganic; M - Metal

5.4 CONTAINMENT TECHNOLOGIES

5.4.1. Background

The potential for migration of pollutants from former industrial sites and landfills is accepted as a serious problem. If there were no consideration of cost, it is desired that all contaminated sites should be cleaned so as to remove the pollutants. Containment may be necessary because:

- There is no proven or environmentally cost effective cleanup technique available.
- Containment can provide immediate control.
- Some contaminants such as heavy metals cannot be destroyed and thus containment or extraction and recycling are the only options.
- The available cleanup options are so slow in operation that the pollution will spread to an unacceptable extent during the clean-up process.

The simplest approach to containment is to require that there should be no leakage of the contained material [16]. The barriers of a containment system may have to retain not only water but also aggressive aqueous solutions, non aqueous phase liquids (NAPLs), gases and solids and semi-solids. The rate of escape will be controlled by the overall permeability of the barrier. Barriers may need to be installed at existing contaminated sites or at new sites such as landfills.

Some of the containment systems in use are:

1. Clay Liners:

The clay liners are manufactured using bentonite clay. The clay liners consist of clay cement mixes and clay with other additives. These are used for landfills, surface impoundments and other disposal systems.

2. Cover Layers:

The main function of the cover layers is to prevent upward migration of contaminants and to limit human intrusion rather than to prevent the infiltration of rainwater. It may also be necessary to provide a capillary break layer under a clay cap to prevent the upward migration of contaminants by capillary in dry seasons.

The cover layer for a landfill should have a permeability of 10^{-9} m/s or less. If the cover is to be formed from clay, it will be necessary to specify the compaction procedure

and in addition it would be useful to specify the parameters such as minimum clay content of 10%, a liquid limit not exceeding 90% and a plasticity index not exceeding 65%.

3. Slurry Trench Cutoff Walls:

If a trench is excavated in the ground, in order to keep the trench open and excavate to almost any depth without collapse, it should be filled with an appropriate fluid. The fluid must exert sufficient hydrostatic pressure to maintain trench stability and it must not drain away into the ground to an unacceptable extent. There are a significant number of different types of slurry trench cutoff walls such as clay cutoffs, clay-cement cutoffs, cutoffs with membranes, high density walls, bentonite clay slurry walls, and bentonite cement slurry cutoff walls.

4. Capping/Sealing:

The containment with capping and sealing aids in that it prevents and restricts surface water infiltration and leachate formation. It controls erosion and contains contaminated wastes.

5. Horizontal Barriers:

The techniques available to form horizontal barriers under a contaminated area are limited to grout injection or jet grouting. To obtain a low permeability barrier it is necessary to use several stages of grouting at reducing centers. In this case, the overall permeability significantly better than 10^{-7} m/s can be achieved.

6. Secant Piling:

Secant piling is often used to provide structural walls which also function of cutoff. Secant pile type walls can be formed by mix-in-place techniques whereby a grout is mixed into the soil with a system of augers. The system may be used to produce either vertical or inclined walls.

7. Activated Bioscreens:

In situ bioscreens represent a new and emerging technology for in situ isolation and extensive remediation of contaminated sites. An in situ bioscreen is a local zone in a natural porous medium that has a high contaminant retention capacity and an increased bioactivity towards the biodegradation of hazardous organics and/or the immobilization of dissolved heavy metals. Contaminants are thus removed from groundwater flowing through such a

screen. The groundwater flows through the bioscreen under the influence of natural hydraulic potential gradient slightly adjusted by a minimum for pumping.

8. Bio-barriers:

Bio-barriers are used to clog a leachate or gas migration path with the clogging bacteria actually feeding on the leachate or gas. Certain bacteria species on staving may remain viable but reduce very substantially in size and develop an electrically neutral cell wall. The formation to be blocked is permeated with a culture of the ultra-micro bacteria and a slow acting feed. When provided with food, the bacteria slowly develop and may expand sufficiently to block the formation.

9. Vertical Barriers:

Vertical barriers are widely used for pollution control and especially for gas and leachate control. Slurry trench walls are the most widely used form of vertical barriers.

10. Shallow Cutoff Walls:

Shallow cutoff walls may be formed by excavating a narrow slot with some form of trench cutter and inserting a geomembrane. An alternative way of forming a shallow cut off is to excavate a wide trench and backfill it with compacted clay. The trench needs to have battered sides to avoid any risk of collapse during the compaction works.

11. Driven Barriers:

Driven barriers may be formed by driving sheet piles, or concrete or HDPE membrane elements into the ground. The fundamental requirements are that the elements are durable and can be joined to form a suitably impermeable wall. The advantage of driven barriers is that there is no need for excavation and disposal of possibly contaminated arisings.

12. Vibrated Beam Wall:

The vibrated beam wall is a combination of a driven barrier and an injected barrier. In the process, an H-pile is vibrated into the ground and then extracted. During extraction, a cement based grout is injected at the toe of the pile. The pile is then stepped forward and re-driven. The technique produces a relatively thin wall which is not ideal for pollution control.

Out of the 60 case studies documented, 10% used containment technologies. Since the wastes are contained within a certain area, the remediation is not complete and hence, contaminating groundwater with time is a possibility. This calls for monitoring of the groundwater in the vicinity; but in cases where time is a constraint, containment is a better solution rather than using treatment technologies.

5.4.2. Summary

Containment technologies are not the permanent solution to the contamination, but the waste is contained within an area so that it prevents migration and spreading of contamination to the surroundings. The containment technologies are becoming popular and are considered to be more cost effective if the sites are away from population centers. About 10% of the case studies collected during this study have used containment technologies.

5.5 LAND DISPOSAL METHODS

5.5.1. Background

Land disposal is the most cost-effective option available to many transportation agencies for disposing of contaminated soils, particularly in states where contaminated soil has not been banned or become too costly to dispose of in landfills. The high frequency of landfilling or land disposal occurs despite the long term liability that may accompany this activity. The land disposal is the most preferred soil remediation option for most transportation agencies and it is inexpensive in many states compared to other remedial options, especially when small quantities of soil are involved. Many state transportation agencies resort to the landfill option only when disposing of soils that contain very low concentrations of contaminants.

The classification systems adopted by the state of California in 1984 are the most widely accepted classification systems for landfills (Tchobanoglous *et. al.*, 1994). In these systems, three classifications are used:

Class I - Waste Management Units for Hazardous Waste

These sites have become residual repositories and accept only hazardous waste treatment residues. A Class I site must be designed and constructed to have ground water monitoring wells, leak detection systems, covers, liners and leachate collection systems. In addition to these, one would expect to implement air, wildlife, surface runoff, abandonment and other environmental and community protection systems.

Class II - Waste Management Units for Designated Waste

These sites allow only certain solid hazardous wastes, such as soil with low-level contamination and asbestos, for which they are specifically designed. The Class II sites have some, but not all, of the control systems present in a Class I site.

Class III - Landfills for Nonhazardous Waste

These sites accept common household trash and construction debris and are normally called municipal solid waste (MSW) landfills. In many cases, however, hazardous waste ends up in these sites because of error, ignorance, or lack of concern and results in environmental damage.

The use of landfills as the preferred disposal option may not pose as great a risk as would the use for disposing of soils contaminated with heavier petroleum products or hazardous waste. Under Texas Environmental Regulations, the Texas Department of Transportation can dispose of mildly contaminated soil (TPH<1500 ppm, BTEX<10 ppm, when referred to petroleum contamination) in municipal landfills for approximately \$13 per cubic meters. Soils containing higher levels of petroleum contamination are sent to commercial biopads where they are treated to below 1500 ppm TPH and then sent to a municipal landfill for use as daily cover. This method will cost around \$40 per cubic meters.

On October 19, 1991, the EPA published amended rules governing MSW landfills in response to directives contained in Subtitle D of the RCRA. Texas has subsequently amended its MSW rules to comply with the federal requirements (TNRCC, Municipal Solid Waste Management in Texas: Status Report). With the implementation of Subtitle D requirements, there are now only two types of MSW landfills in Texas, Type I and Type IV. Type I landfills are the standard facilities for the disposal of MSW and the waste must be compacted and covered daily. In 1994, there were 217 Type I landfills open in Texas. Type IV landfills may only accept construction & demolition debris, brush and other nonputrescible materials. Type IV landfills must be compacted and covered at least weekly. In 1994, there were 40 Type IV landfills open in Texas.

5.5.2. Summary

Land disposal methods are selected when there is not enough time for treating the soil. But the increasing costs involved in land disposal makes the option unattractive for disposal of large volumes of contaminated soils.

5.6 PETROLEUM CONTAMINATED SOILS

5.6.1. Background

Millions of underground storage tanks which have been installed over the years leaked and released their stored contents, usually petroleum products, into the environment. Many agencies have become responsible for cleaning up the petroleum contamination from leaking storage tanks they encounter when acquiring the land for, or during the construction of, new transportation facilities.

A survey found that approximately 90 percent of the petroleum contaminated sites being cleaned up by state transportation agencies involve gasoline and/or diesel fuel contaminated soils. Remediation of petroleum contaminated soils requires careful planning. Sites can be as simple as a corner service station with little contamination to a refinery contaminated with hundreds of compounds covering the entire area. The situation has become so serious that it is no longer a matter of digging out to the property line and backfilling the excavation. Remedial technologies that are effective for removing petroleum hydrocarbons that exist in one phase may not work well with another phase, and remediation systems that work at one site may not work at a different site. Effective remediation is thus determined on a site by site basis and is designed to address the contamination present in all phases and media affected at that location. No one technology is presently available to singularly remedy contaminants present in all phases and media.

The factors affecting the selection of a soil remediation technology are:

- (1) **Site Screening**: Specific conditions at the contaminated site are carefully evaluated. The type of contaminants found at the site may affect the selection of a technology. Time requirements may also be important in the selection process.
- (2) **Regulatory Screening**: An environmental regulatory agency's receptivity to a particular type of remediation technology, the agency's existing corrective action requirements, and its approach to the establishment of cleanup standards at petroleum contaminated sites can often unduly influence the cleanup options available to a transportation agency.
- (3) **Technology Screening**: Specific information and data concerning the design of a technology and its anticipated cost and effectiveness are assembled and evaluated. In this phase, a particular technology is more carefully matched with the site conditions and site cleanup levels established in the earlier phases.

Remedial options available for the treatment of petroleum contaminated soils can be segregated into the following two main categories:

- (1) In situ treatment technologies that do not require the removal of soil from the ground;
- (2) Ex situ technologies requiring excavation of the soils. Once excavated, contaminated soils can be treated on site or brought off-site for treatment.

5.6.2. Biological Technologies

- a) In situ Biological Technologies: Passive Biodegradation, Bioventing, In situ Biodegradation [NCHRP Report 226].
- b) Ex situ Biological Technologies: Biopiles, Land Treatment or Land Farming, Slurry Biodegradation [NCHRP Report 226].

5.6.3. Chemical Technologies

- a) In situ Chemical Technologies: Chemical Oxidation/Reduction [NCHRP Report 226].
- b) Ex situ Chemical Technologies: Solvent Extraction, Chemical Oxidation/Reduction [NCHRP Report 226].

5.6.4. Physical Technologies

- a) In situ Physical Technologies: Conventional Soil Venting, Hot Air or Steam Stripping, Soil Flushing [NCHRP Report 226].
- b) Ex situ Physical Technologies: Soil Washing, Coal Tar Agglomeration [NCHRP Report 226].

5.6.5. Thermal Technologies

- a) In situ Thermal Technologies: Vitrification, Radio Frequency Heating [NCHRP Report 226].
- b) Ex situ Thermal Technologies: Thermal Desorption by Low and High Temperature Thermal Strippers, Vitrification [NCHRP Report 226].

5.6.6. Analysis of Treatment Methods for Petroleum Contaminated Soils

Data provided in NCHRP 226 was analyzed. A total of 76 projects have been documented. The distribution of various treatment methods used on petroleum contaminated sites and the costs are shown in Figs. 5.11 and 5.12. Landfarming/composting is the most popular technology. Landfarming/composting is a controlled biological process by which biodegradable hazardous materials are converted by

microorganisms to innocuous, stabilized byproducts, typically at elevated temperatures in the range of 50 to 55°C. From the projects reported, biological methods were used in 46% of the cases. Land disposal (18%) and thermal methods (17%) have also been used in treating petroleum contaminated sites. No chemical method was used. Even though biological methods take longer time for treatment, they are the most popular for remediating petroleum contaminated sites.

5.6.7. Summary

Biological technologies are the most commonly used method for treating petroleum contaminated sites. Land disposal and thermal methods are also used.

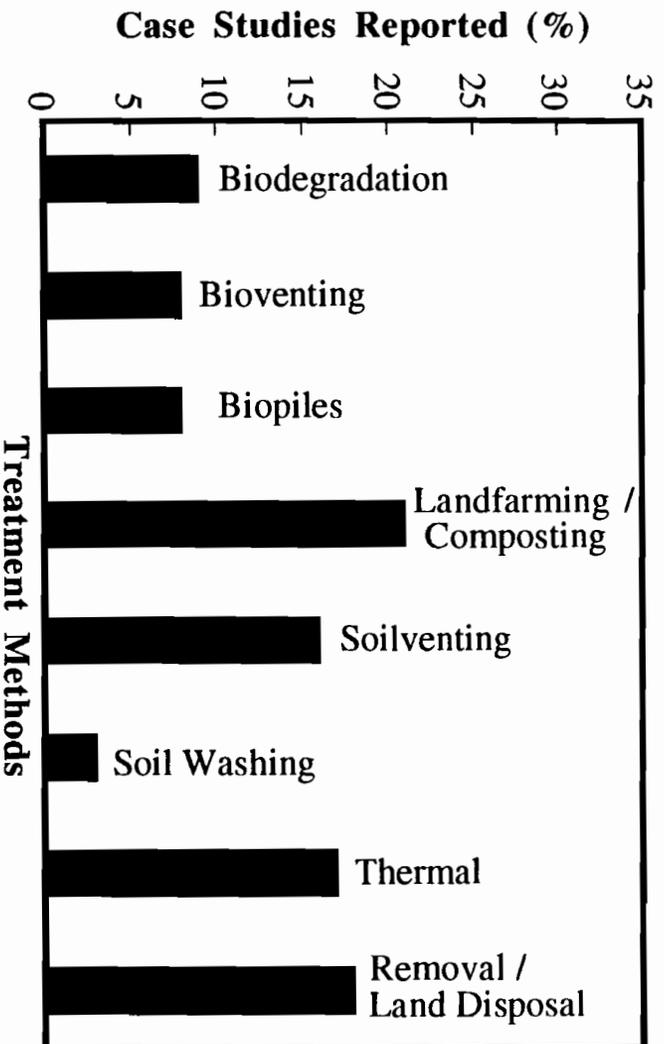


Figure 5.11. Distribution of Treatment Methods for Petroleum Contaminated Soils

Reference: NCHRP synthesis 226

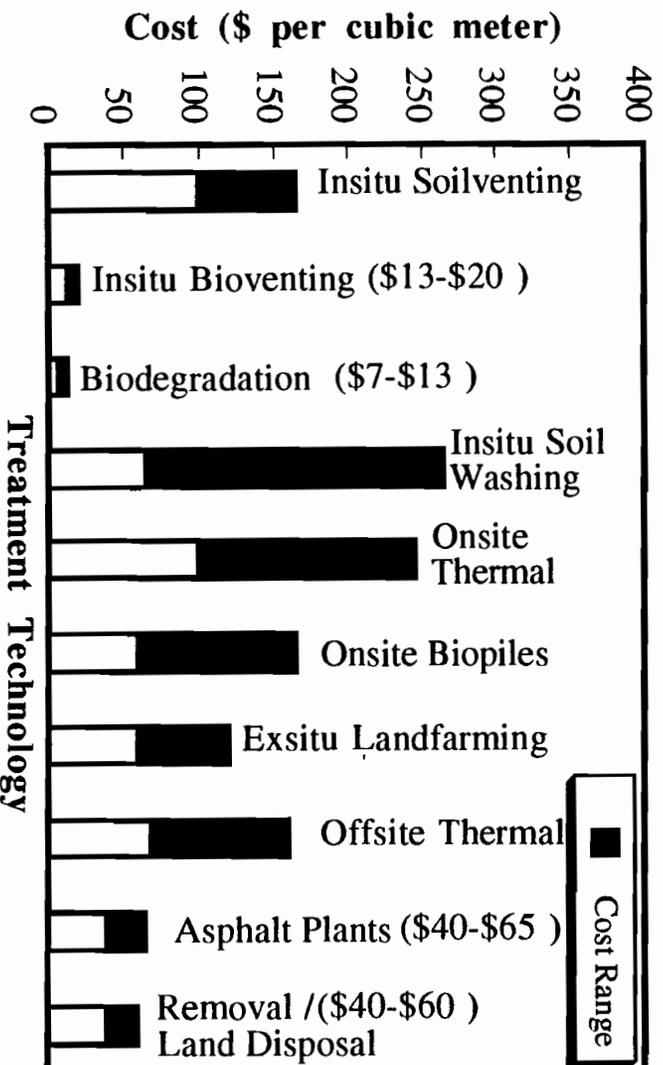


Figure 5.12. Cost Ranges for Treatment Methods for Petroleum Contaminated Soils

Reference : NCHRP Synthesis 226

5.7 CONCLUSIONS

The contaminants detected at a site and remedial technology used are reviewed in this chapter. The following conclusions can be advanced:

- (1) Over 70 treatment methods and 12 containment methods have been identified. Also cost of remediation is included for some of the methods.
- (2) Physical treatment methods are the most popular and economical technologies to remedy hazardous waste contaminated sites. Biological and thermal methods have also been used.
- (3) For petroleum contaminated sites, especially related to DOT sites, biological methods were the the most popular. Land disposal and thermal treatment methods are also used.
- (4) Containment methods are becoming popular in recent times but very limited information is available in the literature.

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Chapter 6

Regulations and Specifications

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6.1. INTRODUCTION

The Environmental Protection Agency (EPA) is the federal agency with environmental protection regulatory and enforcement authority. The EPA administers such acts as the Clean Air Act (CAA), Clean Water Act (CWA), Resource Conservation and Recovery Act (RCRA), Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Superfund Amendments and Reauthorization Act (SARA), Toxic Substance Control Act (TSCA) and other federal environmental laws. RCRA (1976), CERCLA (1980) and SARA (1986) are the three most important federal regulations that are of concern in hazardous waste site remediation. Some states also have regulations with regard to site remediation [1, 4, 6, 10, 11, 16, 28, 29]. Both federal and state requirements must be complied with during remediation. The basic goals of an environmental cleanup, under state and federal programs, is the prevention of adverse impacts on human health and the environment.

During the early 1970's, several environmental regulations were promulgated. As these regulations grew in complexity, a process called environmental auditing evolved to serve as a tool for managing environmental compliance with the regulations and to resolve liabilities associated with the ownership of contaminated property. The history of various federal and State of Texas laws that were introduced are summarized in Table 6.1 in chronological order.

Since the enactment of the CERCLA in 1980, previous and current owners and operators of a property can be held strictly liable for contamination on their property regardless of how long the situation existed or who was responsible for creating the contamination. The SARA (1986) offers a provision for a landowner to establish innocence regarding knowledge that on-site contamination had occurred. To establish this defense, the owner must demonstrate that, at the time of the acquisition, the owner did not know or have reason to know that hazardous substances were released or disposed of on the property. To preserve that defense, the owner must demonstrate that he carried out "all appropriate inquiry into the previous ownership and uses of the property consistent with good commercial and customary practice in an effort to minimize liability" (CERCLA, §101(35)(b)).

In response to liability under the CERCLA legislation and to provide protection under the SARA provisions, various professional associations and technical societies have developed guidance or standards for conducting appropriate inquiry into the

environmental status of property. Professional societies such as the Association of GroundWater Scientists and Engineers (AGWSE) and Professional Firms Practicing in Geosciences (ASFE) have developed procedures for Initial Site Investigation (Phase I). American Society of Civil Engineers (ASCE) guideline [1] details the process to conduct Phase I and Phase II of the HWMP and provides preliminary summaries on Phase III and Phase IV (ASCE, 1996). ASTM standards are focused on the Phase I (ASTM E 1527) and Phase II (ASTM E 1903) processes of the HWMP; also, several other ASTM standards are available for detailed site investigations.

CERCLA imposes joint liability on potentially responsible parties (PRP's) without regard to fault for all costs associated with cleaning up contaminated properties. PRP's include, but are not limited to:

- (1) the owner or operator of the property,
- (2) the owner or operator of the property at the time the hazardous substances were disposed of,
- (3) any person who arranged (by contract, agreement, or otherwise) for the disposal or treatment, or arranged with a transporter for transport for disposal or treatment of the hazardous substances, and
- (4) any person who accepts hazardous substances for transport to disposal or treatment facilities.

Also, **CERCLA** provides four opportunities for minimizing liabilities in real estate transactions. Section 107(b) of the act allows a defendant to minimize or escape liability, known as the "Third Party Defense," if they can establish "by a preponderance of the evidence" that the release or threatened release of hazardous substances and resulting damages were caused solely by:

- (a) an act of God,
- (b) an act of war,
- (c) an act or omission of a third party other than an employee or agent of the defendant, or that one whose act or omission occurs in connection with a contractual relationship, existing directly or indirectly with the defendant..., if the defendant establishes that
 - (i) he exercised due care with respect to the hazardous substance and
 - (ii) he took precautions against foreseeable acts or omissions of any such third party and the consequences that could foreseeably result from such acts or omissions, and
- (d) any combination of (a), (b) or (c).

With the passage of **SARA** (1986), other provisions for minimizing liability were made available:

- (1) at the time the defendant acquired the facility the defendant did not know and had no reason to know that any hazardous substance which is the subject of the release or threatened release was disposed of on, in, or at the facility,
- (2) the defendant is a government entity that acquired the facility by escheat, or through any other involuntary transfer or acquisition, or through the exercise of eminent domain authority by purchase or condemnation, and
- (3) the defendant acquired the facility by inheritance or bequest.

Some of the federal and state regulations are discussed in sections 6.2 through 6.5 in this chapter.

Table 6.1. Summary of Important Environmental Regulations and Special Events

Year	Act or Event	Objective	Details	Comments
1963	Clean Air Act (CAA)	Regulates air pollution and sets emission standards	Title I: Air pollution prevention and control; Title II: Emission standards and moving sources; Title III: General; Title IV: Acid deposition control; Title V: Permits; Title VI: Stratospheric ozone; Title VII: Acid precipitation program and carbon dioxide study.	Hazardous Waste Management by Charles A. Wentz, 1995
1970	EPA was created	Mission is for pollution prevention and to stop producing hazardous wastes.	To streamline activities around the nation. Develop rules and guidelines for handling hazardous wastes.	U.S. Congress.
1970	Occupational Safety and Health Act (OSHA)	Regulates occupational exposures to hazardous substances.	Health related requirements of OSHA typically key on the presence of TOTAL amounts of listed elemental constituents. Established for the regulation of <u>site safety procedures, worker training, and worker safety and health standards.</u> A specific listing of chemicals is found in Table Z, 29 CFR 1910.1000.	Title 29 CFR (Code of Federal Regulations) sections 1910 and 1926.
1974	Safe Drinking Water Act (SDWA)	Establishes and regulates Maximum Contaminant Levels (MCL) of hazardous substances for public drinking water systems.	MCLs are used by EPA as the basis for <u>groundwater cleanup criteria under CERCLA</u>	Hazardous Waste Management by Charles A. Wentz, 1995
1976	Resource Conservation and Recovery Act (RCRA) (Replaced the Solid Waste Disposal Act of 1965)	Gave EPA the power to regulate hazardous wastes. The act regulates not only the <u>generation, transportation, treatment, storage and disposal of hazardous wastes</u> , but also <u>municipal solid waste</u> disposal facilities.	Title II: Solid waste disposal (a) Subtitle C - Regulates the ongoing generation, transportation, treatment, storage, and disposal of hazardous wastes. Subtitle I - <u>Regulates management of underground storage tanks</u> . Each owner must notify the state or local controlling agency as to the existence of such a tank, detailing the age, size, type, location, and use. releases must also be reported and corrective actions taken. Subtitle J - Regulates medical waste. RCRA seeks to better manage <u>active</u> hazardous waste treatment, storage, and disposal facilities so new superfund sites will not be created in the future.	Hazardous Waste Management by Charles A. Wentz, 1995
1976	Toxic Substance Control Act (TSCA)	Regulates the manufacturer and distribution of hazardous chemical substances within the United States. Participants must maintain records and submit reports to EPA on routine basis.	Title I: Control of toxic substances.	Hazardous Waste Management by Charles A. Wentz, 1995

Year	Act or Event	Objective	Details	Comments
1977	Clean Water Act (CWA)	Regulates the amount of discharge of oil or hazardous substances into or upon the navigable waters and adjoining shorelines of the United States in any harmful quantity as determined by regulations	Title I: Research and related programs; Title II: Grants for construction of treatment works; Title III: Standards and enforcement; Title IV: Permits and licenses; Title V: General provisions; Title VI: State water pollution control revolving funds. Restore and maintain the chemical, physical, and biological integrity of Nation's waters.	Hazardous Waste Management by Charles A. Wentz, 1995
1980	Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or the "Superfund" Act)	Requires notification of any release of "reportable quantities" of hazardous substances (does not apply to federally permitted releases or to the application of pesticides). Gives the federal government the power to respond to releases. or threatened releases, of any hazardous substance into the environment and danger to public health or welfare.	Title I: Hazardous substances releases, liability, compensation; Title II: Establishment of hazardous substance response trust fund; Title III: Miscellaneous provisions; Title IV: Pollution insurance. CERCLA is a remedial statute designed to deal with problems of past mismanagement of hazardous waste. Focuses on the cleanup of uncontrolled or <u>abandoned site</u> . Under CERCLA, the government created a process for <u>identifying liable parties</u> and ordering them to take the responsibility for cleanup operations.	40 CFR Parts 300 to 355.
1986	Superfund Amendments and Reauthorization Act (SARA)	Amplifies CERCLA requirements. Amended CERCLA and introduced more stringent and <u>detailed guidelines for cleanups</u> .	Title III: Emergency planning and community <u>right-to-know act</u> of 1986- Requires certain businesses to prepare inventory reports listing hazardous chemicals in their possession, to assist in the development of local emergency response plans, to prepare annual reports of releases of hazardous substances, and to report immediately certain ultra-hazardous releases; Title IV: Radon gas and indoor air quality research	Hazardous Waste Management by Charles A. Wentz, 1995
1986	Asbestos Hazard Emergency response Act (AHERA)	Regulates asbestos management and control procedures in public schools.	Included as Title II in TSCA (1976). If the material is found, it must be removed prior to demolition for health and environmental protection reasons.	Hazardous Waste Management by Charles A. Wentz, 1995
1990	Clean Air Act Amendments	Regulates air quality issues.	Amendments to the 1963 CAA.	Charles A. Wentz, 1995
1990	National Pollutant Discharge Elimination System (NPDES)	Storm water pollution program	Includes methods to minimize problems in storm sewers.	Government publication 55 FR 47990 (November 16, 1990) and 57 FR 11394 (April 2, 1992).
1991 (Centennial)	Rail Road Commission of Texas (RRC)	To regulate and control natural resources such as gas and oil	RRC was created in 1891. Has rules on cleanup of soil contaminated by oil spill. Also has rules for management of hazardous oil and gas waste	Rail Road Commission 1997

Year	Act or Event	Objective	Details	Comments
1993	Texas Natural Resource Conservation Commission (TNRCC)	TNRCC adopts and administers rules under Title 30 of the Texas Administrative Code (TAC)	TNRCC was created on September 1, 1993 by consolidating the following agencies: Texas Water Commission; Texas Air Control Board; Water Well Drillers Board and Board of Irrigators; and Texas Department of Health Programs (Solid Waste, Water Hygiene, Radioactive Waste, On-site Sewage Disposal and Wastewater Treatment Research.	Texas Senate Bill 2 of the 72nd Texas Legislature
1993	RRC Rule 91	Cleaning-up of Soil Contaminated by a Crude Oil Spill	Includes requirements for cleanup, remediation of soil and reporting.	Section 3.91; Rail Road Commission
1993	TNRCC. 30 TAC Chapter 334; Subchapter K;	Section 334.484; Registration for petroleum storage and treatment facilities. Section 334.503; Reuse of petroleum substance waste. Section 334.504; Contaminant assessment program and corrective action.	Rules and conditions for storing and treating petroleum wastes. Reuse of petroleum wastes.	30 TAC Chapter 334.
1996	RRC Rule 98	Standards for Management of Hazardous Oil and Gas Wastes	Includes general prohibitions, hazardous waste determination , notification, contingency plan and emergency procedures personnel training, disposition of hazardous oil and gas waste, and record keeping and reporting.	Section 3.98; Rail Road Commission
1995	TNRCC. 30 TAC Chapter 334; Subchapter A; Section 334.1	Comprehensive regulatory program for underground storage tanks and above ground storage tanks.	To establish minimum standards and procedures to protect and maintain the quality of state' groundwater and surface water.	30 TAC Chapter 334.
1996	TNRCC	Suggested Analytical Testing for Special Waste disposal	Methods for analyzing for various contaminants in the waste	RG-69/Revised 9-96. TNRCC Publication

6.2. FEDERAL REGULATIONS

In this section, each federal regulation which impacts the cleaning up operations is introduced and the regulations are summarized in the Table 6.2.

6.2.1. Occupational Safety and Health Act (OSHA) (29 CFR Section 1910 and 1926)

(a) What is OSHA (1970) ?

The Occupational Safety and Health Act (OSHA) of 1970 was passed to “assure so far as possible every working man and woman in the nation safe and healthy working conditions and to preserve human resources”. OSHA also has training requirements for workers on hazardous waste sites.

6.2.2. Resource Conservation and Recovery Act (RCRA) (40 CFR 260-272)

(a) What is RCRA (1976) ?

The Resource Conservation and Recovery Act of 1976 (RCRA) is about the policy concerning the methods of managing hazardous waste.

The goals set in RCRA as follows:

- (i) Protection of human health and the environment
- (ii) Reduction of waste and conservation of energy and natural resources
- (iii) Reduction or termination of hazardous waste generation.

(b) What is ‘Hazardous Waste’ ? (40 CFR 261.3, 40 CFR 6903)

Hazardous waste is defined as a solid waste, or a combination of solid wastes, which because of its “quantity, concentration, or physical, chemical, or infectious characteristics” may cause or significantly contribute to increases in mortality or serious illnesses, or pose a substantial threat to human health or the environment when improperly treated, stored, transported, or disposed of , or otherwise managed.

The four characteristics of a hazardous waste as determined by the EPA are as follows:

- a) Ignitability: A liquid, except aqueous solutions containing less than 24% alcohol that has a flash point less than 60° C, which under standard temperature and pressure may cause a fire through friction, moisture absorption or spontaneous reactions, and burn so energetically that it creates a hazard; or an oxidizer or ignitable compressed gas

under Department of Transportation (DOT) regulations 49 CFR 173. Ignitable hazardous wastes have EPA hazardous waste number D001. (Examples of ignitable wastes are paint wastes, degreasers, solvents).

- b) **Corrosivity:** A liquid that has a pH of between 2.0 and 12.5 and corrodes steel faster than one quarter inch per year under certain conditions. Corrosive hazardous wastes have EPA hazardous waste number D002. (Examples of corrosive wastes are rust removers, alkaline cleaning fluids, and battery acid).
- c) **Reactivity:** The liquid is very unstable and readily undergoes violent change without detonating; it reacts violently, forms potentially explosive mixtures, or generates dangerous toxic gases when mixed with water; it may explode or detonate under certain conditions; it can generate dangerous toxic gases when exposed to a pH level of between 2 and 12.5; or it is a forbidden explosive by 49 CFR 173. Reactive hazardous wastes have EPA hazardous waste number D003. (Examples of reactive wastes are cyanide plating wastes, waste bleaches, other waste oxidizers).
- d) **Toxicity:** The extract from a representative sample contains certain contaminants in greater concentrations than permissible as listed in Table 1 of Section 261.24 (40 CFR). The test method used to determine toxicity is Toxicity Characteristic Leaching Procedure (TCLP). Toxic hazardous wastes have EPA hazardous waste numbers D004 to D043 as summarized in Table 1. (Examples of toxic wastes are mercury (D009), cadmium (D006), lead (D008) and specific pesticides).

6.2.3. Toxic Substances Control Act (TSCA) (15 SC sections 2601-2692 and 40 CF 700-766)

(a) What is TSCA (1976) ?

TSCA is the federal legislation governing the use, production and distribution of toxic substances and is implemented by 40 CF 700-766. The policy behind TSCA is that the manufacturers or processors of chemical substances must develop adequate data to understand the effects of their products on human health and environment.

(b) What are the Reporting and Record Keeping Requirements ?

The reporting and record-keeping requirements for in 40 CF 704.3 and 710.2.

(c) What are the Emergency Plans and Notification Requirements ?

The regulations for emergency plans and notification are in (40 CF 355.30). Determine if the facility contains PQ (threshold planning quantity) amounts of extremely hazardous substances and triggers the regulatory requirements.

No : No compliance program necessary.

Yes: Notify State Emergency Response Commission and designate a facility emergency coordinator to participate in local emergency planning.

Does the facility store CERCLA hazardous substances or extremely hazardous substances?

No : No reporting necessary.

Yes: Facility must have in place spill reporting procedures per 40 CF 355.40.

6.2.4. Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) (42 SC sections 9601-9675)

(a) What is CERCLA (1980) ?

CERCLA is unique among environmental laws in that it does not focus much effort on regulating current behavior, but instead deals with cleaning up the results of the past actions or present spills. CERCLA authorizes the federal government, states, private parties and Indian tribes to cleanup polluted sites and to impose liability on others to recover some or all of the cleanup costs [Bremen, 1996].

(b) What are the objectives under CERCLA?

CERCLA compliance program may be broken into three main parts:

1. Involving the only major behavioral requirement, which in section 42 SC 9603 directs facilities to report certain releases of hazardous substances;
2. EPA's liability either to respond to a contamination incident on its own under section 42 USC 9604 or to direct a facility, under 42 USC 9606, to conduct cleanup actions.
3. A compliance officer must be well versed in the liability issues presented by both CERCLA and by courts interpreting the act.

(c) What are the Notification Requirements ?

42 USC 9603 of the Act requires "any person in charge" of a vessel or facility to notify the National Response Center (1-800-424-8802) when there is an unpermitted

release of a hazardous substance above a specific quantity take place. Failure to provide prompt notification of a release after gaining knowledge of it can result in significant criminal and civil liabilities for the person in charge of the relevant vessel or facility. The penalties include up to 5 years in prison and fines or penalties up to \$25,000 per day.

(d) What are the Cleanup Standards ?

The five requirements that all CERCLA remediation actions must meet are as follows (42 USC 9621):

1. Protect human health and the environment.
2. Utilize permanent solutions and alternative treatment/resource recovery technologies as much as practicable.
3. Be cost-effective.
4. Attain compliance with applicable or relevant and appropriate requirements where hazardous substances will remain on site.
5. Be in accordance with National Contingency Plan as much as possible.

(e) Who may be liable ?

CERCLA liability, as described in 42 USC 9607 of the Act, include the present owner and operator of the site, as well as any other owner or operator of the site during the time it was contaminated, any transporters who selected the site and anyone who arranged for treatment or disposal of the hazardous substance.

6.2.5. Superfund Amendments and Reauthorization Act (SARA) (40 CFR 355-372)

(a) What is SARA (1986) ?

The Superfund Amendments and Reauthorization Act (SARA) of 1986 strengthened CERCLA (1980) by providing new cleanup standards, requiring cleanup schedules, aiming certain provisions directly at federal facilities, and increasing settlement, liability and enforcement powers for the Environmental Protection agency (EPA) and private citizens.

Table 6.2. Relevant EPA Regulations Related to Contaminated Sites

Chapter	Chapter Title	Section	Contents	Purpose
42 USC (CERCLA)	Unspecified	9601	Definitions of Removal, Remedial Action, Response	Contaminated soil and Groundwater
		9603	Directions to Report the Releases of Hazardous Substances, Notification Requirements	
		9604	EPA's Ability to Respond to a Contamination Incident on its Own	
		9605	EPA's Ability to Direct a Facility to Respond to a Contamination Incident,	
		9606	Conducting Cleanup actions, Abatement Actions	
		9609	Awards for Information on Violation, Fines	
		9659	Filing Suits, Judicial Implementation	
		9607	Responsibility for Response Costs	
		9621	Cleanup Standards	
		9622	Authorization for Cleanup	
		9221	State Involvement in Superfund Cleanups	
		9607	Liability, Parties Liable	
		9620	State and Federal Government Liabilities, Definition of Owner or Operator, Federal Owned Properties	
40 CFR	Unspecified	302	Explain Notification Requirements in Detail	Contaminated soil and Groundwater, PSTs
		300.430	Steps to Establish a Remediation Plan	
		300.400	EPA's right to enter and Carry out Response Actions	
		300	Requirements on Response Actions to Oil Releases and Hazardous Substance Releases	
		305 & 307	Process to Seek Compensation from the Superfund	
		300.575	Nonfinancial Requirements for State Involvement in EPA led Responses	
		430	Concentration Levels, Standards, PS/RI Programs	
40 CFR Parts 260- 281 (RCRA)	Subtitle C	261.3001	Identification and Listing of Hazardous Waste	Contaminated soil and Groundwater
		262.3002	Standards applicable to generators of hazardous waste	
		263.3003	Standards applicable to transporters of hazardous waste	
		268.3013	Land Disposal Restrictions	
		270.3005	Permits	
		271.3006	State hazardous waste program	
		280.9003	Corrective Action	

6.3. TNRCC REGULATIONS

(URL: <http://www.tnrcc.state.tx.us>)

The TNRCC regulations related to Hazardous Waste Management Plan are summarized in Table 6.3. Responses to some of the frequently asked questions are summarized below.

6.3.1. General

(a) What are the groundwater standards available under TNRCC ?

The groundwater standards are defined under 30 TAC 330.235.

(b) What is corrective action assessment under TNRCC ?

The corrective action assessment is described in 30 TAC 330.236. Within 30 days of completion of the assessment of corrective action, the owner shall submit a report to the executive director for review and approval.

(c) Where are the standards for management of wastes specified?

The standards for management of wastes relating to implementation of corrective action program are specified in 30 TAC 330.238.

6.3.2 Hazardous Waste

(a) What is hazardous waste ? (RG-86, July 1994)

TNRCC embrace the same definition of 'hazardous waste' as found in Title 40 Code of Federal Regulations (CFR) section 261.3.

(b) What is characteristically hazardous waste according to TNRCC ? (40 CFR Part 261 Subpart C)

Any waste that exhibits the characteristic of ignitability, corrosivity, reactivity and/or toxicity as defined by the EPA in 40 CFR Part 261 Subpart C. These are often referred to as the "D" wastes.

(c) How do you determine hazardous waste ? (RG-100, November 1994) (30 TAC 335.504)

Under 30 TAC Chapter 335, Subchapter A of the TNRCC rules, all solid waste must be managed in accordance to its classification as hazardous or nonhazardous. Once the material is found to be solid waste, it is required to make a hazardous waste determination pursuant to 30 TAC 335.62. If analytical results show that a waste exhibits

one or more characteristics of a hazardous waste as defined in 40 CFR Part 261 Subpart C, the waste must be managed under industrial and hazardous waste rules in 30 TAC Chapter 335.

(d) What is Class 1 waste under TNRCC? (30 TAC 335.1)

Any waste or mixture of waste which, because of its concentration or physical or chemical characteristics is toxic, corrosive, flammable, a strong sensitizer or irritant, a generator of sudden pressure by decomposition, heat or other means, and may pose a substantial present or potential danger to human health or the environment when improperly processed, stored, transported, or disposed of or otherwise.

6. 3. 3. Nonhazardous Waste

(a) What is Class 2 waste under TNRCC ? (30 TAC 335.1)

Any individual waste or combination of waste which cannot be described as hazardous, Class 1 or Class 3 waste.

(b) What is Class 3 waste under TNRCC ? (30 TAC 335.1)

Inert and essentially insoluble waste, usually including but not limited to, materials such as rock, brick, glass, dirt, and certain plastics and rubber, etc. that are not readily decomposable.

(c) What are medical wastes ? (30 TAC 335.508)

Nonhazardous medical wastes which are subject to the provisions of 30 TAC Chapter 330 Subchapter Y are designated as class 2 wastes. An example of such wastes is needle bearing syringes from hospitals.

6. 3. 4. Petroleum Wastes

(a) What are the petroleum wastes ? (30 TAC 335.508)

Wastes resulting from the cleanup of leaking underground storage tanks (USTs) which are regulated under 30 TAC Chapter 334 Subchapter K (relating to petroleum waste) are not subject to classification under 30 TAC Chapter 335 Subchapter R.

(b) What are the petroleum substances according to TNRCC ? (RG-22, August 1995)

A crude oil or any refined or unrefined fraction or derivative of crude oil which is a liquid at standard conditions of temperature and pressure. Various types of petroleum substances are as follows:

- (i) basic petroleum substances - crude oils, crude oil fractions, petroleum feed stocks, and petroleum fractions;
- (ii) motor fuels - a petroleum substance which is typically used for the operation of internal combustion engines and /or motors (which includes but is not limited to stationary engines and engines used in transportation vehicles and marine vessels);
- (iii) aviation gasoline - Grade 80, Grade 100, and Grade 100-LL;
- (iv) aviation jet fuels - Jet A, Jet A-1, Jet B, JP-4, JP-5, JP-8;
- (v) distillate fuel oils - Number 1-D, Number 1, Number 2-D, and Number 2;
- (vi) residual fuel oils - Number 4-D, Number 4-light, Number 4, Number 5-light, Number 5-heavy, and Number 6;
- (vii) gas-turbine fuel oils - Grade O-GT, Grade 1-GT, Grade 2-GT, and Grade 3-GT;
- (viii) illuminating oils - kerosene, mineral seal oil, long-term burning oils, 300 oil, and mineral colza oil;
- (ix) lubricants - automotive and industrial lubricants;
- (x) building materials - liquid asphalt and dust-laying oils;
- (xi) insulating and water proofing materials - transformer oils and cable oils;
- (xii) used oils.

(c) What material is not considered petroleum substance according to TNRCC? (RG-22, August 1995)

The following materials are not considered petroleum substances:

- (i) polymerized materials, i.e., plastics, synthetic rubber, polystyrene, high and low density polyethylene;
- (ii) animal, microbial, and vegetable fats;
- (iii) food grade oils;
- (iv) hardened asphalt and solid asphaltic materials - i.e., roofing shingles, roofing felt, hot mix; and
- (v) cosmetics.

6.3.5. Others

(a) How to analyze the groundwater and soil samples? (RG-17, October 1996)

Samples should be analyzed using the analytical methods specified in the TNRCC publication 'Soil and Groundwater and Sampling and Analysis (RG-14)''.

Table 6.3: Relevant TNRCC Regulations Related to Contaminated Sites

Chapter / subchapter	Chapter Title	Section	Section Title/ Date Effective	Contents	Purpose
305 / Subchapter G	Consolidated Permits / Additional Conditions for Hazardous and Industrial Solid Waste Storage, Processing, or Disposal Permits	305.141	Applicability / June 14, 1996	All hazardous and industrial solid waste storage, processing, or disposal permits	Contaminated Soil, Municipal and Industrial Hazardous waste
		305.143	Record keeping	Records for groundwater monitoring wells and associated groundwater surface elevations	
		305.145	Release or Discharges of Solid Waste	Solid waste release, fire or explosion from a facility, notice requirements	
		305.146	Reporting	Manifest discrepancy report, waste report, annual report, monthly summary	
		305.148	Impact of New Hazardous Waste Management Facilities on Local Land Use	Permit, land use	
		305.149	Time Limitation for Construction of Commercial Units / November 20, 1996	Storage, processing or disposal of hazardous waste, permits as per the class under which the waste falls	
308 / Subchapter A	Criteria and Standards for Imposing Technology Based Treatment Requirements	308.1	Criteria and Standards for Imposing Technology Based Treatment Requirements / October 8, 1990.	Refer Section 40 CFR part 125, subpart A	Contaminated Soil, Municipal and Industrial Hazardous waste
314 / Subchapter A	Toxic Pollutant Effluent Standards	314.1	Toxic Pollutant Effluent Standards and Prohibitions	Refer Section 40 CFR part 129, subpart A	Contaminated Soil, Hazardous waste
323	Waste Disposal Approvals	323.21	Rating Systems / April 24, 1995	Approval of system for evaluating waste disposal facilities	Contaminated Soil, Municipal and Industrial Hazardous waste
Unspecified	Unspecified	RG-4	Asbestos Waste Disposal / September, 1996	Definitions for Asbestos Materials, Management of Regulated Asbestos Containing Material	Contaminated Soil

Table 6.3: Relevant TNRCC Regulations Related to Contaminated Sites (Contd.)

Chapter / subchapter	Chapter Title	Section	Section Title/ Date Effective	Contents	Purpose
335 / Subchapter A	Industrial Solid Waste and Municipal Hazardous Waste in General	335.1	Definitions / September 23, 1997	Definitions of aboveground storage tanks, class I waste, class II waste, class III waste, contingency plan, disposal facility, closure, hazardous waste	Contaminated Soil, Municipal and Industrial, Hazardous waste, Storage Tanks
		335.2	Permit Required / September 23, 1997	Permit for physical construction of a new waste management facility, no permit required condition	
		335.3	Technical Guidelines / September 23, 1997	For collection, handling, storage, processing, and disposal of industrial solid waste, recycling	
		335.4	General Prohibitions / September 23, 1997	Endangerment of public health, and welfare	
		335.6	Notification Requirements / March 6, 1996	Requirements to store, process, or dispose of industrial solid waste and for generator of hazardous waste, recycling	
		335.8	Closure / September 23, 1997	Regulations for closure of facilities used for storage, processing or disposal of waste, notification of spills	
		335.28	Adoption of Memoranda of Understanding / November 20, 1996	MOU between commission and other state agencies as in TWC section 5.104	
335 Subchapter D	Standards Applicable to Transporters of Hazardous Waste	335.91	Scope	Establishes standards for transporters of hazardous waste to offsite storage, processing or disposal facilities	Contaminated Soil, Hazardous Waste
		335.92	EPA Identification Number	Requirement for EPA ID number	
		335.93	Hazardous Waste Discharges	Notification, cleanup, report	

Table 6.3: Relevant TNRCC Regulations Related to Contaminated Sites (Contd.)

Chapter / subchapter	Chapter Title	Section	Section Title/ Date Effective	Contents	Purpose
Unspecified	Unspecified	RG-86	Waste Transportation Regulation in Texas / July 1994	Hazardous Waste Transportation, Transportation of Other Wastes	Contaminated Soil
Unspecified	Unspecified	RG-69	Suggested Analytical Testing for Special Wastes Disposal / September 1996	Table with Information on Treatment or Testing Suggested with Reference to Waste Items	Contaminated Soil, Municipal Solid Waste Landfills
Unspecified	Unspecified	RG-14	Soil and Groundwater Sampling and Analysis / April 1995	Soil Sample Collection, sample handling and selection, groundwater sample collection, soil and groundwater sample analysis	Contaminated Soil, Groundwater
Unspecified	Unspecified	RG-44	Selecting an Environmental Consultant or Corrective action specialist / February 1995	Researching consulting companies, selection making, TNRCC registration of consultants	Contaminated Soil
Unspecified	Unspecified	RG-234B	Managing Hazardous waste generation and/ or handling / May 1996	storing and treating hazardous waste, hazardous wastes vs. Hazardous materials	Hazardous waste sites
Unspecified	Unspecified	RG-03	Disposal of Special Wastes Associated with Development of Oil, Gas and Geothermal Resources	Table with information on RCRA exempt, treatment or testing recommended, TNRCC approval necessary for landfill disposal for waste items	Municipal solid waste, Municipal landfills
Unspecified	Unspecified	RG-29	What is 'Special Waste'? / September 1996	Special Waste, Approval Requirement	Municipal Solid Waste
Unspecified	Unspecified	RG-74	Guidelines for Preparing a Groundwater Sampling and Analysis Plan / May 1994	Sample collection, preservation, QA/QC, Statistical models, Reporting and Submittals	Municipal Landfills

6.4. RAILROAD COMMISSION OF TEXAS (RRC)

(URL: <http://www.rrc.state.tx.us/>) **Established in 1891.**

The relevant RRC regulations are summarized in the Table 6.4 and some of the regulations are discussed.

6.4.1. Cleanup of Soil Contaminated by a Crude Oil Spill (Section 3.91: Rule 91):

(Adopted Effective November 1, 1993).

The rule deals with the procedures and standards applied to the cleanup of soil contaminated with crude oil spills. These cleanup standards and procedures apply to the cleanup of soil in non-sensitive areas contaminated by crude oil spills from activities associated with the exploration, development, and production, including transportation, of oil or gas or geothermal resources. Cleanup requirements for crude oil contamination that occurred wholly or partially prior to the effective date of this section will also be determined on a case-by-case basis.

(a) What are the requirements for cleanup?

- (i) **Removal of Free Oil:**- To minimize the depth of oil penetration, all free oil must be removed immediately for reclamation or disposal.
- (ii) **Delineation:**- Once all free oil has been removed, the area of contamination must be immediately delineated, both vertically and horizontally. The area of contamination means the affected area with more than 1.0% by weight total petroleum hydrocarbons.
- (iii) **Excavation:**- At a minimum, all soil containing over 1.0% by weight total petroleum hydrocarbons must be brought to the surface for disposal or remediation.
- (iv) **Prevention of storm water contamination:**- To prevent storm water contamination, soil excavated from the spill site containing over 5.0% by weight total petroleum hydrocarbons must immediately be:
 - (a) mixed in place; or
 - (b) removed to an approved disposal site;
 - (c) removed to a secure interim storage location for future remediation or disposal.

(b) What is the final cleanup level for total hydrocarbons ? (Remediation of soil)

A final cleanup level of 1.0% by weight total hydrocarbons must be achieved as soon as technically feasible, but not later than one year after the spill incident.

(c) What are the requirements for Bioremediation ?

The soil to be bioremediated must be mixed with ambient or other soil to achieve a uniform mix that is no more than 18 inches in depth and that it contains no more than 5.0% by weight TPHs.

6.4.2. What are the standards for management of hazardous oil and gas waste ?

(Section 3.98: Rule 98): (Adopted Effective April 1, 1996).

The purpose of this section is to establish standards for management of hazardous and oil wastes. The parameters discussed are:

(a) Who does it apply ?

- (i) To any person who generates hazardous oil and gas waste and to any person who transports hazardous oil and gas waste.
- (ii) An owner or operator of a treatment, storage, or disposal facility regulated by TNRCC's industrial and hazardous waste program, shall be subject to the standards for generators of hazardous waste found in Title 30, Texas Administrative Code (TAC), Chapter 335, Subchapter C.

(b) Any General Prohibitions ?

No person may cause, suffer, allow, or permit the collection, handling, storage, transportation, treatment, or disposal of hazardous oil and gas waste in a manner that would violate the provisions of this section.

(c) How to determine Hazardous Waste Site ?

The operator of a facility where waste is generated shall determine if such waste is hazardous oil and gas waste as provided in this subsection. A hazardous oil and gas waste is a waste that:

- (i) is defined in subsection (b) of this section (relating to definitions) as an oil and gas waste;
- (ii) is not described in 40 CFR, §261.4(a) (which describes wastes that are not considered solid wastes); and
- (iii) is not described in 40 CFR, §261.4(b) (which describes solid wastes that are exempt from regulation under RCRA Subtitle C).

(d) What are the Standards Used for Tank Systems ?

(1) Large Quantity Generators (LOGs): LOGs accumulating hazardous oil and gas waste in tanks must:

- (i) comply with the provisions applicable to owners or operators of 40 CFR, Part 265, Subpart J, except 265.197(c) and §265.200;
- (ii) comply with the provisions applicable to owners or operators of 40 CFR, §265.111 and §265.114 (relating to closure performance standards and disposal of contaminated equipment and media); and
- (iii) clearly label or mark each tank being used to accumulate

(2) Small Quantity Generators (SQGs): SQGs accumulating hazardous oil and gas waste in tanks must:

- (i) comply with the provisions of 40 CFR, §265.201 (relating to accumulation of waste in tanks by small quantity generators); and
- (ii) clearly label or mark each tank being used to accumulate hazardous oil and gas waste with the words "Hazardous Waste."

(e) What are the procedures for disposition of hazardous oil and gas waste ?

- (1) On-site treatment, storage, disposal, recycling, and reclamation. Except as otherwise specifically provided in this section, no person may treat, store, dispose of, recycle, or reclaim any hazardous oil and gas waste on-site.
- (2) Transport to Authorized Facility.

(A) Except as otherwise specifically provided in this section and subject to all other applicable requirements of state or federal law, a generator of hazardous oil and gas waste must send his or her waste to one of the following categories of facilities for treatment, storage, disposal, recycling, or reclamation:

- (i) an authorized recycling or reclamation facility;
- (ii) an authorized treatment, storage, or disposal facility;
- (iii) a facility located outside the United States, provided that the requirements of subsection (v)(1) of this section (relating to exports of hazardous waste) are met;
- (iv) a transfer facility, provided that the requirements of subsection (w)(3) of this section are met;
- (v) if the waste is generated by a CESQG, a facility permitted licensed, or registered by a state to manage municipal or industrial solid waste;
- (vi) if the waste is generated by a CESQG, a centralized W8 collection facility (CWCF) that meets the requirements of subsection (m)(3).

(B) Notwithstanding any contrary provision of this subsection, hazardous oil and gas wastes may be treated or stored on-site in an element neutralization unit or a totally enclosed treatment facility.

(3) **Centralized Collection of Hazardous Oil and Gas Waste.**

Provided that the requirements of this paragraph are met, a person may maintain at a CWCF hazardous oil and gas waste that is generated:

- (i) by that person; and
- (ii) at sites where that person is considered a CESQG under the provisions of this section.

(e) EPA ID Numbers:

(1) **Generators:** No LQG or SQG may transport or offer for transportation any hazardous oil and gas waste until such generator has obtained an EPA ID number by filing the prescribed form (currently EPA Form 8700-12) with the Commission.

(2) **Transporters:** No LQG or SQG may allow his or her hazardous oil and gas waste to be transported by a transporter that does not have an EPA ID number.

(3) **Treatment, Storage, or Disposal Facilities:** Except in the case of facilities specified in subsection (m)(2)(A)(iii), (vi), and (v) of this section, no LQG or SQG may send his or her hazardous oil and gas waste to a treatment, storage, or disposal facility unless that facility:

- (A) is a designated facility as defined in this section; and
- (B) has an EPA ID number.

(f) Discharges:

(1) Reporting Requirements.

(A) Commission. A person subject to regulation under this section shall immediately notify the Commission upon discovery of any discharge in which a reportable quantity of a hazardous oil and gas waste is discharged. Such notification shall be made by contacting the appropriate Commission district office.

(B) Federal. Persons subject to regulation under this section shall comply with applicable reporting requirements of 40 CFR, Parts 117, 263, and 302.

(2) Initial Response.

(A) Immediate Action. Upon discovery of a discharge of hazardous oil and gas waste, the generator or transporter must take appropriate immediate action to protect human

health and the environment (e.g., notify local authorities, where appropriate, and dike the discharge area).

(B) Permitting Exemption. The prohibition of on-site treatment, storage, disposal, recycling, or reclamation activities in subsection (m)(1) of this section does not apply to activities performed by a person engaged in treatment or containment activities during immediate response to a discharge of hazardous oil and gas waste; an imminent and substantial threat of a discharge of hazardous oil and gas waste; or a discharge of a substance which, when discharged, would become a hazardous oil and gas waste, provided that:

- (i) any hazardous oil and gas waste associated with such discharge is managed in accordance with applicable provisions of subsections (h)
- (ii) the applicable discharge reporting requirements of subsection (x) of this section are complied with.

Table 6.4: Relevant RRC Regulations Related to Contaminated Sites

Section	Date Effective	Rule	Rule Title	Contents	Purpose
3.91	November 1, 1993	91	Cleanup of Soil Contaminated by a Crude Oil Spill	<p>Scope: Application of these standards to the cleanup of soil.</p> <p>Requirements for Cleanup: Removal of free oil, Excavation, Prevention of stormwater contamination</p> <p>Remediation of Soil: Final cleanup level, requirements for bioremediation</p> <p>Reporting Requirements: for Crude oil spills over five barrels, Crude oil spills over 25 barrels, Crude oil spills of five barrels or less</p> <p>Alternatives: Alternatives to the standards, Approval by commission</p>	Contaminated Soil
3.98	April 1, 1996	98	Standards for Management of Hazardous Oil and Gas Waste	<p>Purpose: To establish standards for management of hazardous waste</p> <p>Definitions: Authorized facility, contaminated media, EPA hazardous waste number</p> <p>Applicability: For persons who transports oil and gas waste</p> <p>Hazardous Waste Determination: Determination, Land ban, Exclusions and Exemptions</p> <p>Disposition of Hazardous Oil and Gas Waste: Onsite treatment, storage, disposal, recycling, and reclamation, transport to authorized facility</p> <p>EPA ID Numbers: Transporters, Treatment, storage, and disposal facilities</p> <p>Record Keeping: Annual reports, exception reports, inspection reports, extension</p> <p>Standards: For transporters of hazardous waste and oil</p>	Contaminated Soil

6.5. REGULATIONS FOR UST

6.5.1. EPA Regulations

EPA regulations for USTs are summarized in the Table 6.5.

(a) What is an UST? (40 CFR 280.12)

An UST is any tank, including underground piping connected to the tank, that has at least 10 percent of its volume underground. The regulations apply only to USTs storing either petroleum or certain hazardous chemicals.

(b) What is the primary regulatory program for USTs ? (40 CFR 280)

RCRA Subtitle I, which is codified in the Solid Waste disposal act 42 USC 6991. The federal regulations are located at 40 CFR 280.

(c) Why the USTs needs special consideration ? (EPA, 1995)

Congress estimated that there were between 75,000 and 100,000 leaking USTs in the US. The concern with USTs revolve around whether they leak, how to keep them from leaking and what to do if they are leaking.

(d) What are the notification requirements of USTs ? (40 CFR 280.22)

One notification may be used for several tanks located on one site, but owners of tanks located at more than one place of operation must file a separate notification form for each place of operation. Specific notification requirements are listed in 40 CFR 280.22. The notification forms themselves are published in Appendix I of 40 CFR 264 and the agencies to which notification should be sent are listed in Appendix II.

(e) How to detect leaks from USTs ? (40 CFR 280, Subpart D)

Tanks must be checked at least once a month to see if they are leaking, and must use one (or a combination) of the following monthly monitoring methods:

- (i) Automatic tank gauging;
- (ii) Monitoring for vapors in the soil;
- (iii) Intestinal monitoring; and
- (iv) Other approved methods.

The release detection requirements differ for petroleum UST systems than for hazardous substance UST systems [Lieberman, 1994].

(f) What are the regulatory standards for USTs ? (40 CFR 280, Subpart E)

40 CFR 280.50 requires that owners and operators of UST systems must report suspected or known releases of regulated substances from a UST to the agency within 24 hours or within some other reasonable time period specified by the agency.

Table 6.5 EPA Regulations Related to USTs

Chapter	Chapter Title	Section	Contents	Purpose
42 USC Subtitle I	Regulation of Underground Storage Tanks	9001	Definitions for underground storage tank, regulated substance	USTs, PSTs
		9003	Regulations, Distinctions in regulations, Requirements, Financial responsibility, Performance standards, Effective dates, EPA response program for petroleum, priority of corrective actions, Recovery of costs, State Authorities, Definition of owner	
		9004	Approval of state programs, elements , Federal standards, Financial responsibility, EPA determination, Withdrawal of authorization	
		9005	Inspections, monitoring, testing, and corrective action, Furnishing information, Confidentiality	
		9006	Federal enforcement, Compliance orders, Contents of order, Civil penalties	
		9007	Federal facilities, Application, Presidential exemption	
		9008	State authority	
		9009	Petroleum tanks, Other tanks, Elements of studies, Reports, Reimbursement,	
		9002	Notification, Underground storage tanks, State Inventories	
		281	Regulations to protect human health and environment from USTs	
40 CFR	Technical Standards and Corrective Action Requirements for Owners and Operators of USTs	280.22	Notification requirements	USTs, PSTs
		subpart D	Release detection	
		subpart E	Release reporting, investigation, and confirmation	
		subpart F	Release response and corrective action for UST systems containing petroleum and hazardous substances	
		282.50- 282.105	Codification of individual state and territorial UST programs	
		280.31	Operation and Maintenance	

(g) What are the corrective action ? (40 CFR 280, subpart F)

Corrective action is implemented in accordance with 40 CFR 280 Subpart F.

(h) What are the closure requirements ? (40 CFR subpart G)

The closure requirements of an UST must comply with those stated in 40 CFR subpart G. UST systems may be shut down temporarily or permanently. If a system is only temporarily closed, compliance officers should contact local authorities to determine how long a UST may be closed before it must be removed.

6.5.2. TNRCC Regulations

TNRCC is the responsible organization in the state that provided regulations on hazardous waste and petroleum contaminants. TNRCC regulations for USTs are listed and summarized in the Table 6.6.

(a) What is the definition for UST under TNRCC ? (RG-42, November 1995)

A UST is defined under Title 30, Texas Administrative Code, Chapter 334.2 as any one or combination of underground tanks and any connecting underground pipes used to contain an accumulation of regulated substances, the volume of which, including the volume of the underground pipes, is ten percent or more beneath the surface of the ground.

(b) What is hazardous waste ? (RG-86, July 1994)

TNRCC embrace the same definition of 'hazardous waste' as found in Title 40 Code of Federal Regulations (CFR) section 261.3.

(c) What is the definition of 'Release' under TNRCC ? (RG-17, October 1996)

Release is defined in 30 TAC section 334.2 as 'any spilling including overfills, leaking, emitting, discharging, escaping, leaching, or disposing from an underground storage tank into groundwater, surface water, or subsurface soils'.

(d) Where should the release be reported ? (RG-17, October 1996)

The release must be reported to the local TNRCC office within 24 hours of confirmation.

(e) Who should be contacted regarding the information on CAP? (RG-41, November 1996)

For any questions regarding Corrective Action Plan (CAP), TNRCC coordinator assigned to the case or Responsible Party Remediation Section of the PST division should be contacted at (512) 239-2200.

(f) What are the action levels of the contaminants under TNRCC ? (RG-17, October 1996)

The term 'action level' indicate the concentration of constituents in the native soil or water at which some level of corrective action will be required. The action levels are given in the PST document RG-17 of TNRCC regulatory guidance.

(g) What should you do when a storage tank is leaking ? (RG-018, May 1996)

If a storage tank is leaking, the following actions should be taken:

- (i) Act on hazards (protect on site workers and neighbours)
- (ii) Report the leak or spill (at TNRCC regional office within 24 hours of discovering a spill). The regional offices are listed in the PST document RG-018.
- (iii) Find the leak
- (iv) Stop the release
- (v) Begin cleanup
- (vi) File report with TNRCC within 20 days of discovery or suspicion of a leak (form number : TNRCC-0621).

(h) What are the guidelines for groundwater monitoring and reporting at leaking petroleum storage tank sites ? (RG-43, September, 1996)

The guidelines can be obtained from the TNRCC regulatory guidance document RG-43, 'Groundwater Monitoring and Reporting'.

(i) Where is the information on Remedial Action Plans available? (RG-41/PST April 1995)

The information on Remedial Action Plans is available in TNRCC technical guidance document RG-41/PST April 1995.

(j) Where is CAP guidance manual available ? (RG-41, November 1996)

TNRCC petroleum storage tank division use EPA CAP manual (EPA 510-B-95-007, May 1995) for leaking petroleum storage tank sites. Copies of the document can be ordered by calling EPA's hotline at 1-800-424-9346.

(k) When is CAP necessary? (RG-41, November 1996)

A CAP is necessary for sites that do not meet the closure criteria.

(l) What should be in the CAP report ? (RG-41, November 1996)

The contents of the CAP will vary according to the type of remedial technology proposed. The details of the information that must be submitted in CAP can be obtained from the TNRCC regulatory guidance document RG-41, November 1996.

(m) What is OMP plan ? (RG-261, October 1996)

OMP plan is 'Operation, Maintenance, and Performance Plan' and is an integral part of any corrective action plan and is essential for determining remedial system success and attainment of cleanup goals.

(n) Is your underground storage tank regulated ?

Owners of certain underground storage tanks (USTs) existing on or after September 1, 1987 are required to register these tanks with the Texas Natural Resource Conservation Commission (TNRCC), unless they were emptied and filled in place before January 1, 1974. Tanks that are empty or unused still need to be registered.

Table 6.6 TNRCC Regulations Related to USTs

Chapter / subchapter	Chapter Title	Section	Section Title/ Date Effective	Contents	Purpose
Unspecified	Unspecified	RG-018	Leaking Storage Tanks - What Should I Do? / May, 1996	Act on Hazards, Report the Leak, Find the Leak, Stop the Release, Begin Cleanup, File Report, Regional Offices List	USTs, PSTs
Unspecified	Unspecified	RG-17	Action Levels for LPST Sites / October, 1996	Action Levels, Screening Levels	PSTs
Unspecified	Unspecified	RG-42	Am I Regulated? / November, 1995	Definition of Petroleum Products, Registration Requirements of the Tanks	USTs, PSTs
Unspecified	Unspecified	RG-16	How To Remove Your UST From the Ground	Notification and Advance Preparation, Tank Removal, Tank Transportation, Release Determination, Release Reporting, Waste Handling, Disposal or Treatment, Tank Removal Documentation	USTs
334 / Subchapter K	Underground and Aboveground Storage Tanks / Storage, Treatment, and reuse Procedures for Petroleum Substance Contaminated Soil	334.484	Registration Required for Petroleum Substance Waste Storage or Treatment Facilities / March, 1993	Registration Requirements	Contaminated Soil USTs, PSTs
		334.495	Location standards for Class A Petroleum Substance Waste storage or treatment Facilities / December, 1996	Standards	
		334.503	Reuse of Petroleum Substance Waste / December, 1996	Conditions for Reusing Petroleum Substance Waste	
		334.504	Contaminant assessment Program and Corrective Action / December, 1996	Corrective Action	
		334.508	Closure Requirements Applicable to Class A and Class B Facilities	Closure Requirements	

Table 6.6 TNRCC Regulations Related to USTs (contd.)

Chapter / subchapter	Chapter Title	Section	Section Title/ Date Effective	Contents	Purpose
37 / Subchapter K	Financial Assurance Requirements for Class A or Petroleum Substance Contaminated Soil Storage, Treatment and Reuse Facilities	37.1001	Applicability / December 30, 1996	Storage, Treatment and Reuse Facilities	Petroleum Contaminated Soils
		37.1011	Financial Assurance Requirements for Class A and B Facilities / December 30, 1996	Requirements, Closure, Financial Assurance	USTs, PSTs
Unspecified	Unspecified	RG-261	Operation, Monitoring and Performance (OMP) of Remedial Systems at LPST Sites/ October 1996	OMP plan, OMP report, existing remedial systems, Groundwater monitoring at existing sites, tables with monitoring requirements for remedial techniques	PSTs
Unspecified	Unspecified	RG-43	Groundwater Monitoring and Reporting / September 1996	Sampling, Gauging and submittal of gradient maps,/ reporting, GW monitoring and remedial action, Final monitoring	PSTs
Unspecified	Unspecified	RG-41	Remedial Action Plans / April 1995	Technology selection criteria, background data requirements, remedial technology and testing requirements, remedial action plan implementation	PSTs

6.6. SPECIFICATIONS

The ASTM specifications that are available for conducting site assessments and site characterization are summarized in Table 6.7 (URL: <http://www.astm.org>). The specifications mainly pertain to ASTM standards that are available in the volumes 4.08, 4.09, 11.04 and 11.05.

(a) ASTM E 1527-94 (Vol. 11.04) "Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process"

The purpose of this practice and practice E 1528 is to define commercial and customary practice in the United States of America for conducting an environmental site assessment for a commercial property with respect to the potential presence of a range of contaminants which are within the scope of CERCLA as well as petroleum products.

(b) ASTM E-1903-97 (Vol. 11.04) "Standard Guide for Environmental Site Assessments: Phase II Environmental Site Assessment Process"

This guide covers a framework for employing good commercial and customary practices in conducting a Phase II Environmental Site Assessment (ESA) of a commercial property with respect to the potential presence of a range of contaminants which are within the scope of CERCLA as well as petroleum products. This guide is intended to provide practical procedural guidance for the continuation of an assessment conducted in accordance with the most recent edition of the practice E 1527 or E 1528.

(c) ASTM E-1599-94 (Vol. 11.04) "Standard Guide for Corrective Action for Petroleum Releases"

This guide covers corrective action for petroleum releases. It describes the approach for assessment and remediation of releases to protect human health, safety, and the environment. It is intended to complement but not supersede federal, state and local regulations.

6.7. CONCLUSIONS

The federal and state regulations that affect the environmental site assessment and remedial alternative for cleaning up a site have been summarized. The federal regulations from EPA, RCRA, CERCLA are mainly discussed. State agencies, TNRCC and RRC, have regulations for contaminated sites. Federal and state regulations for Underground Storage Tanks are discussed separately. The ASTM specifications that provide guidelines for environmental site characterization and waste sampling have been listed.

Table 6.7 Listing of ASTM Standards for Site Characterization, Sampling and Petroleum Release

Topic	ASTM designation	Year	Title	Volume
Site Characterization	D 420-93	1993	Site Characterization for Engineering, Design, and Construction Purposes	4.08
	D 2113-83(1993)	1993	Diamond Core Drilling for Site Investigation	4.08
	D 2487-93	1993	Soils for Engineering Purposes (Unified Soil Classification System)	4.09
	D 2488-93	1993	Description and Identification of Soils (Visual-Manual Procedure)	4.08
	D 5126-90	1990	Comparison of Field Methods for Determining Hydraulic Conductivity in the Vadose Zone	4.09
	D 5434-93	1993	Field Logging of Subsurface Explorations of Soil and Rock	4.09
	D 5730-96	1996	Site Characteristics for Environmental Purposes With Emphasis on Soil, Rock, the Vadose Zone and Ground Water	4.09
	D 5745-95	1995	Developing and Implementing Short-Term Measures or Early Actions for Site Remediation	11.04
	D 5746-95	1995	Environmental Condition of Property Area Types	11.04
	D 5753-95	1995	Planning and Conducting Borehole Geophysical Logging	4.09
	D 5777-95	1995	Using the Seismic Refraction Method for Subsurface Investigation	4.09
	D 5781-95	1995	Use of Dual-Wall Reverse-Circulation Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices	4.09
	D 5782-95	1995	Use of Direct Air-Rotary Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices	4.09
	D 5783-95	1995	Use of Direct Rotary Drilling with Water-Based Drilling Fluid for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices	4.09
	D 5784-95	1995	Use of Hollow-Stem Augers for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices	4.09
	D 5872-95	1995	Use of Casing Advancement Drilling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices	4.09
	D 5878-95	1995	Using Rock Mass Classification Systems for Engineering Purposes	4.09
	D 5979-96	1996	Conceptualization and Characterization of Ground-Water Systems	4.09
	D 5980-96	1996	Selection and Documentation of Existing Wells for Use in Environmental Site Characterization and Monitoring	4.09
	D 5995-96	1996	Environmental Site Characterization in Cold Regions	4.09
	D 6000-96	1996	Presentation of Water-Level Information From Ground-Water Sites	4.09
	D 6008-96	1996	Conducting Environmental Baseline Surveys	11.04
	E 1527-97	1997	Environmental Site Assessments: Phase I Environmental Site Assessment Process	11.04
E 1528-96	1996	Environmental Site Assessments: Transaction Screen Process	11.04	
E 1689-95	1995	Developing Conceptual Site Models for Contaminated Sites	11.05	
E 1903-97	1998	Environmental Site Assessments: Phase II Environmental Site Assessment Process	11.04	
PS 3-95	1995	Accelerated Site Characterization for Confirmed or Suspected Petroleum Releases	11.04	

Table 6.7 Listing of ASTM Standards for Site Characterization, Sampling and Petroleum Release (contd.)

Topic	ASTM designation	Year	Title	Volume
Site Characterization	PS 11-95	1995	Environmental Regulatory Compliance Audits	11.04
	PS 78-97	1997	Professional Guide for Selecting Surface Geophysical Methods	4.09
	PS 85-96	1996	Expedited Site Characterization of Hazardous Waste Contaminated Sites	4.09
Sampling	D 1452-80(1995)	1995	Soil Investigation and Sampling by Auger Borings	4.08
	D 1586-84(1992)	1992	Penetration Test and Split-Barrel Sampling of Soils	4.08
	D 1587-94	1994	Thin-Walled Tube Geotechnical Sampling of Soils	4.08
	D 3017-96	1996	Water Content of Soil and Rock in Place by Nuclear Methods (Shallow Depth)	4.08
	D 3404-91	1991	Measuring Matric Potential in the Vadose Zone Using Tensiometers	4.08
	D 3550-84(1995)	1995	Ring-Lined Barrel Sampling of Soils	4.08
	D 4220-95	1995	Preserving and Transporting Soil Samples	4.08
	D 4696-92	1992	Pore-Liquid Sampling from the Vadose Zone	4.08
	D 4700-91	1991	Soil Sampling from the Vadose Zone	4.08
	D 4944-89	1989	Field Determination of Water (Moisture) Content of Soil by the Calcium Carbide Gas Pressure Tester Method	4.09
	D 5079-90	1990	Preserving and Transporting Rock Core Samples	4.09
	D 5220-92	1992	Water Content of Soil and Rock In-Place by the Neutron Depth Probe Method	4.09
	D 5314-92	1992	Soil Gas Monitoring in the Vadose Zone	4.09
D 6031-96	1996	Logging In Situ Moisture Content and Density of Soil and Rock by the Nuclear Method in Horizontal, Slanted, and Vertical Access Tubes	4.09	
Petroleum Release	E 1599-94	1994	Corrective Action for Petroleum Release	11.04
	E 1739-95	1995	Risk-Based Corrective Action Applied at Petroleum Release Sites	11.04

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Chapter 7

Training Program and Other DOTs

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7.1. INTRODUCTION

The presence or likely presence of hazardous substances or petroleum products can pose health and safety risks and also cause a series of legal, regulatory, financial and technical problems to TxDOT. Because of the seriousness of the safety and health hazards related to hazardous waste operations, the Occupational Safety and Health Administration (OSHA) has issued a final standard specifically developed to protect workers in this environment and to help them handle hazardous wastes safely and effectively [13, 15]. Training programs and Safety and Health programs (OSHA 3110, 1989) are an integral part of a cost effective waste management program. Training for workers involved with hazardous substances is required by OSHA (29 CFR), EPA (40 CFR) and DOT (49 CFR). In this chapter, guidelines and procedures developed by eleven other state DOTs to handle contamination in construction sites have been summarized. Also, the training programs adopted by other state DOTs have been reviewed [1 - 8, 10, 12, 14, 17, 18].

7.2. TRAINING REQUIREMENTS

Why Training?

TxDOT personnel, unfamiliar with the signs and properties of hazardous substances or petroleum products, can expose themselves to considerable safety and health risks. Training makes workers aware of the potential hazards they may encounter and provides the necessary knowledge and skills to perform their work with minimal risk to their safety and health. Hence all TxDOT personnel likely to be on sites should be given basic training in hazardous waste awareness, so that they understand OSHA, EPA and DOT policies and know how to protect themselves.

Who should be trained?

Employee training requirements are defined by the nature of the work. Based on the type of work involved, the training requirements for workers are summarized in Table 7.1 and 7.2 (OSHA 3114, 54 FR 42:9294, March 6, 1989). OSHA has identified a total of fourteen training topics for three job categories. It should be noted that these training requirements were developed for cleanup operations at hazardous waste sites and at EPA-licensed waste treatment, storage and disposal facilities. It also covers workers responding to emergencies involving hazardous materials (example: spills). Some state DOTs have adopted these training requirements for their staff and managers. It should be noted that the training

Table 7.1. Recommended Training by Job Category (OSHA 3114, Session 9.1A, NIOSH, 1985)

Training Topic	Emphasis of Training	General Site Worker	Onsite Management and Supervisors	Health and Safety Staff
Biology, chemistry, and physics of hazardous materials	<ul style="list-style-type: none"> Chemical and physical properties, chemical reactions, chemical compatibilities. 	R	R	R
Toxicology	<ul style="list-style-type: none"> Dosage, routes of exposure, toxic effects, immediately dangerous to life or health values, permissible exposure limits, recommended exposure limits, threshold limit values. 	R	R	R
Industrial Hygiene	<ul style="list-style-type: none"> Selection and monitoring of personal protective clothing and equipment. Calculation of doses and exposure levels, evaluation of hazards, selection of worker health and safety protective measures. 		R R	R R
Rights and responsibilities of workers under OSHA	<ul style="list-style-type: none"> Applicable provisions of title 29 of the Code of Federal Regulations (the OSHA Act) 	R	R	R
Monitoring Equipment	<ul style="list-style-type: none"> Functions, capabilities, selection, use, limitations, and maintenance. 	R	R	R
Hazard Evaluation	<ul style="list-style-type: none"> Techniques of sampling and assessment. Evaluation of field and lab results. Risk Assessment 		R R O	R R R
Site safety plan	<ul style="list-style-type: none"> Safe practices, safety briefings and meetings, standard operating procedures, site safety map 	R	R	R
Standard operating procedures (SOPs)	<ul style="list-style-type: none"> Hands-on practice Development and compliance 	R	R R	R R
Engineering controls	<ul style="list-style-type: none"> The use of barriers, isolation, and distance to minimize hazards 	R	R	R
Personal protective clothing and equipment (PPE)	<ul style="list-style-type: none"> Assignment, sizing, fit-testing, maintenance, use, limitation and hands-on training. Selection of PPE Ergonomics 	R	R O	R R
Medical program	<ul style="list-style-type: none"> Medical monitoring, first aid, stress recognition. Advanced first aid, cardiopulmonary resuscitation, emergency drills. Design, Planning and implementation. 	R O	R R	R R R
Decontamination	<ul style="list-style-type: none"> Hands-on training using simulated field conditions. Design and maintenance. 	R R	R R	R R
Legal and regulatory aspects	<ul style="list-style-type: none"> Applicable safety and health regulations (OSHA, EPA,) 	O	R	R
Emergencies	<ul style="list-style-type: none"> Emergency help and self rescue; emergency drills. Response to emergencies; follow-up investigation and documentation. 	R	R R	R R

R - Recommended; O - Optional

requirement for general site employees in treatment and disposal sites will be less (compared to Table 7.2).

Table 7.2. Training Hours for Workers on Hazardous Waste Clean-Up Sites
(29 CFR 1910 120 (e))

Type of Worker	Amount of Training
General Site Workers	40 hours initial + 24 hours field experience
Occasional Site Workers (minimal exposure)	24 hours initial + 8 hours field experience
Non-routine site workers	24 hours initial + 8 hours of field experience
Managers and Supervisors	40 hours initial + 24 hours field + 8 hours hazardous waste management
Emergency Response Personnel	Trained to a level of competency
All site workers	8 hours of annual refresher training

It is unlikely that TxDOT will experience hazardous waste problems frequently enough to justify more specialized training. If personnel do receive specialized training, it must be updated periodically, and TxDOT must commit resources to keeping current with changes in technology, regulations, and field experiences. All emergency responders must receive refresher training sufficient to maintain or demonstrate competency annually. There are two general components to training requirements in 40 CFR 265.16 (EPA regulations regarding personnel training). Personnel must be taught the following:

- (1) how to perform their duties in a way that ensures TxDOT compliance with the regulations, and
- (2) how to respond to emergencies (spills, accidents) involving hazardous substances or petroleum products.

What is a Safety and Health Program ?

A comprehensive safety and health program is essential in reducing work-related injuries and illnesses and in maintaining a safe and healthy work environment at the construction sites (OSHA). This program should include the following: (1) personal protective equipment program (2) monitoring (3) decontamination procedures and (4) emergency response program. The written safety and health program must be periodically updated and made available to all affected employees, contractors and subcontractors.

What Happened to the NHI Course ?

For several years the National Highway Institute (NHI) had a course entitled "Hazardous Waste: Impacts on Highway Project Development, Construction, and Maintenance" (NHI Course # 14229; NHI, 1992). This course has been discontinued. NHI is in the process of modifying and updating the course notes.

7.3. OTHER DOTs

All the state DOTs were contacted either by phone, fax, and/or email and were asked to provide information on their hazardous waste management plan, only twelve responded. Ten DOTs had handbooks/documentation on handling contamination on construction sites and the California DOT had it on their web site. The South Dakota DOT and Oklahoma DOT had the most comprehensive handbooks. Guidelines and procedures collected from eleven DOTs have been summarized in Table 7.3 and Section 7.5. Some state DOTs responded in the following manner:

- (1) The Florida DOT responded. But the contact person said that there were no written procedures in dealing with the cleanup of contaminated sites in the DOT projects.
- (2) The contact person at the Oregon DOT informed that the ODOT follows the standard FHWA guidelines for dealing with contaminated construction sites and that they have no special procedures of their own.
- (3) The contact person at the Ohio DOT informed that they do not have specific guidelines for contaminated sites.
- (4) The contact person at the Washington DOT provided some useful information but admitted that there are no written procedures in the form of an Handbook in dealing with contaminated sites. The information provided is summarized in section 7.5.

Based on the information collected from 11 DOTs the following can be concluded.

- (1) Over 50% of the cases, State Regulatory Agencies (SRA's) were responsible for the cleanup of contamination.
- (2) Over 50% of the DOTs have a Memorandum of Understanding (MOU) with the SRA.

Table 7.3 Summary of Other DOT Handbooks Related to Contaminated Sites

No.	State (year)	Agency Responsible for Cleanup	MOU	Training Program	Federal Agencies	State Agencies	Section on UST	Asbestos	Costs
1	Alaska (1994)	Alaska Department of Environmental Conservation	MOU available	Not available	U.S.EPA	Alaska DEC and Alaska DOT/PF	Not available	Not available	Available
2	California (NA)	Owner / responsible party (s)	MOU available	Not available	U.S.EPA	Department of Health Services	Available	Not available	Not available
3	Illinois (1989)	Division of Highways, Department of Transportation	Not available	Not available	U.S.EPA	State EPA, Department of Transportation, Office of the State Fire Marshall	Available	Not available	Available
4	Iowa (1995)	Iowa Department of Natural Resources	Not available	Available	U.S.EPA, OSHA	Iowa DNR	Available	Available	Not available
5	Kansas	DOT/ the Owner	Not available	Not available	U.S.EPA	Kansas Department of Health and Environment	Available	Available	Available
6	Louisiana (1993)	Director of Engineering Design and Contract Management	MOU available	Not available	U.S.EPA	Louisiana DOT, Department of Environmental Quality.	Available	Not available	Available
7	New Jersey (1994)	New Jersey Department of Environmental Protection	MOU available	Not available	U.S.EPA, FHWA	New Jersey Department of Environmental Protection	Not available	Not available	Available
8	Oklahoma (1995)	Oklahoma Department of Environmental Quality	MOU available	Available	U.S.EPA	ODEQ, ODH, OCC	Available	Not available	Available
9	South Dakota (1995)	South Dakota Department of Environment and Natural Resources	Not available	Not available	U.S.EPA	SDDENR, Department of Commerce and Regulation	Available	Not available	Not available
10	Washington (NA)	Owner / responsible party (s)	Not available	Not available	U.S.EPA	Caltrans Environmental Department	Not Available	Not available	Available
11	Wyoming (1993)	Wyoming Department of Environmental Quality	MOU available	Not available	U.S.EPA	Wyoming Department of Environmental Quality	Available	Not available	Not available
Remarks	Total of 11 DOTs	Department of Environmental quality / Natural Resources is the responsible agency.	6 of 11 states have MOU.	2 of 11 states have training program.	U.S. EPA acts as federal guiding agency	Department of Environmental quality / Natural Resources is the responsible agency.	8 of 11 states have a section on USTs.	2 of 11 states have a section on asbestos.	7 of 11 states have a section on costs.

- (3) Only two of the states have a formal employee training program outlined in their document.
- (4) Over 70 percent of the states have a section on UST.
- (5) Only two states have information on asbestos.

7.4. CONCLUSIONS

Based on the review of OSHA documents and analyses of the information provided by eleven other state DOTs the following can be concluded:

- (1) Training for personnel dealing with contamination on construction sites should be provided according to OSHA regulations. It should be noted that these training requirements were developed for cleanup operations at hazardous waste sites and at EPA-licensed waste treatment, storage and disposal facilities. Only 20% of the state DOTs have a section on training in their handbooks.
- (2) Over 70% of the state DOTs have a section on underground storage tanks (USTs). Only 20% of the DOTs have a section on asbestos. U.S. EPA acts as the federal guiding agency for all state DOTs.

7. 5. 1 Alaska DOT (1994)

1. **REPORT TITLE:** Memorandum of Agreement (MOA) between the Alaska Department of Environmental Conservation (DEC) and the Alaska Department of Transportation and Public Facilities (DOT/PF).
2. **PREPARED BY:** Alaska DEC, Alaska DOT /PF.
3. **PUBLISHED DATE:** June 8, 1994.
4. **WHO IS IN CHARGE?** Alaska DEC or Alaska DOT /PF
5. **IS IT A CENTRALIZED OPERATION:** Yes.
6. **WHO DOES THE CLEAN UP?** Alaska DEC is charged with the responsibility to conduct, oversee and approve cleanup activities associated hazardous substance pollution or abandoned containers holding hazardous substances.
7. **FEDERAL AGENCIES IN ACTION:.**
8. **STATE AGENCIES IN ACTION:** DEC and DOT/PF.
9. **ENVIRONMENTAL REGULATIONS:** Regulations as per U.S.EPA and Department of Environmental Conservation.
10. **REGULATORY CLEANUP LEVELS:** Not available.
11. **UNDERGROUND STORAGE TANKS (UST):** Section not available on USTs.
12. **PETROLEUM CONTAMINATED SOILS:** Not available.
13. **PETROLEUM CONTAMINATED PROJECTS REPORTED (NCHRP 226):**
None
14. **COMMONLY ENCOUNTERED PETROLEUM CONTAMINANTS:** Not available.
15. **ASBESTOS:** Not available.
16. **TRAINING PROGRAM:** Not available.
17. **HAZARDOUS WASTE MANAGEMENT PLAN (HWMP):** Not available.
18. **COSTS:** Following completion of cost recovery actions against third parties by DEC, DOT/PF, in conjunction with DEC, will prepare a special budget request to the

legislature for that portion of the expenses from the response fund for activities under this MOA where costs were not recovered.

19. **CLOSURE REPORT:** Not available.
20. **DETAILED SUMMARY:** Alaska DEC is charged with responsibility under Alaska Statute AS 46.03, AS 46.04, and AS 46.09, and Alaska Regulations 48 AAC 20 and AAC 75 to conduct and oversee, and approve activities associated with oil and hazardous substance pollution cleanup. DOT/PF is charged with responsibility under Alaska Statute Titles 2, 19, 25 and 35 to plan, construct, maintain, protect and control land associated with state highways, airports and public works. DOT/PF will assign a project manager with responsibility for overseeing the general non-technical efforts during the cleanup. DEC will perform in an oversight and technical role during restoration activities.
21. **CONTACT PERSON:** Greg Otto, Alaska DOT, 3132 Channel Drive, Juneau, Alaska 99801-7898; Phone: (907) 465-2960

7.5.2 California DOT

(www.dot.ca.gov/hq/oppd/pdpm)

1. **REPORT TITLE:** California State Department of Transportation Project Development Procedures Manual (PDPM) - Chapter 18-Hazardous Waste.
2. **PREPARED BY:** California State Department of Transportation.
3. **PUBLISHED DATE:** Not available.
4. **WHO IS IN CHARGE?** Environmental Program, California Department of Transportation (Caltrans).
5. **IS IT A CENTRALIZED OPERATION:** No. The central office and divisions cooperate in their plan of action.
6. **WHO DOES THE CLEAN UP?** The owner or responsible party(s) should investigate and cleanup the contamination.
7. **FEDERAL AGENCIES IN ACTION:** U.S.EPA.
8. **STATE AGENCIES IN ACTION:** California Department of Health Services (DHS) and Caltrans, Hazardous Waste Management Office in the Environmental Program
9. **ENVIRONMENTAL REGULATIONS:** Not available in detail, but all the actions follow Caltrans environmental department guidelines.
10. **REGULATORY CLEANUP LEVELS:** Not available.
11. **UNDERGROUND STORAGE TANKS (UST):** A Special report on "A California Tank Owner's Guide for Upgrading Underground Storage Tanks" is also included in with the documented (State Water Resources Control Board, Sacramento California).
12. **PETROLEUM CONTAMINATED SOILS:** Not available.
13. **PETROLEUM CONTAMINATED PROJECTS REPORTED (NCHRP 226):** 5

14. **COMMONLY ENCOUNTERED PETROLEUM CONTAMINANTS:** Gasoline and Diesel fuel oil
15. **ASBESTOS:** Not available.
16. **TRAINING PROGRAM:** Not available.
17. **HAZARDOUS WASTE MANAGEMENT PLAN (HWMP):** Has a detailed explanation of all the phases but post site monitoring is not included.
18. **COSTS:** Not available.
19. **CLOSURE REPORT:** Not available.
20. **DETAILED SUMMARY:** California state has its own Hazardous Waste Management Plan that completes the process from initial site investigation through remedial action implementation. MOU was signed on July 14, 1989 with DHS to over see cleanups of contaminated sites or actual cleanups itself [Schick, TRR 1312].
21. **CONTACT PERSON:** Edward J. Imai, Senior Environmental Planner, Department of Transportation, Environmental Program, Hazardous Waste Management Office, 1120 N Street, P.O. Box 942874, Sacramento, CA 94274-0001. Phone: (916) 653-3352; Fax: (916) 653-5927; email: eimai@trmx3.dot.ca.gov.

7. 5. 3 Illinois DOT (1989)

1. **REPORT TITLE:** Policy On Identifying And Responding To Hazardous Substances, Hazardous Wastes, And Special Wastes In Highway Project Development
2. **PREPARED BY:** Illinois Department of Transportation - Departmental Policies.
3. **PUBLISHED DATE:** June 19, 1989.
4. **WHO IS IN CHARGE?** Bureau of Location and Environment, Office of Division of Highways.
5. **IS IT A CENTRALIZED OPERATION:** No. The central office and divisions cooperate in their plan of action.
6. **WHO DOES THE CLEAN UP?** Division of Highways, Department of Transportation.
7. **FEDERAL AGENCIES IN ACTION:** U.S.EPA.
8. **STATE AGENCIES IN ACTION:** Illinois State EPA, Illinois Department of Transportation, Office of the State Fire Marshall (OSFM)
9. **ENVIRONMENTAL REGULATIONS:** Offices of the Division of Highways (Division) is responsible for development and implementation of State highway projects shall consider hazardous substances, hazardous wastes, and special wastes in project development and shall comply with applicable controls. Where hazardous substances, hazardous wastes, or special wastes are located on property acquired or otherwise under state control for state highway project purposes, or where such substances or wastes are generated as a result of project actions, treatment of the substances and/or wastes shall conform to current legal and regulatory requirements.

Where other parties are responsible under the law for hazardous substances, hazardous wastes, or special wastes on property under state control for State highway project purposes, or on properties to the acquired for highway purposes, all available avenues shall be considered for recovering costs from such parties for assessment and remediation of the hazardous substances and/or petroleum products.
10. **REGULATORY CLEANUP LEVELS:** The levels to be followed are as defined by OSFM and Illinois EPA.

11. **UNDERGROUND STORAGE TANKS (UST):** A Special report on "Leaking Underground Storage Tank Program" has been developed by Illinois Environmental Protection Agency. Illinois has entered into a cooperative agreement with U.S.EPA in which Illinois EPA and the Office of the State Fire Marshall (OSFM) administer a comprehensive underground storage tank program at the state level. Under a Memorandum of Agreement (MOA), OSFM administers the preventive side of the state program, and Illinois EPA administers the remedial investigation and corrective action portion of the state program and the state UST fund reimbursements.

Once the site has met the appropriate remediation objectives and program requirements, the Illinois EPA issues a "No Further Remediation" letter for the release. The OSFM regulates daily operation and maintenance of UST programs, including oversight for tank removals.

12. **PETROLEUM CONTAMINATED SOILS:** Not available.
13. **PETROLEUM CONTAMINATED PROJECTS REPORTED (NCHRP 226):** 1
14. **COMMONLY ENCOUNTERED PETROLEUM CONTAMINANTS:** Gasoline and Diesel fuel oil
15. **ASBESTOS:** Not available.
16. **TRAINING PROGRAM:** Not available.
17. **HAZARDOUS WASTE MANAGEMENT PLAN (HWMP):** Has a detailed explanation of all the phases.
18. **COSTS:** Federal regulations require petroleum tank owners and operators to demonstrate the financial ability to remediate tank releases and to pay for damages to third parties. Federal UST regulations allow, but do not require, states to set up publicly financed UST funds.
19. **CLOSURE REPORT:** Not available.
20. **DETAILED SUMMARY:** Districts shall screen all highway projects to determine whether they require further assessment for special waste contamination. Districts shall follow the Special Waste Assessment (SWA) Screening Criteria flow chart accompanying this memorandum and shall use the SWA Screen/Survey Request Form

(issued via BDE Technical Environmental Memorandum) for documenting the screening results). The district need not undertake further action to identify and evaluate special wastes if completion of the SWA screening process results in the determination of new right-of-way easements.

The district person preparing the SWA screen / survey request form shall sign and date the form. If application of the SWA screening procedure leads to a determination that further assessment of the project for special wastes is required, a Preliminary Environmental Site Assessment will be necessary.

21. **CONTACT PERSON:** John R . Washburn, Manager, Geologic and Waste Assessment Unit, Environment Section, Bureau of Design and Environment, Illinois Department of Transportation, Phone: (217) 782-7074, Fax: (217) 524-9356.

7. 5. 4 Iowa DOT (1995)

1. **REPORT TITLE:** Construction Manual - Chapter 10, Environmental.
2. **PREPARED BY:** Not available.
3. **PUBLISHED DATE:** December 1st, 1995.
4. **WHO IS IN CHARGE?** Iowa Department of Natural Resources and U.S. Environmental Protection Agency.
5. **IS IT A CENTRALIZED OPERATION:** Yes.
6. **WHO DOES THE CLEAN UP?** Iowa Department of Natural Resources.
7. **FEDERAL AGENCIES IN ACTION:** U.S.EPA, OSHA (Occupational Safety and Health Act).
8. **STATE AGENCIES IN ACTION:** Iowa Department of Natural Resources.
9. **ENVIRONMENTAL REGULATIONS:** Regulations as per U.S.EPA (which is responsible for CERCLA and RCRA programs), OSHA and Iowa DNR.
10. **REGULATORY CLEANUP LEVELS:** The regulatory levels are listed in Appendix 10.3 of the document.
11. **UNDERGROUND STORAGE TANKS (UST):** In Iowa DOT, this division is administrated by Iowa DNR. All USTs were required to be registered with the Iowa DNR by October 1989. Tanks < 3,164 L have a permanent tag issued, while tanks > 3, 164 L are issued a yearly tag on or about April 1.
Removal of USTs: The procedure is based on Iowa DNR regulations codified in 567 IAC, chapters 135 and 136.

Removal of known USTs: These tanks are the once identified on the project plans and will be noted for removal.

(a) Removal Process: Check for the registration tag. If the tank is registered, the registration number is noted. Otherwise, the project engineer must notify the office of construction immediately. Non registered tanks cannot be removed until they have been registered.

(b) Closure Notification: The project engineer submits a notification for tank closure and he must sign the form as Iowa DOT's authorized agent. After the form has been processed, Iowa DNR will send the necessary instructions to the project engineer.

12. **PETROLEUM CONTAMINATED SOILS**: Not available.
13. **PETROLEUM CONTAMINATED PROJECTS REPORTED (NCHRP 226)**:0
14. **COMMONLY ENCOUNTERED PETROLEUM CONTAMINANTS**: Not available
15. **ASBESTOS**: U.S.EPA regulates the asbestos-containing material from buildings and structures which are being demolished and renovated. The following procedure is followed:
 - Buildings and structures that are scheduled for renovation or demolition shall be inspected for the presence of asbestos.
 - U.S.EPA, Iowa DNR, and Iowa Division of Labor shall be notified at least 10 calendar days prior to asbestos abatement activities.
 - Regulated Asbestos-Containing material must be removed prior to any activities that would disturb the materials or prevent future access to them for removal.
 - All asbestos removal and handling operations must be performed under the supervision of an individual trained and certified in asbestos handling by the Iowa Division of Labor.
 - U.S.DOT regulates the transportation of asbestos and identifies it as a hazardous material.
16. **TRAINING PROGRAM**: Employees shall not engage in field activities until they have been trained to a level commensurate with their job function. Regulations require that everyone entering a hazardous waste site must be able to recognize and understand the potential hazards to health and safety associated with the work at the site. OSHA has two levels of training depending on the individual's involvement at the site:
 1. 40-hr training is required of anyone involving actively in the cleanup activity.
 2. 20-Hr training is required for anyone who is not actively involved, but has intermittent occasion to be on site.
17. **HAZARDOUS WASTE MANAGEMENT PLAN**: Not available.
18. **COSTS**: Not available.

19. **CLOSURE REPORT:** The contract and /or the contractor's environmental consultant are responsible to complete the closure report. These reports are to be submitted to the project engineer within 20 days of completion of sample analysis.

20. **DETAILED SUMMARY:** Iowa DNR does have specific regulatory authorities in Iowa. Iowa DNR has sign-off responsibility for RCRA and CERCLA actions in Iowa. Very often Iowa DNR is asked to be the regulatory agency's on site coordinator. Section 10.40 of the Construction Manual covers the Worker Health and Safety. A flow chart has been developed for evaluating hazardous waste on construction site.

21. **CONTACT PERSON:** Jim Rost, Iowa DOT

7. 5. 5 Kansas DOT

1. **REPORT TITLE:** Hazardous Waste Site Detection - Section 5.1.7.
2. **PREPARED BY:** Not available.
3. **PUBLISHED DATE:** Not available.
4. **WHO IS IN CHARGE?** Once contaminated property is purchased, the current owner is responsible and liable for all of the impacts of past, hazardous waste disposal, and for the total cost of finding and implementing an acceptable remedy. An owner is responsible for the transportation and disposal of the wastes at a site and assumes additional liability for any site to which the waste is sent for disposal. Kansas Department of Health and Environment (KDHE) regulates the USTs in the state.
5. **IS IT A CENTRALIZED OPERATION?** Yes.
6. **WHO DOES THE CLEAN UP?** Once contaminated property is purchased, the current owner is responsible and liable for all of the impacts of past, hazardous waste disposal, and for the total cost of finding and implementing an acceptable remedy.
7. **FEDERAL AGENCIES IN ACTION:** U.S.EPA.
8. **STATE AGENCIES IN ACTION:** KDHE.
9. **ENVIRONMENTAL REGULATIONS:** The regulations are followed as per EPA, KDHE, CERCLA, RCRA, SARA and BER (Bureau of Environmental Regulations).
10. **REGULATORY CLEANUP LEVELS:** Not available.
11. **UNDERGROUND STORAGE TANKS (UST):** The existence of underground storage tanks may be discovered during the hazardous waste assessment process. The following procedure should be followed when ever an UST is found at the site:
 - Determine the approximate location of the proposed right-of-way limits and the location and approximate boundary of all tanks as well as the approximate date of their installation.
 - Determine if right-of-way needs will necessitate removing or relocating tanks. If the project right-of-way is no closer than five feet to the closest point of any tank and there are no other obvious reasons to suspect hazardous waste contamination, the project can proceed without further investigation.

- If operating facilities are within five feet of the right-of-way, further investigation is warranted.
 - If abandoned tanks are found near the proposed right-of-way, a site assessment may be initiated to determine if the right-of-way is contaminated.
 - If tanks are located within the right-of-way and need removing, determine the contents so they can be safely emptied and removed. Any surrounding soil contaminated by the contents of the tanks must also be considered hazardous, and should be disposed of in accordance with KDHE recommendations.
12. **PETROLEUM CONTAMINATED SOILS:** A separate section is not available.
 13. **PETROLEUM CONTAMINATED PROJECTS REPORTED (NCHRP 226):**3
 14. **COMMONLY ENCOUNTERED PETROLEUM CONTAMINANTS:** Gasoline and diesel fuel in soil and water.
 15. **ASBESTOS:** Anytime asbestos is discovered at a project site and must be removed, either a licensed asbestos removal contractor should be employed or trained department personnel should be notified to ascertain the cost of removal.
 16. **TRAINING PROGRAM:** Not available.
 17. **HAZARDOUS WASTE MANAGEMENT PLAN:** Hazardous waste management plan is available.
 18. **COSTS:** Once contaminated property is purchased, the current owner is responsible and liable for all of the impacts of past, hazardous waste disposal, and for the total cost of finding and implementing an acceptable remedy.
 19. **CLOSURE REPORT:** Not available.
 20. **DETAILED SUMMARY:** In dealing with hazardous waste, the U.S.EPA and KDHE must be consulted. General procedure for Initial Site Assessment (ISA) and Detailed Site Investigation are available.
 21. **CONTACT PERSONS:** Ken Miller, Kansas DOT

7. 5. 6. Louisiana DOT (1993)

1. **REPORT TITLE:** Louisiana Department of Transportation and Development Secretary's Policy and Procedure Memorandum - Underground Storage Tank and Contaminated Site Policy.
2. **PREPARED BY:** Louisiana Department of Transportation.
3. **PUBLISHED DATE:** April 30, 1993.
4. **WHO IS IN CHARGE?** The Director of Engineering Design and Contract Management is responsible for coordination of the Department of Transportation and Development's policy regarding underground storage tanks and contaminated sites.
5. **IS IT A CENTRALIZED OPERATION:** Yes.
6. **WHO DOES THE CLEAN UP?** Not available.
7. **FEDERAL AGENCIES IN ACTION:** U.S.EPA.
8. **STATE AGENCIES IN ACTION:** Louisiana DOT, Department of Environmental Quality.
9. **ENVIRONMENTAL REGULATIONS:** Not available.
10. **REGULATORY CLEANUP LEVELS:** Not available.
11. **UNDERGROUND STORAGE TANKS (UST):** The Memorandum of Agreement (MOA) is for underground storage tanks.
12. **PETROLEUM CONTAMINATED SOILS:** No separate section on petroleum contaminated soils is available.
13. **PETROLEUM CONTAMINATED PROJECTS REPORTED (NCHRP 226):** 1
14. **COMMONLY ENCOUNTERED PETROLEUM CONTAMINANTS:** Gasoline, diesel fuel and used oil in soil and ground water.
15. **ASBESTOS:** Not available.
16. **TRAINING PROGRAM:** Not available.
17. **HAZARDOUS WASTE MANAGEMENT PLAN:** Not available.

18. **COSTS:** Not available.
19. **CLOSURE REPORT:** Not available.
20. **DETAILED SUMMARY:** The Department's policy regarding the handling of possibly contaminated sites will be divided into four categories or phases of activity:
 - a. Pre-Design.
 - b. Design.
 - c. Acquisition.
 - d. Construction.

Pre-Design:

- (a) The Environmental Section will study the scope of the project in relation to available aerial photographs, historical data, and other available information to determine possible contaminated sites.
- (b) Preliminary site inspections by the respective Design Section(s) should include a representative of the Environmental Section to ensure that signs of possible contaminated sites are recognized.
- (c) If signs of contamination are found during preliminary site inspections, the UST/Contaminated Site Information Form will be completed and furnished to the Materials and Testing Section.
- (d) Upon receipt of a UST/Contaminated Site Information Form, the Materials and Testing Section will inspect and investigate the site, perform testing if necessary, and determine if contamination is present. If no contamination is found, the normal project development process will continue to the Design phase 1
- (e) The Materials and Testing Section may perform additional testing to further define the limits of contamination or to determine if an assessment will be required by DEQ. If an assessment is required, the Materials and Testing Section will then obtain approval from the Director of Engineering Design and contract Management to contract with an assessment firm to continue the assessment process to determine the full extent of the contamination.
- (f) An estimated cost of clean-up will be developed by the Materials and Testing Section, in coordination with the Contracts and Specifications Section.

Design:

Personnel conducting plan-in-hand and design-stage site inspections will look for signs of previously undiscovered possible contaminated sites. If contamination is

found to be present on the project the Director of Engineering Design and Contract Management will make the decision as to what direction the development of the project should take. His decision will be based on such factors as degree of contamination (hazardous, non-hazardous, etc.), possible alternatives, priority of and need for project, cost of clean-up, consequences and cost of avoidance, and other factors which may arise on a project by project basis.

Acquisition:

- (a) When contamination is discovered during pre-design or design phases of the project, but the decision is made to acquire the contaminated property for the project construction, the Real Estate Directorate will take the necessary steps to notify the owner of the contaminated property that he/she is responsible for clean-up.
- (b) In those instances where the presence of contamination does not become known until after definite alignment has been chosen or design has been completed, the Real Estate Directorate will adhere to the established policy and guidelines.

Possible Options to the Department in Handling the Contamination are as Follows:

- (a) Department may enter into a separate contract with an environmental remediation firm.
 - (b) Site clean-up specifications may be included in the proposal and contract for the project.
 - (c) Department may request that DEQ take legal action against the property owner to force a clean-up of the property prior to acquisition.
 - (d) Site clean-up may be performed by the owner. One possible course of action where clean-up will be handled by the owner is for the cost of clean-up to be deducted from just compensation, held in escrow, and released to the owner upon receipt of sufficient documentation that the clean-up is completed.
- 21. CONTACT PERSON:** Curtis A. Fletcher, Materials Research Manager, 4101 Gourrier, Baton Rouge, Louisiana 70808, Phone: (504) 767-9131, Fax: (504) 767-9108.

7. 5. 7. New Jersey DOT (1994)

1. **REPORT TITLE:** Alternatives to the Disposal of Contaminated Soil - Guidance Manual .
2. **PREPARED BY:** New Jersey Hazardous Substance Research Center.
3. **PUBLISHED DATE:** April, 1994.
4. **WHO IS IN CHARGE?** Bureau of Environmental Analysis is responsible for providing basic guidance on environmental issues of highway projects.
5. **IS IT A CENTRALIZED OPERATION:** Yes.
6. **WHO DOES THE CLEAN UP?** New Jersey Department of Environmental Protection (NJDEP) is responsible for the cleanup.
7. **FEDERAL AGENCIES IN ACTION:** FHWA, U.S.EPA
8. **STATE AGENCIES IN ACTION:** New Jersey Department of Environmental Protection (NJDEP).
9. **ENVIRONMENTAL REGULATIONS:** Regulations as per U.S.EPA, New Jersey Department of Environmental Protection should be used.
10. **REGULATORY CLEANUP LEVELS:** Information not included.
11. **UNDERGROUND STORAGE TANKS (UST):** Section not available on USTs.
12. **PETROLEUM CONTAMINATED SOILS:** The report is prepared for mainly petroleum contaminated soils even though other contaminants are also considered.
13. **PETROLEUM CONTAMINATED PROJECTS REPORTED(NCHRP 226):** 0
14. **COMMONLY ENCOUNTERED PETROLEUM CONTAMINANTS:** Total Petroleum Hydrocarbons.
15. **ASBESTOS:** Not available.
16. **TRAINING PROGRAM:** Not available.
17. **HAZARDOUS WASTE MANAGEMENT PLAN:** Yes.
18. **COSTS:** Where contamination is found, the Department always seek cost recovery unless there are compelling reasons to refrain from cost recovery.

19. **CLOSURE REPORT:** Upon completion of the remedial investigation, the Remedial Action Report should be submitted to NJDEP which details final placement of contaminated soils, final costs and any other special measures.
20. **DETAILED SUMMARY:** The Manual discusses various treatment technologies for contaminated soils. It has been noted that total petroleum hydrocarbon contaminated soil is a major contaminant associated with the acquisition of gas stations, fuel depots and industrial sites. MOU was signed between NJDOT and NJDEP in 1989.
21. **CONTACT PERSONS:** Bob Cebrick, New Jersey DOT, Phone: (609) 530-2838.

7. 5. 8. Oklahoma DOT (1995)

1. **REPORT TITLE:** Hazardous Waste and Leaking Underground Storage Tank Task Force.
2. **PREPARED BY:** Oklahoma Department of Transportation Task Force
3. **PUBLISHED DATE:** January 25, 1995.
4. **WHO IS IN CHARGE?** Oklahoma Department of Environmental Quality. Maintenance Division is responsible for administering the hazardous waste response and removal contract.
5. **IS IT A CENTRALIZED OPERATION:** Yes.
6. **WHO DOES THE CLEAN UP?** The Department of Environmental Quality (DEQ) is the agency that monitors the compliance of rules and regulations for hazardous materials handling and disposal. DEQ has a 24 hour number which can be used for emergencies (1-800-522-0206).
7. **FEDERAL AGENCIES IN ACTION:** U.S.EPA
8. **STATE AGENCIES IN ACTION:** Oklahoma Corporation Commission, Oklahoma Department of Environmental Quality, Oklahoma Department of Health, Waste Management.
9. **ENVIRONMENTAL REGULATIONS:** Regulations as per U.S.EPA and Oklahoma Department of Environmental Quality should be followed.
10. **REGULATORY CLEANUP LEVELS:** Not available.
11. **UNDERGROUND STORAGE TANKS (UST):** ODOT has a Memorandum of Understanding with the Oklahoma Corporation Commission to meet the goals of completing transportation projects and protecting the public health and environment while complying with state and federal laws and regulations for Underground Storage Tanks.

The following procedures are used when the USTs are encountered during the construction of a project:

1. If the UST is located within present right-of-way or is partially located on private property, then it should be treated as an encroachment. A "Notice and Demand" form

should be delivered to the proper individual, and a reasonable time frame (normally 7 to 10 days) allowed for the tank removal and site cleanup.

2. Should the individual referenced above refuse to comply with the removal notice, or if the UST is located entirely within the new right-of-way, the excavation is immediately suspended and the respective Division Engineer and the State Construction Engineer of the UST are notified. The State Construction Engineer will then notify the Maintenance Division, who will be entirely responsible for the physical site closure, as well as insuring that proper documentation of the site closure is completed and submitted to the Oklahoma Corporation Commission. The contract time may be suspended during the UST site closure if the delay affects critical path activities.

USTs Discovered Prior to ODOT Assuming Ownership:

The responsibility for corrective measures taken in association with UST rests on the owner of the tank. This may be the owner of the property or any second party holding a title to the tank. State indemnity funds are available for all private UST owners in which a release has occurred. Under this program, funds are available for the removal and remediation efforts associated with the tank once it has been determined that release has occurred. The indemnity fund will pay up to 100% of all these costs after the owner pays the initial deductible amount of \$5,000.

USTs Discovered After ODOT Assumes Ownership:

Upon the discovery of UST's on ODOT right-of-way, Maintenance Division, Safety and Hazards Branch shall be notified as soon as practical. If a UST is identified during the construction phase, the resident engineer shall notify the field division engineer or field construction engineer and state construction engineer. The state construction engineer will then notify the Maintenance Division, Safety and Hazards Branch, who will perform the site closure.

12. **PETROLEUM CONTAMINATED SOILS:** No special section on Petroleum Contaminated soils is available.
13. **PETROLEUM CONTAMINATED PROJECTS REPORTED(NCHRP 226):** 1
14. **COMMONLY ENCOUNTERED PETROLEUM CONTAMINANTS:** Gasoline, diesel fuel and kerosene in soil and ground water.
15. **ASBESTOS:** Not available.

- 16. TRAINING PROGRAM:** Training is the other essential element in a successful program. A formal training program needs to be established for Department personnel and management who may have contact with or responsibilities for these issues. Formal training may include the FHWA training class (NHI Course#14229) entitled: "Hazardous Waste: Impacts on Highway Project Development"; Health and Safety Training, such as OSHA 8-24-40 hour courses, and courses held at universities. Due to technical nature of these issues, more than one person in each essential area should have training. Hazardous waste and LUST research and/or training could be contracted to universities. Possible subjects include investigating the Department's hazardous waste history, mitigation projects and training programs.

Table showing the details of training required for different personnel:

Type of Employee	Required Training
Specifically Identified Project Inspectors	UST Identification + Appropriate Actions
Specifically Identified Resident Engineers	UST Identification + Appropriate Actions
Specifically Identified Construction Engineers	UST Identification + Appropriate Actions
Specifically Identified Personnel in Maintenance Division, Safety and Hazards Branch	UST Identification + Appropriate Actions OCC UST Regulations* EPA UST Regulations*
Specifically Identified Personnel in Preconstruction such as : Hazardous Waste Coordinators, Environmental Coordinators, Survey Supervisors, Project Engineers, Right-of-Way Personnel	UST Identification + Appropriate Actions OCC UST Regulations* EPA UST Regulations*

* Outside training may be required in these areas.

- 17. HAZARDOUS WASTE MANAGEMENT PLAN:** Post monitoring is not included.
- 18. COSTS:** Cost of the disposal of any liquid will be paid in accordance with subsection 619.06 of this report. Removal of Underground storage tanks will be measured for payment for each tank removed. Removal of contaminated soil will be measured for payment by the cubic yard.
- 19. CLOSURE REPORT:** Not available.

20. **DETAILED SUMMARY:** The Department of Environmental Quality (DEQ) is the agency that monitors the compliance of rules and regulations for hazardous materials handling and disposal. DEQ has a 24 hour number which can be used for emergencies (1-800-522-0206).

If any hazardous waste or spills are encountered on ODOT's right-of-way, the safety and hazards branch is available to help each division with the proper disposal of any contamination, the Safety and Hazards Branch can be reached at (405) 521-3025.

Actions to be Taken:

- Avoid contact with spilled material.
- Avoid breathing vapors, smoke, or dust originating from the material.
- Stay upwind; Keep out of low areas.
- Do not cleanup any unfamiliar, unknown, or suspected hazardous material.

Hazardous Waste Sites Discovered Prior to ODOT Assuming Ownership:

If a hazardous waste site is located during preconstruction phases the Hazardous Waste Coordinator in Planning Division should be contacted immediately. The Hazardous Waste Coordinator will coordinate preliminary site investigations.

Hazardous Waste Sites Discovered After ODOT Assumes Ownership:

Maintenance Division is the responsible Division for administering the hazardous waste response and removal contract.

21. **CONTACT PERSONS:** Dawn R.Sullivan, Associate Engineer, Quality Specialist, Planning Division, 200 N.E. 21st street, Oklahoma City, OK 73105-3204, Phone: (405) 521-2515.

7. 5. 9. South Dakota DOT(1995)

1. **REPORT TITLE:** Handbook for Investigation and Corrective Action Requirements for Discharges from Storage Tanks, Piping Systems and Other Releases.
2. **PREPARED BY:** The South Dakota Department of Environment and Natural Resources - Groundwater Quality Program.
3. **PUBLISHED DATE:** Report Version 1.1 - December 18, 1995.
4. **WHO IS IN CHARGE?** South Dakota Department of Environment and Natural Resources. In charge of assessment and corrective action at petroleum and other regulated substance release sites.
5. **IS IT A CENTRALIZED OPERATION:** Yes.
6. **WHO DOES THE CLEAN UP?** Based on the Administrative rules of South Dakota Chapter 74:03:33 "Remediation Criteria for Petroleum Contaminated Soils", the responsible parties must implement the corrective action to reduce the risks associated with petroleum contaminated soils.
7. **FEDERAL AGENCIES IN ACTION:** U.S. Environmental Protection Agency.
8. **STATE AGENCIES IN ACTION:** South Dakota Department of Environment and Natural Resources, Department of Commerce and Regulation.
9. **ENVIRONMENTAL REGULATIONS:** The State of South Dakota has promulgated rules to establish reportable quantities, or limits, for the amount of a substance that can be released before the incident becomes reportable.
Regulated Substances: A material is considered a "regulated substance" if it is any one of the following:
 - Any substance named in the title III list of lists (U.S.EPA, 1994);
 - Any commercial fertilizer;
 - Any pesticide;
 - Any waste classified as Hazardous waste;
 - Any material released in a location where it threatens the waters of the state.
10. **REGULATORY CLEANUP LEVELS:** The cleanup goals for sites contaminated with metals, semi-volatiles, volatiles and other substances may use the Toxicity

Characteristic Leaching Procedure (TCLP) standards for hazardous waste. In some cases, it is acceptable to use a total analysis rather than the TCLP analysis. The result of the total analysis is then divided by 20 to arrive at an estimate of what the TCLP value for the sample would be. If the resulting number is greater than or equal to the TCLP standard, a TCLP analysis will be required to decide if the sample does exceed the standard.

11. **UNDERGROUND STORAGE TANKS (UST):** The “source” of the release should be determined immediately after discovery of a spill or release of a regulated substance. If free product is detected, recovery must be implemented as soon as possible after it has been detected as per ASRD 74:03:28:20 for Underground Storage Tanks and ASRD 74:03:30:24 for above ground storage tanks and regulated substances under ASRD chapter 74:34:01.

The initial steps for tank abandonment were taken from the American Petroleum Institute, “Removal and Disposal of Used Underground Petroleum Storage Tanks”, API Recommended Practice 1604, Second Edition, December 1987.

12. **PETROLEUM CONTAMINATED SOILS:** In South Dakota, rules identify any type of petroleum, or petroleum substance, as a regulated substance. The rules specify that any known reportable quantity release must be reported to the department immediately, and that any suspected reportable quantity release of a regulated substance must be reported to the department within 24 hours.

Reportable Quantity Releases:

A petroleum substance release must be reported to the state and is considered a "reportable quantity" release, if one of the following conditions is met:

- 1) more than 25 gallons of the substance was released;
- 2) the discharge is reportable under SARA Title III Section 304;
- 3) the release occurs in a location where it harms or threatens to impact surface water or ground water.
- 4) the release was not cleaned up within 24 hours.

Release Notification or Reporting Requirements:

When a reportable quantity release occurs, the responsible party must immediately notify the Department’s office. If the release is less than 25 gallons and does not impact surface or ground water and is cleaned up within 24 hours it does not have to be reported.

To report an incident to the department, call (60%) -773-3231 during regular office hours (8 a.m. to 5 p.m.). If surface water is impacted by a release of a regulated substance, the Environmental Protection Agency must also be notified immediately by calling the National Response Center at (800) 424-8802.

Steps Taken After a Petroleum Release is Reported:

When a known or suspected release is reported to the department, state program personnel fill out a "SD spill Report Form", and the department will send a letter to the responsible party, which outlines the assessment / remediation work required. The responsible party must complete the form and return it to the Department within 20 days of receipt of the letter or by the date specified in the letter. If a release poses an immediate threat to human health or the environment, or if such a threat arises, immediate action must be taken by the responsible party.

The soil remediation rules require corrective action if data indicate petroleum vapors have adversely affected structures or utilities or in the opinion of the department, have the potential to occur in future.

- 13. **PETROLEUM CONTAMINATED PROJECTS REPORTED (NCHRP 226):** 2
- 14. **COMMONLY ENCOUNTERED PETROLEUM CONTAMINANTS:** Gasoline and Fuel oil.
- 15. **ASBESTOS:** Not available.
- 16. **TRAINING PROGRAM:** Not available.
- 17. **HAZARDOUS WASTE MANAGEMENT PLAN:** Yes. FHWA flow chart was adopted with slight modification.
- 18. **COSTS:** Not available.
- 19. **CLOSURE REPORT:**

Inactive Site Closure:

When a site is classified as inactive closure, the Department will not require additional monitoring or remediation at the site, while acknowledging the site does not meet state remediation standards, and may never meet these standards.

Active Closure:

When a site has been remediated to the levels specified in ASRD 74:03:33 and the groundwater quality standards have been met, the department will issue a closure

letter for the site. The closure letter will see that if future problems arise from the site, that additional assessment and cleanup may be required, and the responsible party will be required to perform the work. The closure letter will be sent to the responsible party, with copies to the consultant, the county civil defense director and the petroleum release compensation fund.

20. **DETAILED SUMMARY:** The Department requires that each site be classified according to the site characterization into 4 classes:

Class 1 sites:

A class 1 site is a site that poses an immediate threat to human health, safety or sensitive environmental receptors.

Class 2 sites:

A class 2 site is a site that poses a short term (0-2 years) threat to human health, safety or sensitive environmental receptors.

Class 3 sites:

A class 3 site is a site that poses a long term (2 to 10 years) threat to human health, safety, or sensitive environmental receptors.

Class 4 sites:

A class 4 site is a site that poses no demonstrable long term threat to human health, safety or sensitive environmental receptors.

Corrective Action Plan Report and Corrective Action Report:

The corrective action plan report can be submitted as part of the assessment report. The purpose of this report is to propose a corrective action to the department. The corrective action plan must be designed to reduce the risks a site poses to acceptable levels.

If the corrective action plan includes remediation by excavation, soil vapor extraction, pump and treat, air sparging, or other remedial alternatives, the plans and specifications for the remedial action must be submitted to the department. After the corrective action plan has been approved by the Department and implemented by the responsible party, a report that details the effectiveness and outcome of the corrective action plan must be submitted to the Department.

21. **CONTACT PERSONS:** Gary H. Haag, Hydrologist, Department of Environment and Natural Resources, JOE FOSS Building, 523 East Capitol, Pierre South Dakota 57501-3181.

7.5.10. Washington DOT

1. **REPORT TITLE:** No written document. Information collected from Washington DOT Citizen's Representative Office (by e-mail).
2. **PREPARED BY:** Washington State Department of Transportation.
3. **PUBLISHED DATE:** Not applicable.
4. **WHO IS IN CHARGE?** Washington State Department of Transportation.
5. **IS IT A CENTRALIZED OPERATION:** Yes.
6. **WHO DOES THE CLEAN UP?** Not available.
7. **FEDERAL AGENCIES IN ACTION:** U.S.EPA
8. **STATE AGENCIES IN ACTION:** Not available.
9. **ENVIRONMENTAL REGULATIONS:** Toxics Control Act (Revised Code of Washington 70-105D as promulgated through Washington Administrative Code 173-340).
10. **REGULATORY CLEANUP LEVELS:** It had adopted it's own cleanup standards for contaminants.
11. **UNDERGROUND STORAGE TANKS (UST):** Not available.
12. **PETROLEUM CONTAMINATED SOILS:** The vast majority of cleanups have involved petroleum contamination (total petroleum hydrocarbons). The most common disposal methods in Washington state are landfilling and thermal destruction.
13. **PETROLEUM CONTAMINATED PROJECTS REPORTED (NCHRP 226):** 0
14. **COMMONLY ENCOUNTERED PETROLEUM CONTAMINANTS:** Petroleum products including coal tar.
15. **ASBESTOS:** Not available.
16. **TRAINING PROGRAM:** Not available.
17. **HAZARDOUS WASTE MANAGEMENT PLAN:** Not available.

18. COSTS: Transportation cost is around \$3 per ton. For thermal treatment around \$35 to \$42 per ton.

19. CLOSURE REPORT: Not available.

20. DETAILED SUMMARY: The vast majority of cleanups have involved petroleum contamination (total petroleum hydrocarbons). The most common disposal methods in Washington state are landfilling and thermal destruction. Both are very competitive in price, especially in the more population western part of our state (Puget Sound basin). For landfilling, commonly, TPH-contaminated soil is taken to one of several large, lined, regional landfills. The major landfill in Washington accepting TPH soil is the landfill in south-central Washington, near the Columbia River (Regional Disposal Company). Transportation cost is around \$3 per ton.

For thermal treatment, they generally use a major fixed facility in the Tacoma area (TPS Technologies). Costs are slightly higher than landfilling, but it can be cheaper when you factor in the transportation costs. They routinely run around \$35 to \$42 per ton.

They have limited experience with other types of remediation, with the exception of coal tar contaminated soil. They have had a major cleanup involving this contaminant. It was treated similarly to the TPH (taken to TPS in Tacoma for thermal destruction). What they couldn't take was taken to the hazardous waste landfill in Arlington, OR (Waste Management Inc.)

21. CONTACT PERSONS: Rick Singer, Washington State Department of Transportation.
Phone: (360) 705-7402; e-mail: rsinger@wsdot.wa.gov

7.5.11 Wyoming DOT (1995)

1. **REPORT TITLE:** Solid Waste Guideline #2, Petroleum Contaminated Soils.
2. **PREPARED BY:** Wyoming Department of Environmental Quality, Solid and Hazardous Waste Division.
3. **PUBLISHED DATE:** Issued October, 1989 and revised April, 1993.
4. **WHO IS IN CHARGE?** Wyoming Department of Environmental Quality, Solid and Hazardous Waste Division.
5. **IS IT A CENTRALIZED OPERATION:** Yes.
6. **WHO DOES THE CLEAN UP?** Not available.
7. **FEDERAL AGENCIES IN ACTION:** U.S.EPA
8. **STATE AGENCIES IN ACTION:** Wyoming Department of Environmental Quality.
9. **ENVIRONMENTAL REGULATIONS:** Regulations as per U.S.EPA, Wyoming Department of Environmental Quality.
10. **REGULATORY CLEANUP LEVELS:** According to TCLP levels by Wyoming Department of Environmental Quality, Solid and Hazardous Waste Division.
11. **UNDERGROUND STORAGE TANKS (UST):** Section available on USTs.
12. **PETROLEUM CONTAMINATED SOILS:** The report is prepared for mainly petroleum contaminated soils and is not applicable to other wastes.
13. **PETROLEUM CONTAMINATED PROJECTS REPORTED (NCHRP 226):** 0
14. **COMMONLY ENCOUNTERED PETROLEUM CONTAMINANTS:** Not available.
15. **ASBESTOS:** Not available.
16. **TRAINING PROGRAM:** Not available.
17. **HAZARDOUS WASTE MANAGEMENT PLAN:** Not available.
18. **COSTS:** Not available.
19. **CLOSURE REPORT:** Not available.

20. **DETAILED SUMMARY:** The main focus is on petroleum contaminated soils. Soils may be screened in the field using an organic vapor analyzer (OVA) and readings in excess of 20 ppm transported to SHWD-approved storage or treatment unit. The documents provides guidelines for the treatment and disposal of soils which are contaminated with petroleum products. Petroleum contaminated soils are treated and disposed of in compliance with Wyoming Solid waste rules and regulations and properly characterized using the TCLP (EPA method).
21. **CONTACT PERSONS:** David A. Finley, Administrator, Solids and Hazardous Waste Division, Wyoming DEQ, Wyoming.

7. 6. REFERENCES

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- [3] Illinois Department of Transportation (1996), Manual for Conducting Preliminary Environmental Site Assessments for Illinois Department of Transportation Highway Projects, Annual Report.
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- [11] National Highway Institute, (1992), Hazardous Waste: Impacts on highway Project Development, Construction, and Maintenance (NHI Course # 14229), U.S. Department of Transportation, Federal Highway Administration, Washington D. C.
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- [16] Schick, J. R. "Cooperation Between State Highway and Environmental Agencies in Dealing with Hazardous Waste in the Right-of-Way, Transportation Research Record 1312, pp. 15-19.

- [17] South Dakota Department of Transportation (1995), Handbook For Investigation and corrective Action Requirements for Discharges from Storage Tanks, Piping Systems and Other Releases Version 1.1.
- [18] Wyoming Department of Environmental Quality Solid & Hazardous Waste Division (Revised 1993) Solid Waste Guide Line #2, Petroleum Contaminated Soils., 5 p.

APPENDIX A

ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
ACT	Association for Composite Tanks
ANSI	American National Standards Institute.
API	American Petroleum Institute.
ARSD	Administrative Rules of South Dakota
ASTM	American Society for Testing and Materials Standards
BTEX	Benzene, Toluene, Ethylbenzene and Xylene
CAA	Clean Air Act
CAMU	Corrective Action Management Units
CAP	Corrective Action Plan
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CMI	Corrective Measures Implementation
CMS	Corrective Measures Study
COC	Chemical of Concern
CWA	Clean Water Act
DEP	Department of Environmental Protection
DER	Department of Environmental Regulation
DHS	Department of Health Services
DOD	U.S. Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
DSI	Detailed Site Investigation
ECRA	Environmental Cleanup Responsibility Act
EPA	Environmental Protection Agency
FHWA	Federal Highway Administration
FID	Flame Ionization Detector
FLDER	Florida Department of Environmental Regulation
FR	Federal Register
FS	Feasibility Study
GC/MS	Gas Chromatography/Mass Spectrometer
HEAST	Health Effects Assessment Summary Tables
HI	Hazard Index
HQ	Hazard Quotient
HSWA	Hazardous and Solid Waste Amendments
HWMP	Hazardous Waste Management Plan

IRIS	Integrated Risk Information System
ISA	Initial Site Assessment
LDR	Land Disposal Restrictions
LNAPL	Light non-aqueous phase liquids
LPST	Leaking petroleum storage tank
LUST	Leaking underground storage tank
MADEP	Massachusetts Department of Environmental Protection
MCL	Maximum Contaminant Levels
MOU	Memorandum of Understanding
MRC	Minimum Regulatory Control
MSW	Municipal Solid Waste
NACE	National Association of Corrosion Engineers
NAPL	Non Aqueous Phase Liquid
NCHRP	National Cooperative Highway Research Program
NFPA	National Fire Protection Association.
NHI	National Highway Institute
NJDEP	New Jersey Department of Environmental Protection
NPL	National Priorities List
NRC	National Research Council
OSHA	Occupational Safety and Health Administration
OVA	Organic Vapor Analyzer
PCBs	Polychlorinated Biphenals
PEI	Petroleum Equipment Institute.
PID	Photo-Ionization Detector
Plan A:	Involves comparison of a site's degree of contamination to general standards for cleanup.
Plan B:	Involves site specific cleanup goals based on site specific information about contamination.
ppb	parts per billion
ppm	parts per million
PRPs	Potentially Responsible Parties
PSI	Preliminary Site Investigation
PVC	Polyvinyl Chloride
QA/QC	Quality Assurance/Quality Control
RBCA	Risk-Based Corrective Action
RCAS	Registered Corrective Action Specialist

RCRA	Resource Conservation and Recovery Act
RFA	RCRA Facility Assessment
RFD	Reference Dose
ROD	Record of Decision
ROW	Right -of -way
RPI	TNRCC's Responsible Party Investigation Section
RPR	TNRCC's Responsible Party Remediation Section
RRC	Rail Road Commission, Texas
RTS form	Remedial Technology Screening Form
SARA	Superfund Amendments and Reauthorization Act
SD DENR	South Dakota Department of Environment and Natural Resources
SD PRCF	South Dakota Petroleum Release Compensation Fund
SDGS	South Dakota Geological Survey
SOP	Standard Operating Procedure
SPLP	Synthetic Precipitation Leaching Procedure
STI	Steel Tank Institute.
SVE	Soil Vapor Extraction
SWDA	Solid Waste Disposal Act
SWMU	Solid Waste Management Unit
TAC	Texas Administrative Code
TCE	Trichloroethylene
TCLP	Toxicity Characteristic Leaching Procedure
TCLP	Toxicity Characteristic Leaching Procedure
TECE	Tetrachloroethylene
TNRCC	Texas Natural Resources Conservation Commission
TPH	Total Petroleum Hydrocarbons
TRB	Transportation Research Board
TSCA	Toxic Substances Control Act
TSDF	Treatment, Storage, and Disposal Facilities
TWC	Texas Water Commission
US EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UST	Underground Storage Tank
VOC	Volatile Organic Compounds

APPENDIX B

GLOSSARY OF TERMS

Abandonment in-place - A method of permanent removal of an underground storage tank from service where the tank is left in the ground after appropriate preparation and filling with an acceptable solid inert material.

Aboveground release - Any release to the surface of the land or to surface water, including, but not limited to, releases from the aboveground portion of an underground storage tank system and releases associated with overfills and transfer operations during the dispensing, delivering, or removal of regulated substances into or out of an underground storage tank system.

Aboveground tank - A device meeting the definition of 'tank' and is situated in such a way that the entire surface area of the tank is completely above the plane of the adjacent surrounding surface and the entire surface area of the tank is able to be visually inspected.

Accidental release - Any sudden or non sudden release of a petroleum substance from an underground storage tank that results in a need for corrective action and/or compensation for bodily injury or property damage neither expected nor intended by the tank owner or operator.

Action levels - Numeric values or other performance criteria that are protective of human health, safety and the environment.

Ancillary equipment - Any devices that are used to distribute, meter, or control the flow of petroleum substances or hazardous substances into or out of an underground storage tank, including, but not limited to, piping, fittings, flanges, valves, and pumps.

Appropriate district office -The district field office which has jurisdiction for conducting authorized regulatory activities in the area.

Aquifer - A geologic formation or part of a geologic formation that contains sufficient saturated permeable material to yield economical quantities of water to wells and springs.

Below-ground release - Any release to the subsurface of the land or to groundwater, including, but not limited to, releases from the below-ground portions of an underground storage tank system and releases associated with overfills and transfer operations during the dispensing, delivering, or removal of regulated substances or petroleum products into or out of an underground storage tank system.

Bulk storage tank - An underground storage tank having a capacity of 20,000 gallons or more.

Cathodic protection - A technique to prevent corrosion of a metal surface by making that surface the cathode of an electrochemical cell, normally by means of either the attachment of galvanic anodes or the application of impressed current.

CERCLA - The federal Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended.

Chemicals of concern - Specific constituents that are identified for evaluation in the risk assessment process;

Closure letter - A letter issued by the TNRCC to the owner or operator which states that based on the information available, the TNRCC agrees that the owner or operator has completed the corrective action requirements for the referenced release in accordance with commission requirements.

Commission - Texas Natural Resource Conservation Commission, or its predecessor or successor agencies, as applicable.

Containment - The prevention of the spreading of oil and other hazardous materials by placing booms or physical barriers and the use of absorbents, gelling or hardening agents or other materials. It can be used to mitigate the effects of the spill.

Contaminant: means any physical, chemical or biological substance or matter in water and/or soil.

Corrective action - The sequence of actions at a release site that include site assessment, interim remedial action, remedial action, operation and maintenance of equipment, monitoring of progress, and termination of the remedial action.

Corrective Action Plan - As defined in 30 Texas Administrative (TAC) Chapter 334, a corrective action plan is a detailed plan to address the site remediation of soil, groundwater or surface water contamination that provides for adequate protection of human health, safety and the environment.

Direct exposure pathway - an exposure pathway where the point of exposure is at the source, without a release to any other medium

Discharge or hazardous waste discharge - Accidental or intentional spilling, leaking, pumping, pouring, emitting, emptying, or dumping of hazardous waste or petroleum products into or on any land and water.

Disposal facility - A facility at which hazardous waste or petroleum product is intentionally placed into or on any land and water, and at which the waste will remain after closure.

Excavation area - the area containing the tank system and backfill material bounded by the ground surface, the walls and floor of the pit, and the trenches into which the underground storage tank system was placed at the time of installation; or two feet around the underground storage tank system if the limits of the original excavation cannot be determined.

Existing UST system - An underground storage tank system which is used or designed to contain an accumulation of regulated substances for which installation either has commenced prior to December 22, 1988, or has been completed on or prior to December 22, 1988. Installation will be considered to have commenced if the owner or operator has obtained all federal, state, and local approvals or permits necessary to begin physical construction at the site or installation of the tank system, and if either a continuous on-site physical construction or installation program has begun or the owner or operator has entered into contractual obligations (which cannot be canceled or modified without substantial loss) which require that the physical construction at the site or installation of the tank system is to be completed within a reasonable time.

Exposure - contact with a chemical of concern

Exposure assessment - the estimation (qualitative or quantitative) of the magnitude, frequency, and duration of exposure to a chemical of concern, and the route of exposure

Exposure pathway - the course a chemical or physical agent takes from a source to an exposed person/population. An exposure pathway describes a unique mechanism by which an individual or population is exposed to chemicals or physical agents at or originating from a site. Each exposure pathway includes a source or release from a source, an exposure point, and an exposure route. If the exposure point differs from a source, a transport/exposure medium (wind, water) is also included.

External release detection - A method of release detection which includes equipment or procedures designed to effectively monitor or measure for the presence of regulated substances in the excavation zone, soil, or other media outside of a single-wall or double-wall underground storage tank system.

Facility - The site, tract, or other defined area where one or more underground storage tank systems are located, and which includes all adjoining contiguous land and associated improvements.

Facility owner - Any person who currently holds legal possession or ownership of a total or partial interest in an underground storage tank or other facility.

Free phase product - Petroleum product floating on the groundwater or surface water, or on the ground surface.

Free-product - A regulated substance in its free-flowing non-aqueous liquid phase at standard conditions of temperature and pressure.

Generator: means any person, by site location, whose act or process produces hazardous waste or petroleum product identified.

Hazardous substance - Any substance defined or listed in the federal Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), §101(14) (42 United States Code §9601, et seq.), and which is not regulated as a hazardous waste under the federal Solid Waste Disposal Act, Subtitle C (42 United States Code §6921, et seq.).

In operation - The description of an in-service underground storage tank which is currently being used on a regular basis for its intended purpose.

Indirect exposure pathway - An exposure pathway with at least one intermediate release to any media (soil, groundwater) between the source and the point(s) of exposure.

Installer - A person who participates in or supervises the installation, repair, or removal of underground storage tanks.

Land disposal - Placement in or on the land and includes, but is not limited to placement in a landfill, surface impoundment, waste pile, injection well, land treatment facility, salt

dome formation, salt bed formation, underground mine or cave, or placement in a concrete vault or bunker intended for disposal purposes.

Landfill - Disposal facility or part of a facility where hazardous waste or petroleum product is placed in or on land.

Maximum contaminant level (MCL) - The maximum permissible level of a contaminant in water which is delivered to the free flowing outlet of the ultimate user of a public water system, except in the case of turbidity where the maximum permissible level is measured at the point of entry to the distribution system.

Monitoring well - An artificial excavation constructed to measure or monitor the quantity or movement of substances, elements, chemicals, or fluids below the surface of the ground. The term shall not include any monitoring well which is used in conjunction with the production of oil, gas, or any other minerals.

Necessary work/technically necessary work - Work which is required and approved by the commission to assess or remediate a leaking petroleum storage tank site.

New UST system - An underground storage tank system which is used or designed to contain an accumulation of regulated substances for which installation has commenced after December 22, 1988; or an underground storage system which is converted from the storage of materials other than regulated substances to the storage of regulated substances after December 22, 1988.

Observation well - A monitoring well or other vertical tubular structure which is constructed, installed, or placed within any portion of a UST excavation zone (including the tank hole and piping trench), and which is designed or used for the observation or monitoring of groundwater, or for the observation, monitoring, recovery, or withdrawal of either released regulated substances (in liquid or vapor phase) or groundwater contaminated by such released regulated substances.

Operator - Any person in control of or having responsibility for, the daily operation of an underground storage tank system.

Owner - Any person who currently holds legal possession or ownership of a total or partial interest in the underground storage tank system. Owner does not include a person who holds an interest in an UST system solely for financial security purposes unless,

through foreclosure or other related actions, the holder of such security interest has taken legal possession of the UST system.

Permanent removal from service - The termination of the use and the operational life of an underground storage tank by means of either removal from the ground, abandonment in-place, or change-in-service.

Petroleum substance - A crude oil or any refined or unrefined fraction or derivative of crude oil which is liquid at standard conditions of temperature and pressure. A “petroleum substance” shall be limited to one or a combination of the substances or mixtures as follows:

- (A) basic petroleum substances - crude oils, crude oil fractions, petroleum feed stocks, and petroleum fractions;
- (B) motor fuels - (see definition for “motor fuel” in this section);
- (C) aviation gasoline - Grade 80, Grade 100, and Grade 100-LL;
- (D) aviation jet fuels - Jet A, Jet A-1, Jet B, JP-4, JP-5, and JP-8;
- (E) distillate fuel oils - Number 1-D, Number 1, Number 2-D, and Number 2;
- (F) residual fuel oils - Number 4-D, Number 4-light, Number 4, Number 5-light, Number 5-heavy, and Number 6;
- (G) gas-turbine fuel oils - Grade O-GT, Grade 1-GT, Grade 2-GT, Grade 3-GT, and Grade 4-GT;
- (H) illuminating oils - kerosene, mineral seal oil, long-time burning oils, 300 oil, and mineral colza oil;
- (I) solvents - Standard solvent, petroleum spirits, mineral spirits, petroleum ether, varnish makers' and painters' naphthas, petroleum extender oils, and commercial hexane;
- (J) lubricants - automotive and industrial lubricants;
- (K) building materials - liquid asphalt and dust-laying oils;
- (L) insulating and waterproofing materials - transformer oils and cable oils;
- (M) used oils - (see definition for “used oil” in this section);
- (N) any other petroleum-based material having physical and chemical properties similar to the above materials and receiving approval by the executive director for designation as a petroleum substance.

Petroleum UST system - An underground storage tank system that contains, has contained, or will contain a petroleum substance, a mixture of two or more petroleum

substances, or a mixture of one or more petroleum substances with very small amounts of one or more hazardous substances.

Reasonable maximum exposure - the highest exposure to a chemical of concern expected to occur at a site.

Receptor - persons, structures, utilities, surface water, groundwater, or water supply wells that are or may be adversely affected by a hazardous waste or petroleum product release.

Regulated substance - An element, compound, mixture, solution, or substance that, when released into the environment, may present substantial danger to the public health, welfare, or the environment.

Release - Any spilling including overfills, leaking, emitting, discharging, escaping, leaching, or disposing from an underground storage tank into groundwater, surface water, or subsurface soils.

Release detection - The process of determining whether a release of a regulated substance has occurred from an underground storage tank system.

Repair - The restoration, renovation, or mending of a damaged or malfunctioning tank or UST system component.

Residential tank - A tank located on property used primarily for dwelling purposes.

Risk-based corrective action - Site assessment or site remediation, the timing, type, and degree of which is determined according to case-by-case consideration of actual or potential risk to public health from environmental exposure to a regulated substance released from a leaking underground or aboveground storage tank.

SARA - Superfund Amendments and Reauthorization Act of 1986.

Secondary containment - A containment method by which a secondary wall or barrier is installed around the primary storage vessel (tank or piping) in a manner designed to prevent a release from migrating beyond the secondary wall or barrier before the release can be detected. Secondary containment systems include, but are not limited to, impervious liners or vaults surrounding a primary (single-wall) tank and/or piping system, and double-wall tank and/or piping systems.

Spill - A release of a regulated substance which results during the filling, placement, or transfer of regulated substances into a UST or during the transfer or removal of regulated substances from a UST system.

Standard conditions of temperature and pressure - A temperature of 60 degrees Fahrenheit and an atmospheric pressure of 14.7 pounds per square inch absolute.

Surface impoundment - A natural topographic depression, man-made excavation, or diked area formed primarily of earthen materials (but possibly lined with man-made materials) that is designed to hold an accumulation of regulated substances.

Tank - A stationary device designed or used to contain an accumulation of regulated substances which is constructed of a non-earthen material (concrete, steel, or plastic) that provides structural support.

Tier 1 assessment - a risk-based analysis to develop non-site specific values for direct and indirect exposure pathways utilizing conservative exposure factors and fate and transport for potential pathways and various property use categories

Tier 2 assessment - a risk-based analysis applying the direct exposure values established under a Tier 1 assessment at the point(s) of exposure developed for a specific site and development of values for potential indirect exposure pathways at the point(s) of exposure based on site specific conditions

Tier 3 assessment - a risk-based analysis to develop values for potential direct and indirect

Texas Water Commission (TWC) - Abolished after August 31, 1993, and now referred as the Texas Natural Resource Conservation Commission (TNRCC).

Underground storage tank - Any one or combination of underground tanks and any connecting underground pipes used to contain an accumulation of regulated substances or petroleum products.

Underground storage tank system - All associated piping and ancillary equipment, spill and overfill prevention equipment, release detection equipment, corrosion protection system, secondary containment equipment, and all other related systems and equipment.

Unsaturated (vadose) zone - The subsurface zone containing water under pressure less than that of the atmosphere (including water held by capillary forces within the soil).

Used oil - Any oil or similar petroleum substance that has been refined from crude oil, used for its designed or intended purposes, and contaminated as a result of such use by physical or chemical impurities (spent motor vehicle and aircraft lubricating oils)

APPENDIX C

CASE STUDIES

CASE STUDY [1] . 1/93

1. **TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Other site (not Superfund, DOT, RCRA, DOE or DOD)
2. **LOCATION:-** At a Nuclear fuel processing plant in Southern Ohio.
3. **NATURE OF SOIL:-** Silts and clays with a permeability of 10^{-6} cm/sec.
4. **AREA OF SITE / CONTAMINATED SITE:-** 2418 sq. m. (26,000 sq. ft.)
5. **DEPTH OF GROUNDWATER TABLE/CONTAMINATION:-** Ground water table was 4m below the grade. Depth of contamination was 6.7 m below the grade.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Not available.
7. **SITE CHARACTERIZATION:-** Not available.
8. **MAJOR CONTAMINANTS:-** Volatile organic compounds which include trichloroethylene (D040), 1,1,1-trichloroethane (F002), 1,1-dichloroethylene (D029), trans 1,2,-dichloroethylene, 1,2-dichloroethane (D028), methylenechloride (F002).
9. **SOURCE OF CONTAMINANTS:-** Past land farming activities of waste oils and degreasing solvents.
10. **CONCENTRATION OF CONTAMINANTS:-**Total mass of target volatile organic compounds were estimated to be 300 kg. 70% of the volatile organic compounds need to be removed.
11. **REGULATIONS:-** Not available.
12. **SPECIFICATIONS:-** Not known.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology :- None.
 - (b) Selected Shallow soil mixing combined with hot air injection and vacuum extraction.
14. **CONTAINMENT TECHNOLOGY:-** No.
15. **RISK ASSESSMENT:-** Details to be collected.
16. **DESCRIPTION OF THE TECHNOLOGY:-** The technology was based on the injection of heated air through jets at the base of the mixing auger, the collection of vapors in a hood which covered the mixing area, and the extraction and treatment of those vapors and dust by vacuum extraction system. Samples were collected from some of every three shallow soil mixing (SSM) columns, at discrete depth intervals. The samples were analyzed on-site for the target volatile organic compounds using a Gas Chromatography equipped with an FID detector and using EPA method 3810 of analysis. 20% of the samples were sent for off-site confirmatory analysis using EPA methods 8260. The vapor recovery system was comprised of three high power vacuum extraction units. Vapor treatment was accomplished using 4536

kg (10,000 pounds) of granular activated carbon. Injected air flow rates ranged between 1,000 to 1,500 standard cubic feet per minute of air heated approximately 250°F.

- 17. DURATION OF REMEDIATION:-** Soil remediation generally required about 1 to 4 hours of mixing and air injection per stroke . The treatment of 680 columns was completed in 10 weeks, operating around the clock seven days per week.
- 18. COST OF REMEDIATION:-** The approximate cost of remediation was \$130.78 per cubic meter (\$100 per cubic yard).
- 19. RESULTS:-** The project resulted in the extraction of approximately 500 kg of volatile organic compounds and 90% reduction in average soil concentration.
- 20. TRAINING PROGRAM:-** None.
- 21. OTHER INFORMATION:-**
 - * The shallow soil mixing columns were 2.4 meters in diameter with 10% overlaps.
 - * Diameter of the mixing auger is 1 to 4 meters.
 - * The method is capable of treating soils up to 10m deep without excavation, shoring or dewatering.
 - * The technology was suggested by the scientists of the Oak Ridge National Laboratories (ORNL).
- 22. CONCLUSIONS:-** The project was a complete success and it can undoubtedly be used in the future at sites where in situ vapor Extraction would require a long remedial time frame due to the low permeability of the soils. The technology may have difficulties with saturated conditions.
- 23. REFERENCES:-** Day, S.R. and Ryan, C.R.(1995). "Containment, Stabilization and Treatment of contaminated soils using in situ soil mixing", Proceedings, ASCE specialty conference, New Orleans, Louisiana, February 22-24, pp 21-29. Published in the book "Innovative technologies for the site remediation and hazardous waste management". Call no: TD 1052. E58 1995.
- 24. KEYWORDS:-** Contaminated soils, Air stripping, Shallow soil mixing, In situ treatment.
- 25. CONTACT PERSONS:-** None.

CASE STUDY [2] . 1/91

1. **TYPE OF PROJECT:-**
 - (a) Treating contaminated saturated soil.
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) DOT (not Superfund, RCRA, DOE or DOD)
2. **LOCATION:-** For a highway expansion in Texas.
3. **NATURE OF SOIL:-** Not specified.
4. **AREA OF SITE/ CONTAMINATION:-** The area of the site was 2 acres. 8000 tons of soil needed treatment.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** Depth of contamination was 5.5 m. (18 ft.)
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Not available.
7. **SITE CHARACTERIZATION:-** Not available.
8. **MAJOR CONTAMINANTS:-** Petroleum products.
9. **SOURCE OF CONTAMINANTS:-** Not known.
10. **CONCENTRATION OF CONTAMINANTS:-** Not known.
11. **REGULATIONS:-** Not available.
12. **SPECIFICATIONS:-** Not available.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected On site thermal desorption. Bioremediation of pumped water.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Not available..
16. **DESCRIPTION OF TECHNOLOGY:-** The technology involves heating soil to volatilize adsorbed contamination. The treatment plan called for a simultaneous, sequential operations in which soil would be
 - (a) categorized according to the degree of contamination present,
 - (b) excavated,
 - (c) stockpiled,
 - (d) treated by thermal desorption,
 - (e) backfilled into the previously excavated area.

The thermal desorption unit was installed by obtaining permission to erect it on concrete slab on adjacent property. While erecting the unit, 8 underground storage tanks were excavated and removed. Shortly after installation, the thermal desorption unit began operating 24 hours a day. A laboratory was set up on site to analyze soil and ground water samples as they were collected. Since the soil contamination extended so far below the water

table, they have to pump water out of the work area during excavation. Approximately 1,892,506 liters (500,000 gallons) of contaminated water were bioremediated in a temporary above ground storage tank prior to reuse on site to moisten soils for compaction or discharge into a storm sewer system.

17. **DURATION OF REMEDIATION:-** Not available..
18. **COST OF REMEDIATION:-** Not available.
19. **RESULTS:-** The thermal desorption unit processed 500 tons of soil per day. In four and half months, 27,500 tons of soil were excavated, treated and backfilled. The project was completed in 1991, at a cost 10% below the adjusted budget and 2 weeks ahead of the adjusted schedule.
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** None.
22. **CONCLUSIONS:-** Thermal desorption was used as the remedial option.
23. **REFERENCES:-** E. A.. Wood, J. R. Crossbie (1994). "CIVIL ENGINEERING", October 1994. pp. 50-53.
24. **KEYWORDS:-** Soil contamination, Thermal desorption, Bioremediation, Highway project, Petroleum contaminated site.
25. **CONTACT PERSONS:-** None.

CASE STUDY[3] . 2/91

1. **TYPE OF PROJECT:-**
 - (a) Treating contaminated soil.
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Other (not Superfund, DOT, RCRA, DOE or DOD)

2. **LOCATION:-** Residential properties along the length of a stream in Northeastern United States.

3. **NATURE OF SOIL:-** Not known.

4. **AREA OF SITE / CONTAMINATED SITE:-** 20 acres.

5. **DEPTH OF GROUNDWATER TABLE/CONTAMINATION:-** The depth of contamination was extended to 1.52 m. (5 ft. depth).

6. **ENVIRONMENTAL SITE ASSESSMENT:-** Details to be known.

7. **SITE CHARACTERIZATION:-** Details to be collected.

8. **MAJOR CONTAMINANTS:-** Lead, Mercury, Zinc, Copper, Barium, Selenium.

9. **SOURCE OF CONTAMINATION:-** An explosives manufacturing plant in Northeastern States.

10. **CONCENTRATION OF CONTAMINANTS:-**

Lead	- 250 parts per million,
Mercury	- 14 parts per million,
Copper	- 1000 parts per million,
Barium	- 660 parts per million,
Zinc	- 1500 parts per million,
Selenium	- 1 part per million.

11. **REGULATIONS:-** Not available.

12. **SPECIFICATIONS:-** Not available.

13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology :- None.
 - (b) Selected Excavation and land filling of soil.

14. **CONTAINMENT TECHNOLOGY:-** None.

15. **RISK ASSESSMENT:-** Details not known.

16. **DESCRIPTION OF TECHNOLOGY:-** Remediation began in September 1991. More than 5000 samples were taken over the 20 acre area. To reduce the time between sampling events, the owner decided to proceed in advance of approval by federal or state regulators. The majority of the contamination was near the surface and extended to 1.52 m. (5 ft.) of the surface. Lead and Mercury were the most prevalent metals and the other metal concentrations were usually below levels of concern. Excavation and land filling of soil was chosen over other remedial alternatives. The excavation proceeded according to these steps :
* The homeowner was offered relocation to a nearby house or apartment.

- * The area was surrounded by a temporary fence.
 - * Windows and doors were covered to prevent dust from entering homes.
 - * Vegetation and yard structures such as sheds and fences are removed.
 - * Contaminated soil was excavated.
 - * The bottom and perimeter of the excavation were tested to confirm that all contamination was removed.
 - * The excavation was backfilled with new soil.
 - * Fencing and other yard items were installed.
 - * The yard was landscaped.
 - * Temporary fencing was moved to the next area.
 - * Homeowners who had been moved returned to their homes.
- The soils were shipped to the Model City landfill in New York, the Grows landfill in Pennsylvania and a landfill in Utah. The remediation ended in late 1994.

17. **DURATION OF REMEDIATION:-** The entire process of excavation took from six to twelve weeks.
18. **COST OF REMEDIATION:-** The estimated cost of remediation was tens of millions of dollars.
19. **RESULTS:-** The remediation involved the excavation and restoration of 150 properties within and near the stream flood plain.
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** The project ended in 1994 successfully removing the contamination several years earlier than would have been possible if any other remedial option is selected.
22. **CONCLUSIONS:-** The project accomplished its major goal of removing the contamination and restoring the affected homes. The project team is in the process of finalizing post remediation reports.
23. **REFERENCE:-** N. E. Kramer, (1994), "Civil Engineering", September 1995. Vol. 65, No. 9, pp. 68-69.
24. **KEY WORDS:-** Land filling, Contaminated soil, Metals, Residential site.
25. **CONTACT PERSONS:-** None.

CASE STUDY [4] . 2/93

1. TYPE OF PROJECT:-

- (a) Treating contaminated soil and groundwater.
- (b) ESI and Site clean-up (HWMP - PHASE II & PHASE IV).
- (c) Other (not Superfund, DOT, RCRA, DOE or DOD)

2. LOCATION:-An oil sump at a truck maintenance facility in Denver.

3. NATURE OF SOIL:- The site is underlain at a depth of about 11m by interbedded claystone and sandstone bedrock of the Denver formation. Alluvial sand and gravel deposits, which are dense and interbedded about 9m thick are overlying the bedrock. A layer of stiff, sandy and silty clay ranging from 1.2 to 3m thick rests on the sand and gravel.

4. AREA OF SITE / CONTAMINATION:- Not available.

5. DEPTH OF GROUND WATER / CONTAMINATION:- Groundwater depth of 4 m.

6. ENVIRONMENTAL SITE ASSESSMENT:- Site assessment included about 9 monitoring wells, about 7.6 m deep using 102 mm diameter polyvinyl chloride casings and a 3 m screen interval. The site assessment indicated that :

*The primary site contaminant was waste oil located in the saturated and unsaturated sediment beneath the former used oil sump.

*A large population of hydrocarbon using bacteria existed within the zone of contamination. Their growth appeared to be restricted by limiting nutrient and oxygen conditions.

* Groundwater occurred at a shallow depth in sediments that appeared to be relatively permeable.

* Groundwater samples showed high levels of BTEX, Total petroleum hydrocarbons (TPH) and Total organic compounds (TOG), with localized but detectable levels of chlorinated organics.

7. SITE CHARACTERIZATION:- Groundwater samples collected from monitoring well 8 located near the former oil sump, contained contamination with highest levels of BTEX, Total petroleum hydrocarbons (TPH) with relatively low but detectable levels chlorinated organics.

8. MAJOR CONTAMINANTS:- BTEX, Total petroleum hydrocarbons (TPH), Total organic compounds (TOG).

9. SOURCE OF CONTAMINANTS:- Nonvolatile petroleum hydrocarbons from used Motor oil, diesel, gasoline and other automotive fluids released to an oil sump.

10. CONCENTRATION OF CONTAMINANTS:- Initial mass balance estimates indicated that about 272 kg of hydrocarbons existed in the zone of groundwater and about 11.7 tons existed in unsaturated and saturated sediments located beneath the former used oil sump.

11. REGULATIONS:- Not available.

12. SPECIFICATIONS:- Not known.

13. TREATMENT TECHNOLOGY:-

- (a) Screening technology:- Not available.
- (b) Selected in situ bioremediation.

14. CONTAMINANT TECHNOLOGY:- None.

15. RISK ASSESSMENT:- Details not available.

16. DESCRIPTION OF THE TECHNOLOGY:- In situ bioremediation, the indigenous microbial populations are stimulated to degrade the contaminants. the method converts organic wastes into biomass and harmless byproducts of metabolism such as CO₂, water and inorganic salts. Oxygen was added by either injecting hydrogen peroxide or installing an air sparging system. For vadose zone contamination, nutrients are added through percolation or injection.

The primary targets for the in situ bioremediation system were sorbed hydrocarbons in the unsaturated and the saturated sediments located beneath the area of the former used oil sump. The primary functions of the system included groundwater recovery, treatment and reinjection, vapor extraction and discharge, stimulation of in situ bioremediation by subsurface inorganic nutrient and oxygen additions, and phase separated hydrocarbon recovery. A 72 hour pump test generated aquifer data for ground water modeling. the modeling showed that a recovery well pumping at a rate of 10 gpm, would induce a sufficient hydraulic gradient to capture injected nutrients and dissolved hydrocarbons. Laboratory tests showed that the hydrogen peroxide and nutrient loading worked best in sediments from the 4m interval. Crews conducted field analysis tests, sampled groundwater and gauged monitoring wells. Average quarterly results showed that benzene and BTEX decreased significantly, especially in monitoring wells 1 and 8. Total petroleum hydrocarbons (TPH) decreased to below detection limits in monitoring well 1 and to approximately 15 ppm in monitoring well 8.

17. DURATION OF REMEDIATION:- Two and a half years.

18 COST OF REMEDIATION:- Not known.

19. RESULTS:- The total petroleum hydrocarbons (TPH) level decreased from 5,200 mg/kg to 55 mg/kg. Total organic compounds (TOG) decreased from 12,000 mg/kg to 1,900 mg/kg. In two and a half years, a total of 16.3 ton of contaminant mass was removed. Phase separated hydrocarbon removed 680 kg (4% of the contamination) from monitoring wells. The vapor-extraction system volatalized 354 kg (2%).

20. TRAINING PROGRAM:- None.

21. OTHER INFORMATION:- None.

22. CONCLUSIONS:- Bioremediation removed contaminant. It was shown that nitrate was very effective electron acceptor in the bioremediation of Alkylbenzene compounds in ground water. Nitrate has a relatively high electron - accepting capacity, compared to oxygen and hydrogen peroxide, and tends to be more stable during ground water migration, thereby having a greater potential to affect downgradient plume areas. EPA conducted additional soil sampling and ground water modeling under the Bioremediation Field Initiative Program to further investigative the results of the remedial effort. The site is currently in closure with the Colorado Department of Health.

23. REFERENCES:- C.H. Nelson, (1993), "Civil Engineering", March 1993, pp. 57-59.

24. KEYWORDS:- Clean up, In situ treatment, Bioremediation, Contaminated soil, Groundwater treatment., Petroleum products

25. CONTACT PERSONS:- None.

CASE STUDY [5] . 3/91

1. **TYPE OF PROJECT :-**
 - (a) Treating groundwater.
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Other (not Superfund, DOT, RCRA, DOE or DOD)
2. **LOCATION :-** An IBM facility in San Jose, California.
3. **NATURE OF SOIL:-** Not known.
4. **AREA OF SITE / CONTAMINATED SITE:-** Not available.
5. **DEPTH OF GROUND WATER TABLE / CONTAMINATION:-** Not known.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Details not known.
7. **SITE CHARACTERIZATION:-** Details not available.
8. **MAJOR CONTAMINANTS:-** Low levels of volatile organic compounds.
9. **SOURCE OF CONTAMINANTS:-** The plant was in operation since 1956 and has used trichloroethane (F002) , freon 113, isopropanol, xylene, acetone, petroleum naphthas and other organic chemicals for the manufacturing of computer systems. The contamination was due to chemicals leaking from underground pipings and fittings and from chemical handling spills.
10. **CONCENTRATION OF CONTAMINANTS:-** The levels of volatile organic compounds were less than 1 part per million by volume.
11. **REGULATIONS:-** Not available.
12. **SPECIFICATIONS:-** Not known.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected Dual system of air stripping and steam stripping.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Not available.
16. **DESCRIPTION OF TECHNOLOGY:-** The treatment plant consists primarily of two series air-stripping towers and a steam-stripping tower, an equalization tank, and the control room with associated auxiliary systems. The plant treats nearly 1 million gallons of water per day. The air-stripping system has a capacity if 1,000 gpm (gallons per minute) and the steam-stripping system has a capacity of 40 gpm (gallons per minute). Both systems remove organic compounds from extracted ground water with an effectiveness rate of greater than 99%. Engineers assessed ground water from each of 22 extraction wells and only seven wells contained semivolatiles or nonvolatiles.

The air-stripping system consists of two fiberglass-reinforced plastic towers, each 9.75 m (32 ft.) high and 2.1 m (7 ft.) in diameter. Ground water from 15 boundary wells at the edge of the site is pumped into the air stripper at the rate of up to 1,000 gpm (gallons per minute).

The extracted water is then raised to the top of the 9.75 m (32 ft.) high tower, where it falls downward through a maze of 30,000 plastic packing units. As the water cascades down, a powerful suction fan forces air to ascend the tower at the rate of up to 7,300 cu ft/min. to meet the onrushing flood. the result is a perpetual storm that mixes air and water with a 65:1 ratio, causing the chemicals to volatalize from the water and rise as vapor. Emissions are released to the atmosphere.

The steam-stripping system includes a 5,000 gallon equalization tank, water softener package, heat exchanger, steam re boiler, steam-stripping tower, condenser, accumulator, overhead product tank and related process pumping system. Extracted ground water from seven wells near source areas on site, containing the less volatile chemicals, is pumped to the steam stripper at the rate of up to 40 gpm(gallons per minute). The water is pumped to the top of a 12 m (40 ft.) high stainless steel tower. The tower is packed with thousands of metal rings that, like the plastic snowflakes in the air stripping system, increase the surface area of the water. the temperature of the steam-stripping process is critical and must be kept between 190F and 210F. An overhead condenser condenses and captures the vapor. After the extracted ground water is cleansed, it is collected in two large seismic-braced storage tanks that hold the water for reuse and aquifer recharge. This water is then kept for reuse purpose.

17. **DURATION OF REMEDIATION:-** Not known.
18. **COST OF REMEDIATION:-** The estimated cost of dual system is about \$5.75 million.
19. **RESULTS:-** The treated water can be used for five different reuse options. Currently, the water irrigates 70 acres of commercial orchard and 140 acres of landscape, fills a fire prevention lake and cooling towers, and provides aquifer injection for recharge.
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-**
 - * Aquifer injection is the most reliable means to achieve 100% reuse.
 - * Engineers designed the ground water treatment plant's control system as an integral part of the manufacturing facility's main control system. It can operate the entire treatment system automatically, from the extraction wells to the treatment processes to reuse.
 - * McLaren / Hart received an award for the plant design from HAZMACON 1992 in a nationwide competition.
22. **CONCLUSIONS:-** The project contributes to the social and economic welfare of the area, and ensures that the region will have enough water for the future.
23. **REFERENCES:-** C. D. Ngo, G.M.Carlton, P.J.Mitchell, J. T. Su, (1992), Civil Engineering Magazine, August 1992, pp. 45-47.
24. **KEY WORDS:-** Groundwater, Air stripping, Steam stripping, Petroleum products
25. **CONTACT PERSONS:-** None.

CASE STUDY [6] . 4/91

1. **TYPE OF PROJECT:-**
 - (a) Treating contaminated groundwater.
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) DOD (not Superfund, DOT, RCRA or DOE)
2. **LOCATION:-** At Tinker air force base in Oklahoma city.
3. **NATURE OF SOIL:-** Not known.
4. **AREA OF SITE / CONTAMINATED SITE:-** The area of site is 61.8 acre. The extent of contaminated ground water plume is 220 acres.
5. **DEPTH OF GROUND WATER TABLE / CONTAMINATION:-** The depth of water table is 4.5-9 m (15-30 ft). Contaminants were found in the top of regional aquifer zone at depths 15-25 m (50-80 ft), and in the regional aquifer to depths of about 53 m (175 ft).
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Not known.
7. **SITE CHARACTERIZATION:-** Not known.
8. **MAJOR CONTAMINANTS:-** Hexavalent chromium (Cr. ⁶⁺) and Trichloroethylene (TCE).
9. **SOURCE OF CONTAMINANTS:-** The contamination resulted from industrial activities in the building and the continued servicing, repairing and upgrading military aircraft and their engines. The contaminants entered the ground water under and adjacent to building through :
 - * Leakage from subsurface degreasing pits.
 - * The intentional discharge of solvents and waste waters into unlined concrete trenches and storm drains.
 - * Improper connections between the waste water and storm drains.
 - * Accidental spills.
10. **CONCENTRATION OF CONTAMINANTS:-** Hexavalent chromium (Cr⁶⁺) concentrations ranged from 80,000 µg/L directly beneath the building in the perched aquifer zone to less than 10 µg/L at the plume limits. Trichloroethylene levels ranged from 330,000 µg/L under the building to less than 5µg/L at the plume limits.
11. **REGULATIONS:-** Not available.
12. **SPECIFICATIONS:-** Not known.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology :- None.
 - (b) Selected air or steam stripping of the volatile organic contaminants and precipitation of the chromium. The Air force selected a sodium metabisulfate for more evaluation.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Details not available.

16. DESCRIPTION OF TECHNOLOGY:- Horizontal directional drilling was used. This would result in capital costs several times higher than for conventional wells. The entire length of a well must be double cased to avoid leaking contaminated ground water into uncontaminated or less contaminated strata. The horizontal extraction wells could be installed without disrupting any activities conducted within the building or disturbing the multitude of utilities buried both beneath and adjacent to the building. These horizontal wells would allow a pumping rate several times greater than vertical wells, accelerating the remediation process and potentially reducing its overall cost.

The studies indicated that the aquifer was of relatively low permeability and would yield only 60 gpm total flow over the entire area. The total number of wells required for contaminated plume control was 33. The site, 61 m (200 ft) west of the building was selected as the initial point from where the well has to be excavated. Five horizontal extraction wells were installed; three in the perched zone, one in the top of the regional zone and one in the regional zone. The remaining 28 were standard vertical wells, divided among three zones. The wells were installed between 12.2 m (40 ft) and 46 m (150 ft) below building floor level and extended horizontally nearly 274 m (900 ft). The wells are controlled automatically from the operator's station in the treatment facility.

The ground water treatment system was designed for an average flow rate of 150 gpm and for peak flows of up to 200 gpm. The treatment system consists of a counterflow, packed bed air-stripping tower to remove volatile organic compounds and a sodium bisulfite reduction or precipitation process that removes the chromium. The stripping tower removes nearly 100% of the TCE and other volatile organics from the ground water. Effluent air from the stripper was passed through activated carbon canisters for vapor phase removal of the stripped organics prior to discharge to the atmosphere. Following air stripping, the water is pumped to the facility's metals removal setup. There, the water is mixed with liquid 38% sodium bisulfite, a reductant, and its pH is lowered by the addition of 95% sulfuric acid. These two processes accelerate the reduction of hexavalent chromium to trivalent chromium. Once the reduction action is complete, the pH is elevated in two steps, using first 50% sodium hydroxide and then 10 % sodium hydroxide to achieve the ideal pH, precipitating chromium hydroxide. The chromium hydroxide flocculent settled out in a plate settler and the effluent water from this settler flows via gravity through continuous backwash sand filters to remove any remaining suspended particles.

17. DURATION OF REMEDIATION:- December 1991 to February 1993.

18. COST OF REMEDIATION:- The estimated cost of project was \$13 million.

19. RESULTS:- The quality of effluent discharged from the building ground water treatment facility is superior to current drinking water standards.

20. TRAINING PROGRAM:- None.

21. OTHER INFORMATION:- None.

22. CONCLUSIONS:- This system resulted in a capital cost less than for a vertical drilling system and also this is the more effective way of decontaminating a site. The treated water from this system is returned for use in industrial purposes.

23. REFERENCES:- V. M. Reid, K. W. Wyatt, J. A. Horn, (1994), Civil Engineering Magazine, April 1994, pp. 56-58.

24. KEY WORDS:- Ground water, Horizontal drilling, Chromium. TCE.

25. CONTACT PERSONS:- None.

CASE STUDY [7] . 1/89

1. **TYPE OF PROJECT:-**
 - (a) Treating contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Other (not Superfund, DOT, RCRA, DOE or DOD)
2. **LOCATION:-** An Agricultural land in Southern Ontario.
3. **NATURE OF SOIL:-** The site's stratigraphy is reasonably uniform and comprises up to 2.5m of brown, fine to coarse grained, loose sand above 0.35m to 2.4m of gravel. Underlying the gravel unit is up to 1.3m of gray, loose to compact, saturated silt and about 20m of gray, soft to firm, wet to saturated clay deposited on limestone bedrock.
4. **AREA OF SITE / CONTAMINATED SITE:-** The area of site is 11.5 ha. The area of contamination is 0.7 ha.
5. **DEPTH OF GROUND WATER TABLE / CONTAMINATION:-** The ground water is about 1.2m below the surface.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Not known.
7. **SITE CHARACTERIZATION:-** Not available.
8. **MAJOR CONTAMINANTS:-** Arsenic, cadmium, lead, nickel, zinc, copper, and molybdenum.
9. **SOURCE OF CONTAMINANTS:-** Not known.
10. **CONCENTRATION OF CONTAMINANTS:-** Details not known.
11. **REGULATIONS:-** Not available.
12. **SPECIFICATIONS:-** Not known.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:- Excavation and land filling of the soil.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Not known.
16. **DESCRIPTION OF TECHNOLOGY:-** It was planned to install a dewatering system, outside the clean line, around the area to be excavated to facilitate excavation and to avoid the concentration of heavy metals in the bottom of the excavation due to settling out in the ground water. The pond was pumped out in about 24 hours by submersible electric pumps prior to the installation of the dewatering system. A trench was excavated about 3.5m down to the clay, and the well points were placed in the position and backfilled with the excavated material. The installation took five days to complete.

Excavation of the contaminated material began with the removal of the wet organic sediments and contaminated soils from the bottom of the drained pond. Prior to receiving permission to use the landfill, these materials were stored temporarily on a concrete

composting pad at a transfer station nearby. Accumulated sediment in the sewer was cleaned on a regular basis and added to the contaminated material for land filling. A total of 51 different vehicles was used to haul the excavated material initially to the transfer station and after to the landfill. Excavation of the main pond and ditch area within in the clean line was completed in two 6-day weeks and the whole job in three weeks. A total of 44,610 tons of contaminated soil was shipped out in 1,773 truck loads.

Confirmatory soil testing for the clean line comprised 17 sampling lines at right angles to the main pond and ditch excavation at intervals of 15m. All the samples were analyzed for arsenic, cadmium, copper, molybdenum and zinc. Molybdenum was the only metal that was present in levels above its residential decommissioning guidelines (RDG) of 5 ppm.

17. **DURATION OF REMEDIATION:-** Not known.
18. **COST OF REMEDIATION:-** Not known.
19. **RESULTS:-** The results indicated that some arsenic and molybdenum values in two test pits were above acceptable levels. Further excavation was done and confirmatory testing showed that all contamination above residential decommissioning guidelines (RDG) levels had been removed. Altogether 1,858 tons of soil were removed in 87 truck loads. The backfilling material which was acceptable with respect to the residential decommissioning guidelines (RDG) and also Ontario Regulation 309 leachate analysis. Approximately 43,000 tons of fill were imported, placed and compacted immediately after the excavation work and confirmatory sampling had verified a clean line.
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** None.
22. **CONCLUSIONS:-** The investigation and remediation were successfully completed within the required time frame and the purchase and sale agreement was executed. The construction began shortly thereafter.
23. **REFERENCES:-** "Proceedings, Canadian Geotechnical Conference, 1989", vol. 44, no 2, pp. 84/1-84/13.
24. **KEY WORDS:-** Contamination soil, Metal, Land filling.
25. **CONTACT PERSONS:-** None.

CASE STUDY [8] . 3/93

1. **TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Other (not Superfund, DOT, RCRA, DOE or DOD)
2. **LOCATION:-** The site is located on Piney Hollow Road in Winslow Township, New Jersey.
3. **NATURE OF SOIL:-** Not known.
4. **AREA OF SITE / CONTAMINATED SITE:-** The area of the site is approximately 10 acres.
5. **DEPTH OF GROUND WATER TABLE / CONTAMINATION:-** Not known.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Details to be collected.
7. **SITE CHARACTERIZATION:-** Details not known.
8. **MAJOR CONTAMINANTS:-** Metals like chromium, copper, and nickel and volatile organic compounds.
9. **SOURCE OF CONTAMINANTS:-** Not known.
10. **CONCENTRATION OF CONTAMINANTS:-** Not known.
11. **REGULATIONS:-** Not available.
12. **SPECIFICATIONS:-** Not known.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:- Soil washing was adopted as a remedial technology.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Not known.
16. **DESCRIPTION OF TECHNOLOGY:-** The first step taken in designing the soil washing plant to clean on-site soils was to conduct treatability and bench-scale studies to define the contaminant or particle-size relationship and construct the particle size curve. A demonstration run was then performed which successfully treated the soils and sludges to the cleanup levels specified in the record of decision (ROD).

The plant consists of four major sub-systems.

 - * Screening
 - * Separation
 - * Froth Floatation
 - * Sludge Management.

During March 1993, the remedial action for soils began with the excavation and off-site disposal of lagoon 4. The treatability studies conducted early in 1992 determined that lagoon

4 contained sludge only and was not amenable to on-site treatment. Following delivery and construction of the soil washing plant at the site, a pilot run was conducted on 1,000 tons of contaminated soils excavated from the site. the pilot run was successful, and again cleanup levels well below the record of decision (ROD) - specified standards were met. Full scale soil washing operations began on June 28, 1993 and were completed on October 10, 1993. During the operation of the soil washing facility, the cleaned soils were returned to the site as backfill. The contaminated fraction was disposed at an off-site facility.

17. **DURATION OF REMEDIATION:-** Soil washing operations began on June 28, 1993 and were completed on October 10, 1993.
18. **COST OF REMEDIATION:-** Not known.
19. **RESULTS:-** The entire project treated 19,507 tons with an achieved volume reduction of 83%.
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** This is the first full-scale soil washing remedial action performed in the united states.
22. **CONCLUSIONS:-** The conclusions listed are:-
 - * Treatability studies should focus on the products of the process, specifically the oversize, the sand, and the sludge cake.
 - * The demonstration of a full-scale process capability prior to the site implementation was extremely helpful.
 - * Since there are many definitions of "soil washing", the project team should clearly understand the technology details for implementation on a specific site.
 - * Define the sampling and analysis program before the process is utilized in the field.
23. **REFERENCES:-** "Environmental Progress", Summer, 1996, Vol. 15, No. 2, pp. 108-111.
24. **KEY WORDS:-** Soil washing, Contamianted soil, Metals, VOC.
25. **CONTACT PERSONS:-** None.

CASE STUDY [9] . 1/82

1. **TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Other (not Superfund, DOT, RCRA, DOE or DOD)
2. **LOCATION:-** A road base in Lake Clear, Ontario.
3. **NATURE OF SOIL:-** Not known.
4. **AREA OF SITE/CONTAMINATED SITE:-** The total volume of contaminated material was estimated to be about 6260 cubic meters.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** Not given.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Details to be collected.
7. **SITE CHARACTERIZATION:-** Not known.
8. **MAJOR CONTAMINANTS:-** High PCB Concentrations.
9. **SOURCE OF CONTAMINANTS:-** Not known.
10. **CONCENTRATION OF CONTAMINANTS :-** Relatively high levels, in the range of 50 to 700 $\mu\text{g/g}$, were identified in the upper levels of the granular roadbase. The high PCB concentrations at the surface decreased to about 1 $\mu\text{g/g}$ at a depth of about 0.5 m.
11. **REGULATIONS:-** After the curing period, the samples were submitted to an environmental laboratory for distilled water leach and Ontario Regulation 309 (acid) leachate extraction analysis. PCB concentration in groundwater should be less than Ontario Drinking Water Quality Objective of 3 $\mu\text{g/l}$.
12. **SPECIFICATIONS:-** Not known.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:- Selected solidification and stabilization of the contaminant.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Not known.
16. **DESCRIPTION OF TECHNOLOGY:-** The criteria made for remediation were:
 - * Contaminated soil was to be stabilized into a solid mass having a permeability of less than 1×10^{-7} cm/sec.
 - * Any offsite migration was to be within acceptable limits.
 - * If considered appropriate after technical evaluation, the disposal site was to be on an identified parcel of crown land about 600m from the lake.

The objectives of the remediation were to encapsulate the PCB contaminated soil into a monolithic, durable mass to prevent the loss of free particles and to reduce the permeability of the mass to less than 1×10^{-7} cm/sec. On the basis of laboratory tests conducted on type 10 portland cement, bentonite, cement-bentonite, it was concluded that satisfactory stabilization and solidification was achieved by using Type 1 Portland cement. The sub excavation of the contaminated soils and road reconstruction were completed under one contract, and the mixing and disposal of the contaminated material were conducted under a separate contract.

Contaminated soil was mixed with the stabilizing agents in advance using a central plant, then the mixture was transported, placed, and compacted at the disposal sites using conventional soil-cement procedures. Before the contaminated soil was processed in the plant, any oversized rocks and boulders were removed by screening. Contaminated materials and the stabilization and solidification mixture were monitored continuously measuring moisture content, Compressive strength development and field compaction.

17. DURATION OF REMEDIATION:- Not known.

18. COST OF REMEDIATION:- The cost of remediation was about \$850,000.

19. RESULTS:- The final volume of the stabilized and solidified monofill was measured to be 8100 cubic meter, with the increase in volume of 1840 cubic meter attributed to the stabilizing agents and some native material picked up when cleaning up the work area. The average PCB concentration of the contaminated soil after screening was about 21.5 $\mu\text{g/g}$.

20. TRAINING PROGRAM:- None.

21. OTHER INFORMATION:- None.

22. CONCLUSIONS:- The concentration of PCB in the groundwater beneath the monofill was between 0.01 and 0.05 $\mu\text{g/l}$, which is well below the Ontario drinking water objective. The Ontario Ministry of the Environment considered the remediation an acceptable solution to treat the PCB residues in Lake Clear.

23. REFERENCES:- M.Mackay, J.Emery, "Transportation Research Record", No. 1458, pp. 67-69.

24. KEY WORDS:- Contaminated soil, Solidification and Stabilization, PCB.

25. CONTACT PERSONS:- None.

CASE STUDY [10] . 1/94

1. **TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Other (not Superfund, DOT, RCRA, DOE or DOD)
2. **LOCATION :-** Petroleum storage tank in Southern California.
3. **NATURE OF SOIL:-** The aggregate was founded on 1.5 m (5 ft.) of compacted soil, which consisted of silty sand, clayey sand, silt, clay, peat and lenses of sand. Permeability of the soil composite was very low.
4. **AREA OF SITE / CONTAMINATED SITE:-** The contamination contained 151,400 lb. (40,000 gallons) of #6 fuel oil which had leaked into the soil beneath the tank.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** The depth of ground water was 4.5 m (15 ft) below the tank bottom. The contamination extended to an average depth of 1 m (3 ft), and as much as 2.4 m (8 ft) at several locations, and had migrated to 1.5 m (5 ft) beyond the tank perimeter.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Laboratory analysis was performed to show that the concentrations of metals, limits of volatile organic compounds and toxicity were within Environmental Protection Agency (EPA) guidelines for non hazardous material, and that the oil met California used oil requirements.
7. **SITE CHARACTERIZATION:-** The field exploration at oil tank 3 included 15 exploratory borings, 3 shallow trenches, and soil sampling which showed the following:
 - * The tank was founded on 12 inches of 3/4 inch, crushed aggregate,
 - * The aggregate was founded on 1.5 m (5 ft) of compacted soil, which consisted of silty sand, clayey sand, silt, clay, peat and lenses of sand,
 - * Permeability of the soil composite was very low,
 - * Oil had saturated the aggregate and soil beneath the tank to an average depth of 0.91 m (3 ft) for a distance of 1.5 m (5 ft) beyond the perimeter of the tank.
8. **MAJOR CONTAMINANTS:-** #6 fuel oil.
9. **SOURCE OF CONTAMINANTS:-** An oil spill or leak from one of the tanks which were used to store fuel oil reserves for emergency steam generation.
10. **CONCENTRATION OF CONTAMINANTS :-** 1,51,400 lb. (40,000 gallons) of the #6 fuel oil.
11. **REGULATIONS:-** Details to be collected.
12. **SPECIFICATIONS:-** Not available.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:- Excavation and replacing of the contaminated soil .
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Details not available.

- 16. DESCRIPTION OF TECHNOLOGY:-** The goal of their remediation was to
- * To reclaim the excess oil from the aggregate,
 - * To support the slab on concrete foundation to allow excavation and replacement of the contaminated soil,
 - * To process the contaminated aggregate into a cold mix asphalt concrete for paving the tank basin,
 - * To thermally treat the contaminated soil for use as engineered fill.

They made an attempt to drain the excess oil from the aggregate, but the weather conditions made it impossible to steam clean the aggregate with 300°F steam. It took 4 hours to clean 0.765 cubic meters (1 cubic yard). The deeper excavations were backfilled immediately with a sand cement slurry. The excavation was backfilled to grade with clean imported sandy soil from outside the tank as soon as concrete attained sufficient strength and completed before starting the interior excavation. The soil was tested for petroleum hydrocarbons and, as necessary, the excavation continued until all the contaminated soil was removed. The thermal treatment plant used was a mobile processing unit with a capacity of 50 tons of soil per hour. The operation consisted of transporting the soil through a low temperature furnace set at to vaporize the oil and moisture. Then the vapors were passed through a baghouse to collect dust particles and finally through a secondary furnace set at 1400°F to destroy the hydrocarbons. The treated soil was placed in 10 tons piles and tested for total petroleum hydrocarbons.

- 17. DURATION OF REMEDIATION:-** Not available.
- 18. COST OF REMEDIATION:-** It cost \$25,000 to evaluate the site, write the specifications and prepare drawings. The actual cost for the remediation was \$1,270,000.
- 19. RESULTS:-** While performing the remediation they encountered four problem areas.
- 20. TRAINING PROGRAM:-** None.
- 21. OTHER INFORMATION:-** The lessons learned from each of the problem were:
- * There was sudden rain and because of that, the schedule during the efforts to reclaim the oil was difficult. From this they learned that oil should be collected as soon after discovery as possible, and the work schedule must consider weather conditions.
 - * During grading of the tank basins, the cathodic protection cables were damaged. From this they could learn that Cathodic protection replacement should be included in the initial scope of work.
 - * Problems with the cold mix asphalt concrete were in obtaining uniform mixing, uniform placement depth and keeping the subgrade soil out of the mix. From this they learned to expect some subgrade soils to be mixed with the aggregate.
- 22. CONCLUSIONS:-** The resulting 2,000 tons of contaminated aggregate was recycled to make asphalt concrete for paving the tank basin and the remaining 5,600 tons of oily soil was thermally treated on site for use as engineered fill at another location. This successful operation provided an economical clean-up solution and eliminated the long term liability of landfill disposal.
- 23. REFERENCES:-** "G. Wallace, Proceedings, American Power Conference", 1994, Call no. TD5.A55, Vol. 56, No.1 1994.
- 24. KEY WORDS:-** Contaminated soil, Fuel oil, Asphalt, Recycling.
- 25. CONTACT PERSONS:-** None.

CASE STUDY [11] . 1/88

1. **TYPE OF PROJECT:-**
 - (a) Treating contaminated soil and groundwater.
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Superfund
2. **LOCATION :-** At Verona well field Superfund site, Michigan.
3. **NATURE OF SOIL:-** The subsurface comprised of clayey soil.
4. **AREA OF SITE / CONTAMINATED SITE:-** Not known.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** Information not available.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Details to be collected.
7. **SITE CHARACTERIZATION:-** The soil has a clay content less than 5%, moisture content 5% and permeability of 10^{-3} cm/sec.
8. **MAJOR CONTAMINANTS:-** Chlorinated and Non chlorinated aliphatics.
9. **SOURCE OF CONTAMINANTS:-** Solvent storage, blending, repackaging, distribution, and disposal.
10. **CONCENTRATION OF CONTAMINANTS :-** The volume of organic compounds has been estimated to be 3,900 lb. in groundwater and 1,700 lb. in soil.
11. **REGULATIONS:-** The regulatory requirements are as per 1991 Record of Decision (ROD) for 19 constituents. The standards in soil ranged from 0.014 mg/kg for carbon tetrachloride and tetrachloro ethane to 16 mg/kg for toluene. The standards in groundwater ranged from 0.001 mg/l for vinyl chloride and benzene to 0.8 mg/kg for toluene.
12. **SPECIFICATIONS:-** Not known.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:- Selected Soil vapor extraction.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Details to be collected.
16. **DESCRIPTION OF TECHNOLOGY:-** The full scale operation of an Soil vapor extraction system to treat the soil began in March 1988 and ran intermittently until May 1992. Over the course of soil vapor extraction operation, both carbon adsorption and catalytic oxidation were utilized to treat the extracted vapors prior to atmospheric discharge. Dual vacuum extraction and nitrogen sparging were implemented to enhance recovery rates during the latter stages of the groundwater remediation effort. A total of 45,000 pounds of volatile organic compounds were removed from the subsurface soil, and 10,000 pounds from the groundwater, during the remediation. Clean-up verification sampling of the soil occurred in June 1992 and the analytical results indicated that soil vapor extraction reduced the constituent concentrations in the soil at this operable unit.

17. **DURATION OF REMEDIATION:-** The period of operation for the technology was from March 1988 to May 1992.
18. **COST OF REMEDIATION:-** The cost attributed to treatment activities for this soil vapor extraction application was approximately \$1, 600,000.
19. **RESULTS:-** The constituent-specific soil cleanup standards established in 1991 Record of Decision (ROD) were met.
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** None.
22. **CONCLUSIONS:-** Catalytic oxidation was identified as preferable for treatment of extracted vapors instead of carbon adsorption for the period of the application where the contaminant mass removed by soil vapor extraction was much greater than 10 to 20 lb/day.
23. **REFERENCES:-** Abstracts of remediation case studies by EPA, EPA-542-R-95-001, March 1995, pp. 80-81.
24. **KEY WORDS:-** Contaminated soil and groundwater, Soil vapor extraction, Chlorinated aliphatics, Volatile organic Compounds.
25. **CONTACT PERSONS:-** Margaret Guerriere, U.S.EPA Region 5, 77 W. Jackson Boulevard, Chicago, IL 60604, Ph: (312) 886-0399.

CASE STUDY [12] .1/90

1. TYPE OF PROJECT:-

- (a) Treating saturated contaminated soil .
- (b) Site clean-up (HWMP - PHASE IV).
- (c) Other (not Superfund, DOT, RCRA, DOE or DOD)

2. LOCATION :- At a large diesel spill site located at a major railroad facility in Nebraska.

3. NATURE OF SOIL:- The soil consists of fine to medium grained, silty sands.

4. AREA OF SITE / CONTAMINATED SITE:- The estimated area of contamination was 11,500 cubic meters.

5. DEPTH OF GROUND WATER / CONTAMINATION:- The contamination extended to a depth of 20m. Groundwater was observed at depths ranging from 20 to 21 meters below the surface.

6. ENVIRONMENTAL SITE ASSESSMENT:- Soils were analyzed using EPA method 418.1 for total recoverable petroleum hydrocarbons. These concentrations are plotted on the geologic section. Based on initial soil analysis, and observations made during drilling, it appears that diesel fuel migrated rapidly downward at the spill site until it encountered the interbedded sand and silt/clay zone at approximately 9.1 to 10.7 meters. At this depth the fuel spread laterally and continued its downward movement through more permeable sand lenses in the interbedded layer.

7. SITE CHARACTERIZATION:- The results of site characterization were:

- * The soil consists of fine to medium grained, silty sands from the ground surface to approximately 9.1 to 10.7 meters below ground surface (upper sand zone), interbedded sand and silt / clay lenses that extend 10.7 to 15.2 meters below ground surface (interbedded zone), and another layer of fine to medium grained silty sand that extends to a depth of 21.3 to 22.9 meters (intermediate sand zone).
- * Soil moisture varied from 2 percent in the intermediate sand to 11 percent in the interbedded silts and clays.

8. MAJOR CONTAMINANTS:- BTEX (Benzene, toluene, ethyl benzene and xylene), #2 diesel oil and total petroleum hydrocarbons.

9. SOURCE OF CONTAMINANTS:- Fuel spilling from a pump house due to a ruptured pipe.

10. CONCENTRATION OF CONTAMINANTS :- Benzene and total petroleum hydrocarbon concentrations exceeded their respective cleanup goals of 5 micrograms per liter (mg/l) and 2 micrograms per liter (mg/l), respectively.

11. REGULATIONS:- BTEX (Benzene, toluene, ethyl benzene and xylene) compounds have been detected in the ground water. However only benzene and total petroleum hydrocarbon concentrations exceeded their respective cleanup goals of 5 micrograms per liter (mg/l) and 2 micrograms per liter (mg/l), respectively.

12. SPECIFICATIONS:- Not known.

13. TREATMENT TECHNOLOGY:-

- (a) Screening technology:- None.
- (b) Selected technology:- Selected in situ bioventing.

14. CONTAINMENT TECHNOLOGY:- None.

15. RISK ASSESSMENT:- Not known.

16. DESCRIPTION OF TECHNOLOGY:- Bioventing incorporates soil vapor extraction or air injection with the objective of supplying oxygen to subsurface bacteria to enhance fuel biodegradation. Soil bacteria also require a variety of nutrients to sustain hydrocarbon degradation. These nutrients include nitrogen, phosphorus, sulfur and metals such as calcium and iron.

Based on the air permeability and oxygen influence, an extraction rate of 2.8 standard cubic meters per minute ($m^3/min.$) was selected for bioventing operations. A 7-hp regenerative blower was required to produce this flow rate. Extraction from the central vent well was selected over air injection because of the immediate need to remove volatile and soluble BTEX compounds from the soil. The bioventing system has operated continuously for over two years with minimum maintenance downtime. At 6-month intervals, an engineer or a technician has inspected the system and performed an in situ respiration test to estimate the level of fuel biodegradation occurring near each vapor monitoring point (VMP). A sample of the soil gas extracted at the vapor extraction well is also sent to a certified laboratory for BTEX analysis.

17. DURATION OF REMEDIATION:- The bioventing system has operated continuously for over two years with minimum maintenance downtime.

18. COST OF REMEDIATION:- The total cost to date of bioventing at this site has been less than \$10 per cubic meter.

19. RESULTS:- The results of respiration tests indicate that in soils with low initial total recoverable petroleum hydrocarbon (TRPH) levels, the apparent rate of oxygen utilization has significantly decrease over the time. The soil sampling at vapor monitoring point 3 (VMP3) confirmed that total recoverable petroleum hydrocarbon (TRPH) levels have been reduced from 194 mg/kg to less than 6 mg/kg.

20. TRAINING PROGRAM:- None.

21. OTHER INFORMATION:- None.

22. CONCLUSIONS:- The bioventing at this diesel spill site has produced encouraging results during the first two years of operation. Remediation is taking place throughout a 20m soil profile with no disruption to railroad activities. To date 90% of the removal can be attributed to insitu biodegradation, while volatilization accounts for less than 10% of the total hydrocarbon removal.

23. REFERENCES:- P. R.. Guest, J.W. Ratz, "Environmental Progress", May, 1995 vol. 14, No. 2, pp. 121-125.

24. KEY WORDS:- Contaminated soil, Bioventing, Biodegradation, #2 fuel oil.

25. CONTACT PERSONS:- None.

CASE STUDY [13] . 1/92

1. **TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Other (not Superfund, DOT, RCRA, DOE or DOD)
2. **LOCATION :-** SMS Instruments Superfund site in Deer Park, New York.
3. **NATURE OF SOIL:-** The subsurface soil consisted of well-sorted sands to silty sands with fine gravel, the permeability being 0.00227 to 0.00333 cm/sec.
4. **AREA OF SITE / CONTAMINATED SITE:-** Not known.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** Not known.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Details to be collected.
7. **SITE CHARACTERIZATION:-** Not known.
8. **MAJOR CONTAMINANTS:-** Chlorinated and Non-Chlorinated Aliphatics and Semivolatile Organic Compounds.
9. **SOURCE OF CONTAMINANTS:-** Leakage from the Underground storage tank.
10. **CONCENTRATION OF CONTAMINANTS :-** Concentration of specific volatiles ranged as high as 1,200 mg/kg and the concentration of specific semivolatiles ranged as high as 1,800 g/kg.
11. **REGULATIONS:-** Soil cleanup levels established for 9 volatiles and 9 semivolatiles ranged from 0.5 to 5.5 mg/kg.
12. **SPECIFICATIONS:-** Not known.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:- Selected Soil Vapor Extraction system that used horizontal vapor extraction wells and a process control system.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Not known.
16. **DESCRIPTION OF TECHNOLOGY:-** The soil vapor extraction system included two horizontal vapor extraction wells installed in trenches adjacent to the contaminated areas, a catalytic oxidizer, and acid gas scrubber. The treatment unit included two horizontal vapor extraction wells. They were installed in trenches 4.6 m deep, 0.6 m wide, and 23 m long. The extracted vapors were treated using catalytic incineration and scrubbing. A process control system which allowed for remote system monitoring and oversight was used. Based on the results of soil boring data, Soil vapor extraction achieved the cleanup levels and standards for 17 of the 18 specified organic constituents.

17. **DURATION OF REMEDIATION:-** The operation began in May 1992 and was completed in October 1993.
18. **COST OF REMEDIATION:-** The total treatment cost for this application was \$450,420.
19. **RESULTS:-** Soil clean-up was achieved within approximately 400 days after system operation began. 956 cubic meters (1,250 cubic yards) of soil was treated in this application. The treatment method achieved the cleanup levels and standards for 17 of the 18 specified organic constituents. For one constituent, Concentrations were above the specified cleanup levels. According to the EPA, this result may be an anomaly since its concentration in the treated soil was greater than the concentrations identified during the remedial investigation at the site. In addition, the state ambient air guidelines were met during the operation of this system.
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** None.
22. **CONCLUSIONS:-** The treatment indicated that the costs associated with the instrumentation were greater than anticipated and that there was a problem with corrosion of ductwork. The vendor suggested several ideas for reducing the costs of future similar applications including ways to reduce air monitoring costs.
23. **REFERENCES:-** Abstracts of remediation case studies by EPA, EPA-542-R-95-001, March 1995, pp. 78-79.
24. **KEY WORDS:-** Contaminated soil, Soil vapor extraction, Chlorinated compounds.
25. **CONTACT PERSONS:-** Abram Miko Fayon, Remedial project Manager.

CASE STUDY [14] . 2/92

1. **TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Other (not Superfund, DOT, RCRA, DOE or DOD)
2. **LOCATION:-** At Commencement Bay in Tacoma in Washington.
3. **NATURE OF SOIL:-** Upper aquifer consisted of unconfined sand and gravel. Surface soil permeability ranged from 2.8 to 3.6×10^{-3} cm/sec.
4. **AREA OF SITE / CONTAMINATED SITE:-** The volume of the contaminated soil was reported as 75,000 cubic meters (98,203 cubic yards).
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** Depth of contamination was extended up to 12 m (40 ft).
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Details not known.
7. **SITE CHARACTERIZATION:-** Upper aquifer which extended for 15 m (50 ft.) thickness consists of unconfined sand and gravel. Separate liquid phases of volatile organic compounds in soil and ground water were suspected. Also Tar like compounds were also suspected in the soil.
8. **MAJOR CONTAMINANTS:-** Chlorinated aliphatics which includes dichloroethane(DCE), PCA, PCE, TCE.
9. **SOURCE OF CONTAMINANTS:-** The main source is storage drums. Also there was some contamination due to pour off from processing tanks.
10. **CONCENTRATION OF CONTAMINANTS :-** Average volatile organic compound concentrations in top 7.5 m (25 ft.) of soil ranged from 10 to 100 mg/kg. The average PCA concentrations in soil borings ranged from 6,200 at 9 m (30 ft.) depth to over 19,000 mg/kg at 12 m (40 ft.) depth. Approximately 260,000 kg (571,000 lb.) of volatile organic compounds present in unsaturated zone.
11. **REGULATIONS:-** There are no specific cleanup goals identified in Record of Decision. Local permission was required for air emissions. The objective for the treatment system was set at 99% removal.
12. **SPECIFICATIONS:-** Air discharge limits are specified as
 - * PCA 0.07 kg/hr (0.149 lbs/hr)
 - * PCE 0.04 kg/hr (0.095 lb./hr)
 - * TCE 0.16 kg/hr (0.344 lb./hr).
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:- Selected Soil vapor extraction.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Not known.

- 16. DESCRIPTION OF TECHNOLOGY:-** A full scale soil vapor extraction was constructed in 1992. This treatment was selected because of the relatively large volume of the contaminated soil to be treated and also because of the possible presence of separate liquid phases of volatile organic compounds and tar like compounds in soil. The soil vapor extraction system included 22 wells used for vapor extraction, air inlet, and observation. Granular activated carbon (GAC) was used to treat extracted vapors, was regenerated on site using low pressure steam, which was subsequently condensed. The on-site solvent recovery system was used to separate volatile organic compounds from condensate. The design flow rate for the extraction system was at 84 cubic meters per minute (3,000 standard cubic feet per minute (scfm)).
- 17. DURATION OF REMEDIATION:-** The treatment is still ongoing by the time the report is made and the report covers the duration between august 1992 to February 1994.
- 18. COST OF REMEDIATION:-** The total capital cost for the treatment was estimated to be \$5,313,973.
- 19. RESULTS:-** Computer modeling results showed predicted removal rates for VOCs as a function of time. No results were provided for air emissions, treatment system removals or mass discharge rates. Problems were experienced with the operation of the solvent recovery system. The condensed mixed solvents formed an emulsion which did not separate readily from the water.
- 20. TRAINING PROGRAM:-** None.
- 21. OTHER INFORMATION:-** None.
- 22. CONCLUSIONS:-** While no performance data were available at that time, it was noted that soil vapor extraction system seems to be performing
- 23. REFERENCES:-** Abstracts of remediation case studies by EPA, EPA-542-R-95-001, March 1995, pp. 62-63.
- 24. KEY WORDS:-** Contaminated soil, Soil vapor extraction, Chlorinated Aliphatics.
- 25. CONTACT PERSONS:-** Phil Stoa, Remedial Project Manager, U.S.Army corps of Engineers, Seattle district.

CASE STUDY [15] . 2/89

1. **TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Superfund
2. **LOCATION :-** At Fairchild semiconductor corporation superfund site in SanJose, California.
3. **NATURE OF SOIL:-** The subsurface was comprised of sands, silts and clays, the air permeability being 0.12-0.83 cm/sec and the transmissivity being 69,000 to 810,000 gpd/ft.
4. **AREA OF SITE / CONTAMINATED SITE:-** The volume of contaminated site was 32,000 cubic meters (42,000 cubic yards).
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** Not known.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Not known.
7. **SITE CHARACTERIZATION:-** The subsurface was comprised of sands, silts and clays. Since the site comprised of a complex hydrogeology, the soil vapor extraction was selected as a treatment technology.
8. **MAJOR CONTAMINANTS:-** Chlorinated and Non-Chlorinated Aliphatics.
9. **SOURCE OF CONTAMINANTS:-** Leaking from the underground storage tank which was used to store organic solvents.
10. **CONCENTRATION OF CONTAMINANTS :-** The maximum concentration of the total solvents in soil was 4,500 mg/kg. Trichloroethane measured as high as 3,530 mg/kg in soil whereas xylenes measured as high as 141 mg/kg in soil.
11. **REGULATIONS:-** The regulatory requirement was to continue the operation of soil vapor system until total chemical removal rate was less than 4.5 kg/day (10 lb./day) and the chemical removal rate from individual wells decreased to 10% or less of the initial removal rate or the chemical removal rate declined at a rate of less than 1% per day for 10 consecutive days.
12. **SPECIFICATIONS:-** None available.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:-Selected a full scale cleanup by Soil vapor extraction.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Details not available.
16. **DESCRIPTION OF TECHNOLOGY:-** The soil vapor extraction system consisted of 39 extraction wells, two vacuum pumps of capacity 126 cubic meters per minute (4,500 cubic feet per minute) at 0.5 m (20 inches) of mercury. The system operated from January 1989 to April 1990. The vapor treatment system used was dehumidification unit and vapor phase

granular activated carbon. The most rapid reductions in contaminant concentrations occurred during the first two months of operation. After 8 months of operation, the Soil vapor extraction system achieved the cleanup goal of less than 4.5 kg/day (10 lb./day) for total chemical removed. After 16 months of operation, the system achieved a chemical removal rate of less than 1.8 kg/day (4 lb./day), at which time the system was shut off.

17. **DURATION OF REMEDIATION:-** The duration of the remediation was from January 1989 to April 1990.
18. **COST OF REMEDIATION:-** The actual capital costs for the soil vapor extraction treatment system were \$2,100,000 including installation of wells and vapor extraction system, and engineering services. The total operation and maintenance costs for 16 months was \$1,800,000.
19. **RESULTS:-** The soil vapor extraction treatment system achieved the clean-up goal for the 4.5 kg/day (10 lb./day) total chemical removal rate in 8 months. After 16 months of operation, the removal rate for total chemicals was less than 1.8 kg/day (4 lb./day).
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** None.
22. **CONCLUSIONS:-** The annual costs were about 7% less than the projected costs because the time required for clean-up was less than originally estimated. This treatment application was part of a multi-faceted cleanup program which included the installation of a slurry wall and dewatering of the aquifer which accelerated contaminant removal from the soil costs .
23. **REFERENCES:-** Abstracts of remediation case studies by EPA, EPA-542-R-95-001, March 1995, pp. 64-65.
24. **KEY WORDS:-** Contaminated soil, Soil vapor extraction, Chlorinated aliphatics.
25. **CONTACT PERSONS:-** Belinda Wei, U.S. EPA Region 9, 75 Hawthorne Street, San Francisco, CA 94105, Ph. (415) 744-2280.

CASE STUDY [16] . 3/92

1. **TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Other (not Superfund, DOT, RCRA, DOE or DOD)
2. **LOCATION :-** Lowry Air Force Base in Denver, Colorado.
3. **NATURE OF SOIL:-** The sub surface comprised of firm sandy clay and medium to coarse grained sand.
4. **AREA OF SITE / CONTAMINATED SITE:-** Volume of contaminated soil was 4130 cubic meters (5400 cubic yards).
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** Not known.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Details to be collected.
7. **SITE CHARACTERIZATION:-** The sub surface comprised of firm sandy clay and medium to coarse grained sand. The soil moisture content ranged from 6% to 11%.
8. **MAJOR CONTAMINANTS:-** Benzene, toluene, ethyl benzene and xylene (BTEX) and Total Petroleum Hydrocarbons (TPH).
9. **SOURCE OF CONTAMINANTS:-** A leak from the underground storage tanks.
10. **CONCENTRATION OF CONTAMINANTS:-** The BTEX concentration is less than 100 mg/kg. The total recoverable petroleum hydrocarbons were upto 11000 mg/kg. The average being 3100 mg/kg.
11. **REGULATIONS:-** For the treated soils TPH should be less than 500 mg/kg, TRPH should be less than 500 mg/kg and BTEX should be less than 100 mg/kg. The clean up was conducted under EPA and State of Colorado Underground Storage Tanks Regulations and the Colorado Department of Health's Remedial Action Category III (RAC III) action levels.
12. **SPECIFICATIONS:-** Not known.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None
 - (b) Selected technology:- Selected Bio-remediation.
14. **CONTAINMENT TECHNOLOGY:-** None
15. **RISK ASSESSMENT:-** Not known.
16. **DESCRIPTION OF TECHNOLOGY:-** The underground storage tanks in the area were removed and the contaminated soil was excavated. Land treatment was selected for the excavated soil and treatment of about 4130 cubic meters began in July 1992. For this land treatment application, nutrients (Ammonium Nitrate) were added in a one time application, the soils tilled twice a month and soil moisture content is kept between 10 to 15 % by weight. The treatment had not been completed as of September 1993. The levels of total

extractable Petroleum Hydrocarbons sampled as of 1993 showed levels in the range of 1300 to 1700 mg/kg. These results indicated that the land treatment will be effective.

17. **DURATION OF REMEDIATION:-** The treatment is still ongoing by the time the report is made and the report covers the duration from July 1992 to September 1993.
18. **COST OF REMEDIATION:-** The total capital cost for the project was estimated to be \$104257 and the estimated annual operation costs were \$18460 per year.
19. **RESULTS:-** The land treatment project was not complete at the time of this report and no TRPH, BTEX and TPH data are available at this time. The total extractable petroleum hydrocarbons levels as of September 1993 ranged from 1300 to 1700 mg/kg.
20. **TRAINING PROGRAM:-** None
21. **OTHER INFORMATION:-** None
22. **CONCLUSIONS:-** The available information to date indicates that the credibility of the land treatment soil assessment would have been improved if an adequate, random sampling program had been used for sample collection.
23. **REFERENCES:-** Abstracts of remediation case studies by EPA, EPA-542-R-95-001, March 1995, PP 30-31.
24. **KEY WORDS:-** Contaminated soil, Bioremediation, Land treatment, Petroleum products.
25. **CONTACT PERSONS:-** Lt. Tom Williams, 3415 CES/DEV, Lowry AFB, CO 80230.

CASE STUDY [17] . 3/89

1. **TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Superfund
2. **LOCATION :-** Scott Lumber Company Superfund Site in Alton, Missouri.
3. **NATURE OF SOIL:-** The soil was classified as sand as per USBA system.
4. **AREA OF SITE / CONTAMINATED SITE:-** 15961 tons of soil needed treatment.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** Not known.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Details to be collected.
7. **SITE CHARACTERIZATION:-** Approximately 4% of soil passed the #200 sieve. The soil was classified as sand as per USDA system.
8. **MAJOR CONTAMINANTS:-** Poly Nuclear Aromatic Hydrocarbons.
9. **SOURCE OF CONTAMINANTS:-** Surface Impoundment and spill.
10. **CONCENTRATION OF CONTAMINANTS :-** PAH concentrations were measured as high as 0.326 mg/kg in lagoon water, 12400 mg/kg in sludge, and 63000 mg/kg in soils. Benzo(a)pyrene ranged from 16 to 23 mg/kg at initiation of treatment.
11. **REGULATIONS:-** The action levels in soils were established for total PAH at 500 mg/kg. and for benzopyrene at 14 mg/kg. Total PAH was defined as the sum of 16 specific PAH constituents.
12. **SPECIFICATIONS:-** None
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None
 - (b) Selected technology:- Land treatment by bioremediation.
14. **CONTAINMENT TECHNOLOGY:-** None
15. **RISK ASSESSMENT:-** Details to be collected.
16. **DESCRIPTION OF TECHNOLOGY:-** An Action Memorandum was signed in July 1987 which specified the construction and operation of a land treatment unit (LTU) as a removal action for treatment of PAH - contaminated soils at the site. Cleanup activities were performed in three phases. The first two phases involved decontamination and removing of surface debris and sludge at the site of excavation and stockpiling of contaminated soil at the site. Phase III involved on site land treatment of contaminated stockpiled soil.

Land treatment was performed from December 1989 through September 1991, and 15961 tons of soil were treated during this application. Stockpiled soil was placed in the LTU in two lifts. Approximately 91 kg per acre of ammonium phosphate fertilizer were added to the first lift to adjust the nutrients in the soil. No nutrient adjustments were made to

the second lift. Each lift was cultivated once or twice a week and irrigated, as necessary, to maintain a moisture content between 1% and 4%.

17. **DURATION OF REMEDIATION:-** The treatment started in December 1989 to September 1991.
18. **COST OF REMEDIATION:-** The total costs for removal action was estimated to be approximately \$4,047,000.
19. **RESULTS:-** Land treatment achieved specified action levels.
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** None.
22. **CONCLUSIONS:-** Land treatment at the site reduced levels of Benzoapyrene(BAP) and total polynuclear aromatic hydrocarbons(PAHs) to below action levels. In lift 1, Benzoapyrene(BAP) concentrations were reduced from 16 mg/kg to 8 mg/kg and total polynuclear aromatic hydrocarbon (PAH) concentrations were reduced from 560 mg/kg to 130 mg/kg within 6 months. In lift 2, concentrations were reduced from 23 mg/kg to 10 mg/kg for Benzoapyrene(BAP) and from 700 mg/kg to 155 mg/kg for total polynuclear aromatic hydrocarbons (PAHs) within 3 months.
23. **REFERENCES:-** Abstracts of remediation case studies by EPA, EPA-542-R-95-001, March 1995, pp. 32-33.
24. **KEY WORDS:-** Contaminated soil, Bioremediation, Polynuclear aromatic hydrocarbons, Benzoapyrene.
25. **CONTACT PERSONS:-** Bruce A. Morrison, Remedial Project Manager, U.S. EPA Region 7, Emergency Planning and Response Branch, 25 Funston Road, Kansas city, KS 66115, Ph. (913) 551-7755.

CASE STUDY [19] . 4/92

1. **TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Superfund
2. **LOCATION :-** At the Anderson Development company Superfund Site in Adrian, Michigan.
3. **NATURE OF SOIL:-** Not known.
4. **AREA OF SITE / CONTAMINATED SITE:-** 5,100 tons of soil needed treatment.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** Not known.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Details to be collected.
7. **SITE CHARACTERIZATION:-**The soil sludge was reported to be 65-70% before dewatering and 41-44% after dewatering. The pH of the soil was 7 before dewatering and 10.9-11.2 after dewatering.
8. **MAJOR CONTAMINANTS:-** Chlorinated Aliphatics, Polynuclear Aromatic Hydrocarbons, Other organics and Metals.
9. **SOURCE OF CONTAMINANTS:-** The site was formerly used for the manufacture of 4,4-methylene bis(2-chloroaniline), a hardening agent used in plastics manufacturing. Process waste waters were discharged to an unlined lagoon.
10. **CONCENTRATION OF CONTAMINANTS :-** The concentration of the primary contaminant 4,4-methylene bis(2-chloroaniline) in untreated soil was above the regulatory limits and the level of concentration of Manganese was up to 10%.
11. **REGULATIONS:-** The regulations for 4,4-methylene bis(2-chloroaniline) in the soil was 1.684 mg/kg.
12. **SPECIFICATIONS:-** Not known.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:- Selected Thermal desorption.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Not known.
16. **DESCRIPTION OF TECHNOLOGY:-** A remedial investigation determined that soil and sludges in and around the lagoon were contaminated. Contaminated soils and sludges were excavated, dewatered, and stockpiled. A Record of Decision (ROD), signed in September 1991, specified thermal desorption as the remedial technology for the excavated soil. Soil cleanup goals were established for the contaminants. Thermal desorption was performed from January 1992 to June 1993. The thermal processor consisted of two jacketed troughs. The solids were pretreated by shredding, screening, and dewatering. Hollow screw

conveyors move soil across the troughs, and act to mix and heat the contaminated soil. The soil residence time was 90 minutes and the temperature of the sludge or soil was 500-530°F. The treated soil was discharged into a conditioner, where it was sprayed with water. Thermal desorption achieved the soil cleanup goals specified for the contaminants.

17. **DURATION OF REMEDIATION:-** The treatment was started in January 1992 and continued till June 1993.
18. **COST OF REMEDIATION:-** Information not available.
19. **RESULTS:-** Analytical data for 6 piles of treated soil indicated that the cleanup goals for 4,4-methylene bis(2-chloroaniline) and volatile organic compounds were met. Seven of eight semivolatile organic constituents met cleanup goals. Analytical problems were identified for bis(2-ethylhexyl)phthalate. The treated soil was disposed off site due to elevated manganese levels.
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** None.
22. **CONCLUSIONS:-** Information on costs were not available at the time of report. the treated soils were to be used as backfill for the lagoon. However, the state required off-site disposal of treated soils due to the presence of elevated levels of manganese.
23. **REFERENCES:-** Abstracts of remediation case studies by EPA, EPA-542-R-95-001, March 1995, pp. 84-85.
24. **KEY WORDS:-** Contaminated soil, Thermal desorption, Chlorinated aliphatics.
25. **CONTACT PERSONS:-** Jim Hahnenburg, Remedial Project Manager, U.S. EPA Region 5, 77 West Jackson Boulevard, Chicago, IL 60604, Ph. (312) 353-4213.

CASE STUDY [20] . 4/93

1. TYPE OF PROJECT:-

- (a) Treating saturated contaminated soil .
- (b) Site clean-up (HWMP - PHASE IV).
- (c) Superfund

2. LOCATION :- At King Of Prussia Technical Corporation Superfund Site in Winslow Township, New Jersey.

3. NATURE OF SOIL:- Not known.

4. AREA OF SITE / CONTAMINATED SITE:- 19,200 tons of soil needed treatment.

5. DEPTH OF GROUND WATER / CONTAMINATION:- Not known.

6. ENVIRONMENTAL SITE ASSESSMENT:- Not known.

7. SITE CHARACTERIZATION:- The soil and sludge has a moisture content of approximately 15%. The pH of the soil was 6.5.

8. MAJOR CONTAMINANTS:- The major contaminants were the metals Beryllium, Chromium, Copper, Nickel, Zinc, Lead, Mercury.

9. SOURCE OF CONTAMINANTS:- The site has previously been used as a waste recycling facility and an estimated 15 million gallons of liquid industrial waste were processed in six lagoons. This has resulted in the contamination.

10. CONCENTRATION OF CONTAMINANTS :- Highest concentrations in the sediments:-

- Chromium - 8,010 mg/kg,
- Copper - 9,070 mg/kg,
- Mercury - 100 mg/kg.

Highest metal concentrations in sludge:-

- Chromium - 11,300 mg/kg,
- Copper - 16,300 mg/kg,
- Lead - 389 mg/kg,
- Nickel - 11,100 mg/kg.

11. REGULATIONS:- Record of Decision (ROD) for 1990 identified soil cleanup levels for 11 metals as:-

- Arsenic - 190 mg/kg,
- Beryllium - 485 mg/kg,
- Cadmium - 107 mg/kg,
- Copper - 3,571 mg/kg,
- Lead - 500 mg/kg,
- Mercury - 1 mg/kg,
- Nickel - 1,935 mg/kg,
- Selenium - 4 mg/kg,
- Silver - 5 mg/kg,
- Zinc - 3,800 mg/kg.

12. SPECIFICATIONS:- Not known.

13. TREATMENT TECHNOLOGY:-

- (a) Screening technology:- None.
- (b) Selected technology:- Selected Soil Washing.

14. CONTAINMENT TECHNOLOGY:- None.

15. RISK ASSESSMENT:- Not known.

16. DESCRIPTION OF TECHNOLOGY:- The soil washing system at KOP was selected based on the results of a treatability study and data from a demonstration using KOP soil at a full scale unit in the Netherlands. In the process, the materials handling included selective excavation of metals-contaminated soil using visual inspection, confirmed using on-site X-ray fluorescence. The soil washing system consisted a series of hydroclones, conditioners, and froth floatation cells. The soil washing system included four components at a rated feed capacity of 25 tons/hour. The screening unit consisted of multiple screens, coarse screens greater than 0.2 m (8 inches), process oversize greater than 0.05 m (2 inches), and wet screening of less than 0.05 m (2 inch) materials.

The separation unit consisted of hydroclones which separate coarse and fine grained materials. The air floatation treatment units were used for froth floatation. Approximately 19,200 tons of contaminated soil and sludge were treated during this application.

17. DURATION OF REMEDIATION:- The operation began in June 1993 and extended to October 1993.

18. COST OF REMEDIATION:- The total cost for this application was \$7,700,000, including off-site disposal costs for the sludge cake.

19. RESULTS:- The cleanup goals were met for all the 11 metals and these cleanup goals were achieved in less than 4 months.

20. TRAINING PROGRAM:- None.

21. OTHER INFORMATION:- None.

22. CONCLUSIONS:- Selective excavation reduced the overall costs for the application by reducing the amount of soil requiring treatment by a factor of two. Further, the data from the demonstration run expedited the design schedule of the full-scale unit by more than a year.

23. REFERENCES:- Abstracts of remediation case studies by EPA, EPA-542-R-95-001, March 1995, pp. 86-87.

24. KEY WORDS:- Contaminated soil, Soil washing, Metals.

25. CONTACT PERSONS:- John Gorin, Remedila Project Manager, U.S. EPA Region 2, 26 Federal plaza, New York, NY, Ph. (202) 264-7592.

CASE STUDY [21] . 2/90

1. **TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Superfund
2. **LOCATION :-** At the Wide Beach Development Superfund Site in Brant, New York.
3. **NATURE OF SOIL:-** Not known.
4. **AREA OF SITE / CONTAMINATED SITE:-** 42,000 tons of soil needed treatment.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** Not known.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Details to be collected.
7. **SITE CHARACTERIZATION:-** The soil had a moisture of 18.3%. The soil consisted of 12.8% clay and 30.3% silt. The pH of the soil was 7.7.
8. **MAJOR CONTAMINANTS:-** Polychlorinated Biphenyls (PCBs).
9. **SOURCE OF CONTAMINANTS:-** The contamination occurred due to road oiling, the application of Polychlorinated Biphenyls (PCBs) containing waste oils to the roadways for dust control.
10. **CONCENTRATION OF CONTAMINANTS :-** The stockpiled soil contained 10 to 5,000 mg/kg Polychlorinated Biphenyls (PCBs). The material fed into the thermal desorber contained 11 to 68 mg/kg Polychlorinated Biphenyls (PCBs).
11. **REGULATIONS:-** The regulatory requirements or cleanup goals for Polychlorinated Biphenyls (PCBs) in soil are 2 mg/kg.
12. **SPECIFICATIONS:-** Not known.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:- Selected Thermal Desorption and Dehalogenation.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Details not known.
16. **DESCRIPTION OF TECHNOLOGY:-** Contamination of soil at this site resulted from the spraying of waste oil containing polychlorinated biphenyls (PCBs) over the roadways in the community to control dust. This project is notable for using full-scale treatment application using soil Tech's ATP system in conjunction with APEG dechlorination to treat soil at a Superfund site contaminated with PCBs.

During the full scale treatment of soils at the site, samples of untreated soil were occasionally collected from the feed conveyor of the ATP system. The concentrations of polychlorinated biphenyls (PCBs) measured in these samples ranged from 11 to 68 mg/kg, with an average polychlorinated biphenyl (PCB) concentration of 24 mg/kg. Samples of the treated soil were collected either from the treated solids staging area or the tailings

conveyor of the ATP system. The concentrations of polychlorinated biphenyls (PCBs) measured in these samples were generally less than or near the detection limit (approximately 0.5 mg/kg) and all samples were below the 2 mg/kg cleanup level during the treatment application.

17. **DURATION OF REMEDIATION:-** The remediation operation started in October 1990 and completed in September 1991.
18. **COST OF REMEDIATION:-** The actual total costs for cost elements directly associated with treatment were \$11,600,000 which included solids preparation and handling, startup, equipment, and operation.
19. **RESULTS:-** The Polychlorinated Biphenyl (PCB) concentrations reduced from up to 68 to less than 2 mg/kg.
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** None.
22. **CONCLUSIONS:-** An EPA SITE demonstration was conducted during the full-scale operation in May of 1991. The SITE demonstration results indicated that 98% of the Polychlorinated Biphenyls (PCBs) that entered the thermal processor were de chlorinated.
23. **REFERENCES:-** Abstracts of remediation case studies by EPA, EPA-542-R-95-001, March 1995, pp. 98-99.
24. **KEY WORDS:-** Contaminated soil, Polychlorinated Biphenyls (PCB), Thermal desorption.
25. **CONTACT PERSONS:-**
 - * Herb King(RPM), U.S. EPA Region 2, 26 Federal Plaza, New York, NY 10278, Ph. (212) 264- 1129.
 - * Joe Salvatore, USACE c/o 914 TAG, Bldg. 322, Niagara Falls Intl. Airport, Niagara Falls, NY 14304, Ph. (716) 297-8531.

CASE STUDY [22] . 5/93

1. **TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Superfund
2. **LOCATION :-** At T.H. Agriculture and Nutrition Company Superfund Site in Albany, Georgia.
3. **NATURE OF SOIL:-** Not known.
4. **AREA OF SITE / CONTAMINATED SITE:-** 4,300 tons of soil needed treatment.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** Not known.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Details to be collected.
7. **SITE CHARACTERIZATION:-** The subsurface soil had a bulk density of 125.8 to 129.7 lb./cubic feet. The moisture content of the soil was 13 to 19%. The pH of the soil ranged from 5.7 to 6.2.
8. **MAJOR CONTAMINANTS:-** Halogenated Organic Pesticides like dieldrin, toxaphene, DDT, lindane.
9. **SOURCE OF CONTAMINANTS:-** The site was previously used for pesticide formulation and storage. This manufacturing process resulted in the contamination.
10. **CONCENTRATION OF CONTAMINANTS :-** The total organic contents were reported to be 0.2 to 0.23 mg/kg.
11. **REGULATIONS:-** The clean-up goals were identified in March 1992. Unilateral administrative order had treatability variance for proof of process performance test and full scale treatment were:-
 - * Total Organochlorine(OCL) pesticides should be less than 100 mg/kg
 - * The four constituents measured (DDT, toxaphene, BHC-alpha, BHC-beta) should be greater than 90% of measured reduction in concentration.
12. **SPECIFICATIONS:-** Not known.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:- Selected Thermal Desorption.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** None.
16. **DESCRIPTION OF TECHNOLOGY:-** The thermal desorption unit consisted of rotary kiln thermal desorber operated at 833 to 1,080^oF (soil exit temperature) and a 15-minute residence time. An interlock (waste feed cutoff) process control system was used in this application to maintain operation of the unit within allowable limits. The system was operated from July to October 1993. The offgases routed through a baghouse, a water quenching unit,

a reheater, and a vapor phase carbon adsorption bed. Thermal desorption achieved the specified cleanup levels for organochlorine pesticides and air emission rates. Total organochlorine pesticide concentrations in the treated soil ranged from 0.009 to 4.2 mg/kg with an average concentration of 0.5 mg/kg. Average removal efficiencies for the four target organochlorine pesticides were greater than 98%.

17. **DURATION OF REMEDIATION:-** The treatment began in July 1993 and was completed in October 1993.
18. **COST OF REMEDIATION:-** The total treatment cost was estimated to be \$849,996 which included solids preparation and handling, mobilization, startup, system operation, and demobilization.
19. **RESULTS:-** The cleanup goals for soil were met for both total organochlorine pesticides and individual constituents. Air emission standards were achieved during both the proof of process test and during the full scale remediation. The average organochlorine pesticides concentration in treated soil was found to be 0.51 mg/kg. The average removal efficiencies for individual constituents were greater than 98%.
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** None.
22. **CONCLUSIONS:-** The proof of process performance test conducted well before the application provided information on operating conditions and air emissions that were used for the full scale treatment application. The removal efficiencies were greater than 98% and the technology proved to perform as per the expectations for the site.
23. **REFERENCES:-** Abstracts of remediation case studies by EPA, EPA-542-R-95-001, March 1995, PP 96-97.
24. **KEY WORDS:-** Contamination, Thermal Desorption, Organic Contaminants.
25. **CONTACT PERSONS:-** R.Donald Rigger, On-Scene Coordinator, U.S.EPA Region 1V, 345 Courtland Street, N.E., Atlanta, GA 30365, Ph. (404) 347-3931.

CASE STUDY [23] . 5/91

1. **TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) DOD site
2. **LOCATION :-** At Eielson air force base in Fairbanks, Alaska.
3. **NATURE OF SOIL:-** The subsurface soil consisted of interbedded layers of loose to medium dense gravel and sands with varying amounts of silt to 6-9 feet. This is underlain by 600 feet of medium dense to dense sandy gravel.
4. **AREA OF SITE / CONTAMINATED SITE:-** Not known.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** Depth of contamination extended to 6.1 meters in the saturated zone.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Details to be collected.
7. **SITE CHARACTERIZATION:-** Not known.
8. **MAJOR CONTAMINANTS:-** Total Petroleum Hydrocarbons (TPH) and Benzene, Toluene, Ethylbenzenes, Xylenes (BTEX).
9. **SOURCE OF CONTAMINANTS:-** The spills and leaks of JP-4 jet fuel caused the contamination.
10. **CONCENTRATION OF CONTAMINANTS :-** Soil Total Petroleum Hydrocarbon (TPH) levels averaged 1,500 mg/kg.
11. **REGULATIONS:-** The regulatory requirements specified that the Total Petroleum Hydrocarbons (TPH) should be less than 200 mg/kg in soil. The Benzene concentration should be less than 2 lbs/day in extracted soil gas. The remedial activities were to be conducted in accordance with a Federal Facilities Agreement between U.S. Air Force, U.S. EPA, and the Alaska Department of Environmental Conservation.
12. **SPECIFICATIONS:-** Not known.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:- Selected Bioventing.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Details not known.
16. **DESCRIPTION OF TECHNOLOGY:-** A field demonstration of bioventing and three soil warming techniques began in July 1991 including active warming, passive warming and surface warming. Available respiration test data for oxygen consumption rates confirmed the occurrence of biological degradation processes. Preliminary results indicate that bioventing with soil warming achieves biodegradation year round in the subarctic environment. Active warming was found to achieve a higher biodegradation rate than passive or surface warming. It was noted that biodegradation was enhanced by adequate soil oxygen, moisture, and

nutrient levels, that injection wells were impractical at the source areas with naturally high concentration of iron in the groundwater. Also the high moisture content interferes with soil gas monitoring and reduces the number of soil gas monitoring samples that can be sampled.

17. **DURATION OF REMEDIATION:-** The report covers the period of operation from July 1991 to July 1994.
18. **COST OF REMEDIATION:-** The estimated capital costs were \$758,077 and the estimated annual operations and maintenance costs were \$1,77,160.
19. **RESULTS:-** Active warming was found to achieve a higher biodegradation rate than passive or surface warming.
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** None.
22. **CONCLUSIONS:-** Full scale remedial activities at the site were conducted in accordance with a Federal Facilities Agreement between the U.S. Air Force, U.S. EPA, and the Alaska Department of Environmental Conservation.
23. **REFERENCES:-** Abstracts of remediation case studies by EPA, EPA-542-R-95-001, March 1995, pp 20-21.
24. **KEY WORDS:-** Contaminated soil, Bioremediation, Bioventing, Petroleum substances, BTEX.
25. **CONTACT PERSONS:-** Capt. Timothy Merryman, 354 CES/CEVR, 2258 Central Avenue, Suite 1, Eielson AFB, Alaska 99702.

CASE STUDY [24] . 5/92

1. **TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Superfund site
2. **LOCATION :-** At French Limited Superfund Site in Crosby, Texas.
3. **NATURE OF SOIL:-** The soils varied from a fine grained silts to coarse sand.
4. **AREA OF SITE / CONTAMINATED SITE:-** Approximately 300,000 tons of soil needed remediation.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** Not known.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Details to be collected.
7. **SITE CHARACTERIZATION:-** The soils varied from a fine grained silts to coarse sand. The sludges consisted of tar like substance comprising of a mixture of petrochemical sludges, kiln dust, styrene and oils.
8. **MAJOR CONTAMINANTS:-** Polynuclear Aromatic Hydrocarbons (PAHs) and Chlorinated Aliphatics.
9. **SOURCE OF CONTAMINANTS:-** The site was a industrial waste disposal facility where an estimated 70 million gallons of petrochemical wastes were disposed in an unlined lagoon.
10. **CONCENTRATION OF CONTAMINANTS :-** The volatile organics ranged upto 400 mg/Kg. Pentachlorophenol ranged up to 750 mg/kg. Seem volatiles ranged up to 5000 mg/kg. Metals ranged up to 5000 mg/kg and PCB's up to 616 mg/kg.
11. **REGULATIONS:-** The Record of Decision (ROD) specified maximum allowable concentrations in the lagoons of soils and slugs for 5 contaminants as given:
 - * Benz(a)pyre - 9 mg/kg
 - * Total PCBs - 23 mg/kg
 - * Vinyl chloride - 43 mg/kg
 - * Arsenic - 7 mg/kg
 - * Benzene - 14 mg/kg.The Record of Decision (ROD) specified an action level for total volatile organic compounds () of 11 pp. for 5 minutes at the site boundary at any time during treatment.
12. **SPECIFICATIONS:-** Not known.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:-None.
 - (b) Selected technology:- Selected Slurry phase.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Not known.

- 16. DESCRIPTION OF TECHNOLOGY:-** The slurry phase Bio-remediation has been specified by the Record of Decision signed in March 1998. The technology consisted of two treatment cells designed to hold 17 million gallons each. An innovative system was used for aeration in the emissions while supplying oxygen to the Bio-mass. This system used pure oxygen and a series of educators to oxygenate the mixed liquor while minimizing air emissions. During this time, approximately 300,000 tons of contaminated sludge and soils in the lagoon were treated to levels below those specified in the record of decision. The aeration system was used to maintain dissolved oxygen concentration at 2 mg/liter. Tarry sludge was dredged and treated separately from sub-soils in lagoon. In addition air emission limits specified in the Record of Decisions were not exceeded during treatment.
- 17. DURATION OF REMEDIATION:-** The operation began in January 1992 and was completed in November 1993.
- 18. COST OF REMEDIATION:-** The total cost were approximately \$49,000,000 including project management, pilot studies, technology development, EPA oversight and backfill of the lagoon.
- 19. RESULTS:-** The specified clean up criterion were met within 10 months treatment for cell E and 11 months treatment for cell F. There were no exceedances of the established criterion for VOC air emissions.
- 20. TRAINING PROGRAM:-** None.
- 21. OTHER INFORMATION:-** None.
- 22. CONCLUSIONS:-** The slurry phase bioremediation application was notable as being the first application of this kind at a Superfund site, and included approximately \$12,000,000 in technology development and pilot scale and testing work. According to French Limited Task Group, the costs for future applications of slurry phase bio-remediation depend on site specific chemical and physical conditions with oxygen and nutrient supply being key factors affection the cost of bio-remediation systems.
- 23. REFERENCES:-** Abstracts of remediation case studies by EPA, EPA-542-R-95-001, March 1995, PP 22-23.
- 24. KEY WORDS:-** Contaminated soil, slurry phase bioremediation, polynuclear aromatic hydrocarbons, chlorinated aliphatics.
- 25. CONTACT PERSONS:-** Judith Black, Remedial Project Manager, U.S. EPA Region 6, 1445 Ross Avenue, Dallas, TX 75202, Ph: (214)-665-6739.

CASE STUDY [25] . 3/90

1. **TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) DOD site
2. **LOCATION :-** At Hill air force base in Ogden, Utah.
3. **NATURE OF SOIL:-** The subsurface consisted of mixed sands and gravels with occasional clay lenses.
4. **AREA OF SITE / CONTAMINATED SITE:-** 1250 sq. m (13,500 sq. ft) of surface area was contaminated by spill.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** Not available.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** To be collected.
7. **SITE CHARACTERIZATION:-** Approximate extent of 10,000 mg/kg JP-4 contour covered area 30 by 46 m (100 by 150 ft.). The air permeability ranged from 4.7 to 7.8 darcies.
8. **MAJOR CONTAMINANTS:-** Total Petroleum Hydrocarbons (TPH).
9. **SOURCE OF CONTAMINANTS:-** The spill of JP-4 Jet Fuel.
10. **CONCENTRATION OF CONTAMINANTS :-** Total Petroleum Hydrocarbons (TPH) concentrations in untreated soil ranged from less than 20 to 10,200 mg/kg with an average soil Total Petroleum Hydrocarbons (TPH) concentration of 411 mg/kg.
11. **REGULATIONS:-** The regulatory or cleanup goal was 38.1 mg/kg Total Petroleum Hydrocarbons (TPH). The cleanup was conducted under Utah Department of Health's "Guidelines for Estimating Numeric Cleanup Levels for Petroleum Contaminated Soil at Underground Storage Tank Release Sites".
12. **SPECIFICATIONS:-** To be collected.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:- Selected Bioventing preceded by Soil Vapor Extraction.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Not known.
16. **DESCRIPTION OF TECHNOLOGY:-** The remediation of this spill area was conducted from October 1988 to December 1990 in two phases, the soil vapor extraction phase followed by the bioventing phase. The soil vapor extraction system included 7 vent wells located in the areas of highest contamination, 31 monitoring wells and a catalytic incinerator. The typical air flow rate through the vent wells was 700 acfm, with a maximum of 1,500 acfm. In addition, a plastic liner was installed over part of the spill area surface to prevent local air infiltration and bypassing of the airflow to the vent well directly from the surface. Within a year the soil vapor

extraction system removed hydrocarbons from the soil to levels ranging from 33 to 101 mg/kg. Further reduction of the hydrocarbon concentration in the soil, to levels below the specified Total Petroleum Hydrocarbons (TPH) limit, was achieved by using bioventing for 15 months. The bioventing system included 4 vent wells, located on the southern perimeter of the spill area, and the monitoring wells used for soil vapor extraction system. Because hydrocarbon concentrations were less than 50 mg/l in the extracted vapors, the catalytic incinerator was not required for this phase. Biodegradation was enhanced by injecting oxygen, moisture and nutrients to the soil. Average Total Petroleum Hydrocarbon (TPH) concentrations in the treated soil were less than 6 mg/kg.

In monitoring biodegradation rates, oxygen depletion was found to be a more accurate estimator of biodegradation rate than carbon dioxide formation. Carbon dioxide sinks, such as biomass, solubility in water, and reaction with the soil, limited the usefulness of carbon dioxide formation as a process control parameter.

17. **DURATION OF REMEDIATION:-** The remediation of this spill area was conducted from October 1988 to December 1990.
18. **COST OF REMEDIATION:-** The total cost of remediation was \$3,35,000, including capital and 2 years of operating costs. The annual operating costs were estimated to be \$1,32,000.
19. **RESULTS:-** The average Total Petroleum Hydrocarbon (TPH) soil concentrations in treated soil reduced to less than 6 mg/kg. 95,700 kg (2,11,000 lb.) of Total Petroleum Hydrocarbon (TPH) removed in approximately 2 years of operation. The removal rate ranged from 9 to 180 kg/day (20 to 400 lb./day).
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** None.
22. **CONCLUSIONS:-** The remediation project achieved specified Total Petroleum Hydrocarbon (TPH) levels.
23. **REFERENCES:-** Abstracts of remediation case studies by EPA, EPA-542-R-95-001, March 1995, pp 26-27.
24. **KEY WORDS:-** Contaminated soil, Bioremediation, Soil vapor extraction, Total petroleum hydrocarbons.
25. **CONTACT PERSONS:-** Robert Elliot, OO-ACC/EMR, 7274 Wardleigh Road, Hill AFB, Utah, 84055.

CASE STUDY [26] . 1/86

1. **TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Superfund site
2. **LOCATION :-** At McKin Company Superfund Site in Maine, Florida.
3. **NATURE OF SOIL:-** No information available.
4. **AREA OF SITE / CONTAMINATED SITE:-** 8,800 cubic meters of soil needed treatment.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** Not known.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** To be collected.
7. **SITE CHARACTERIZATION:-** No information available.
8. **MAJOR CONTAMINANTS:-** Chlorinated Aliphatics, BTEX (Benzene, Toluene, Ethyl benzene, Xylene), Polynuclear Aromatic Hydrocarbons (PAHs).
9. **SOURCE OF CONTAMINANTS:-** A disposal pit.
10. **CONCENTRATION OF CONTAMINANTS :-** The excavated soil contained up to 3,310 mg/kg trichloroethylene, 130 mg/kg Ethyl benzene, and 35 mg/kg Toluene.
11. **REGULATIONS:-** The soil performance standard of 0.1 mg/kg is allowed for trichloroethylene, 1 mg/kg for individual aromatic organic compounds, 1 mg/kg for individual Polynuclear Aromatic Hydrocarbons (PAHs), and 10 mg/kg for total Polynuclear Aromatic Hydrocarbons (PAHs).
12. **SPECIFICATIONS:-** Not known.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:- Selected Thermal Desorption.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Not available.
16. **DESCRIPTION OF TECHNOLOGY:-** The Record of decision (ROD) identified several areas at the site that required on-site thermal desorption treatment for contaminated soil. These areas were grouped into "VOC- Contaminated area" and "Petroleum Contaminated area". The treatment performance standard, stipulated in the Record of decision (ROD), required treatment of trichloroethylene in the soil to a concentration of 0.1 mg/kg. In addition to the trichloroethylene requirement, treatment performance standards for Polynuclear Aromatic Hydrocarbons (PAHs) and aromatic organics were specified for the petroleum contaminated area. Ambient air monitoring was required during the application.
The thermal desorption system included a rotary kiln desorber with off gases treated using a filter, baghouse, scrubber, and carbon adsorption. Thermal desorption of

approximately 8410 cubic meters of soil was completed between July 1986 and April 1987. This treatment application was notable for being one of the earliest full scale applications of thermal desorption to remediate halogenated volatile organic compounds at a superfund site. Treatment performance and air monitoring data collected during this application indicated that all performance standards and monitoring requirements were achieved through use of the thermal desorption technology.

17. **DURATION OF REMEDIATION:-** The period of operation was from July 1986 and April 1987.
18. **COST OF REMEDIATION:-** The total cost of the project was \$2,90,000.
19. **RESULTS:-** All cleanup goals were achieved by the remediation. 11,500 tons of soil treated within 10 months. The ambient air concentrations for volatile organic compounds (VOCs) were less than 2 ppm above background.
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** None.
22. **CONCLUSIONS:-** A pilot scale treatability study indicated that thermal desorption would be effective in treating soils at this site.
23. **REFERENCES:-** Abstracts of remediation case studies by EPA, EPA-542-R-95-001, March 1995, pp. 88-89.
24. **KEY WORDS:-** Contaminated soil, Thermal desorption, Chlorinated aliphatics, BTEX, Petroleum substances.
25. **CONTACT PERSONS:-** Sheila Eckman, Remedial project manager, U.S.EPA Region I, John F. Kennedy Federal Bldg., Room 2203, Boston, MA 02203, Ph: (617) 573-5784.

CASE STUDY [27] . 6/93

1. **TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Superfund site
2. **LOCATION :-** At Parsons Chemicals/ ETM Enterprises Superfund Site, Michigan.
3. **NATURE OF SOIL:-** The subsurface comprised of silty clay with high moisture content.
4. **AREA OF SITE / CONTAMINATED SITE:-** 2,290 cubic meters of soil needed treatment.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** Not known.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Details not available.
7. **SITE CHARACTERIZATION:-** The soil was reported to be difficult to work with under very wet and very dry conditions.
8. **MAJOR CONTAMINANTS:-** Pesticides, Heavy Metals, Phthalates, Polynuclear Aromatic Hydrocarbons (PAHs), and Dioxins.
9. **SOURCE OF CONTAMINANTS:-** Discharge to sewer or surface water.
10. **CONCENTRATION OF CONTAMINANTS :-** The concentration of pesticides was up to 340 mg/kg. The concentration of heavy metals ranged up to 34 mg/kg for mercury and that of dioxin ranged up to 1.13 µg/kg.
11. **REGULATIONS:-** The soil cleanup or offgas standards were as follows:-
 - * Chlordane - 1 mg/kg per 25 lb./hr
 - * DDT - 4 mg/kg per 0.01 lb./hr
 - * Dieldrin - 0.08 mg/kg per 0.00028 lb./hr
 - * Mercury - 12 mg/kg per 0.00059 lb./hr.
12. **SPECIFICATIONS:-** Not known.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:- Selected Insitu Vitrification.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Not available.
16. **DESCRIPTION OF TECHNOLOGY:-** A full scale soil remediation system using insitu vitrification (ISV) was conducted and sediments at the site were contaminated with pesticides, heavy metals, phthalates, Polynuclear Aromatic Hydrocarbons (PAHs), and dioxins as a result of former agricultural chemical manufacturing processes. Soil cleanup requirements were established for four constituents. In addition, the offgases from the insitu vitrification (ISV) unit were required to meet state air requirements for these constituents during operation.

The insitu vitrification (ISV) system used at this site included 9 melt cells and an air emissions control system. Contaminated soil was excavated and staged at the site due to the shallow nature of the contamination. The melt cells were installed in a treatment trench. Eight melts were completed from June 1993 to May 1994. The melts ranged in the duration from 10 to 19.5 days and consumed between 559,000 and 1,100,000 kilowatt-hours of electricity per melt. Several operational problems were encountered during this period including fires and equipment problems. These problems were addressed through modifications to equipment and operating practices. Because the melt requires approximately one year to cool before samples of the subsurface can be collected, data on the performance of the insitu vitrification would not be available then.

17. **DURATION OF REMEDIATION:-** The period of operation was from May 1993 to May 1994.
18. **COST OF REMEDIATION:-** The cost for this application was \$1,763,000.
19. **RESULTS:-** According to the verification results, near-surface vitrified materials had acceptable levels of pesticides and mercury. Data on air emissions indicates off gases met the state air emission standards.
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** None.
22. **CONCLUSIONS:-** Because the melt requires approximately one year to cool before samples of the subsurface can be collected, data on the performance of the in situ vitrification would not be available then.
23. **REFERENCES:-** Abstracts of remediation case studies by EPA, EPA-542-R-95-001, March 1995, pp. 92-93.
24. **KEY WORDS:-** Contaminated soil, In situ vitrification, Pesticides, Metals, Phthalates, Polynuclear aromatic hydrocarbons, Dioxins.
25. **CONTACT PERSONS:-** Len Zintak, OSC, U.S.EPA Region 5, 77 West Jackson Boulevard, Chicago, IL 60604, Ph: (312) 886-4246.

CASE STUDY [28] . 7/93

1. **TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Superfund- DOD site
2. **LOCATION :-** At an air force base Superfund site, California.
3. **NATURE OF SOIL:-** The subsurface soil comprised of silty sands and sandy silt with oily material, wirewood, and debris.
4. **AREA OF SITE / CONTAMINATED SITE:-** Not known.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** No information available.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Not known.
7. **SITE CHARACTERIZATION:-** The contamination extended into three zones viz., waste pit, intermediate alluvium, and deep alluvium. The permeability of the soil ranged from 0.001 darcies for silty clay to 1.7 darcies for sand.
8. **MAJOR CONTAMINANTS:-** Chlorinated aliphatics, Tetrachloroethene (PCE) (U208), Trichloroethene (TCE) (U227), 1,1-Dichloroethene (U028), Vinyl chloride (D043), 1,1,1-Trichloroethane (U227) , 1,2-Dichloroethane (D028), Freon 113.
9. **SOURCE OF CONTAMINANTS:-** A disposal pit for fuels and solvents.
10. **CONCENTRATION OF CONTAMINANTS :-** Tetrachloroethene (PCE), Trichloroethene (TCE), 1,1-Dichloroethene, Vinyl chloride, 1,1,1-Trichloroethane, 1,2-Dichloroethane, Freon 113 account for over 99% of the speciated volatile organic compound mass in the vadose zone. Maximum borehole concentration of volatile organic compounds in vadose zone was reported up to 2,975,000 µg/kg.
11. **REGULATIONS:-** The regulatory requirement for air emissions was 95% destruction of total volatile organic compounds, required by the Sacramento Air Quality Management District.
12. **SPECIFICATIONS:-** To be collected.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:- In situ soil vapor extraction.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Information to be collected.
16. **DESCRIPTION OF TECHNOLOGY:-** Soil was contaminated with chlorinated and petroleum based volatile organic compounds (VOCs). A 95% destruction and removal efficiency for total volatile organic compounds (VOCs) in the extracted vapors was required by the Sacramento Air Quality Management District.

The Soil vapor extraction system included 17 vapor extraction wells, vapor / liquid separators, a catalytic oxidizer, and a scrubber. These 17 vapor extraction wells extended in three contamination zones. The scrubber was used to control air emissions. The total system average air flow rate was 2,500 standard cubic feet per minute. Results showed that approximately 51250 kgs (113,000 pounds) of volatile organic compounds were extracted in 15 weeks of operation.

- 17. DURATION OF REMEDIATION:-** The project started in 1993 and extended to May 1994.
- 18. COST OF REMEDIATION:-** The total costs of operation were around \$3.8 million.
- 19. RESULTS:-** Approximately 20860 kgs (46,000 lb.) and 51250 kgs (113,000 lb.) of speciated volatile organic compounds were extracted and treated during initial 6 weeks and 15 weeks of operation respectively. More than 90% of the mass of the contaminants was reported to be removed. Up to 68040 kgs (150,000 lb.) of contaminants believed to had been biodegraded in situ during initial 6 weeks of operation.
- 20. TRAINING PROGRAM:-** None.
- 21. OTHER INFORMATION:-** None.
- 22. CONCLUSIONS:-** During this application, it had been observed that the heterogeneity of the soils at this site caused the radius of influence for the extraction wells to vary from 4.6 to 18.2 m (15 to 60 ft.) for a single well. It was also noted that soil vapor extraction (SVE) air pollution control systems should be designed with sufficient capacity to provide for operational flexibility.
- 23. REFERENCES:-** Abstracts of remediation case studies by EPA, EPA-542-R-95-001, March 1995, pp. 72-73.
- 24. KEY WORDS:-** Contaminated soil, Volatile organic compounds, In situ, Soil vapor extraction, Chlorinated aliphatics.
- 25. CONTACT PERSONS:-** Kendall Tanner, Remedial Project Manager, McClellan, AFB.

CASE STUDY [29] . 6/91

1. TYPE OF PROJECT:-

- (a) Treating saturated contaminated soil .
- (b) Site clean-up (HWMP - PHASE IV).
- (c) DOD site

2. LOCATION :- At the Luke Air Force Base, North Fire Training Area, Arizona.

3. NATURE OF SOIL:- The soil comprised of silty sands, clean well graded to poorly graded sands, and permeable to low permeability inorganic silts.

4. AREA OF SITE / CONTAMINATED SITE:- Not known.

5. DEPTH OF GROUND WATER / CONTAMINATION:- Not known.

6. ENVIRONMENTAL SITE ASSESSMENT:- Not known.

7. SITE CHARACTERIZATION:- The soil comprised of permeable silty sands, very permeable, clean well graded to poorly graded sands, and permeable to low permeability inorganic silts. The moisture content of the soil was 10%. The permeability of top soils ranged from 1×10^{-4} to 3×10^{-3} cm/sec. The porosity of the soils ranged from 36 to 46%.

8. MAJOR CONTAMINANTS:- Total Petroleum Hydrocarbons (TPHs), Benzene, Toluene, Ethyl benzene, Xylenes (BTEX), and Methyl ethyl ketone (MEK).

9. SOURCE OF CONTAMINANTS:- A fire training area.

10. CONCENTRATION OF CONTAMINANTS :- The initial soil contamination in two fire training pits had the concentrations of Benzene, Toluene, Ethyl benzene and Xylene as 0.2 to 16 mg/kg, 10 to 183 mg/kg, 21 to 84 mg/kg, 69 to 336 mg/kg respectively. The concentrations of total recoverable petroleum hydrocarbons was 151 to 1380 mg/kg.

11. REGULATIONS:- As per the Arizona action levels for soil, the concentrations of the total petroleum hydrocarbons should be 100 mg/kg. and that of BTEX be 412 mg/kg.

12. SPECIFICATIONS:- Not available.

13. TREATMENT TECHNOLOGY:-

- (a) Screening technology:- None.
- (b) Selected technology:- Soil Vapor Extraction.

14. CONTAINMENT TECHNOLOGY:- None.

15. RISK ASSESSMENT:- Details to be collected.

16. DESCRIPTION OF TECHNOLOGY:- A full scale cleanup using Soil Vapor extraction of the soil in the two pits was conducted from October 1991 until December 1992. The system consisted of one extraction well for each of two fire pits. These wells were constructed with 35 foot screens to depths up to 57 feet. A thermal oxidizer was used for destruction of organic vapors extracted from the soil. The full scale system which used the thermal oxidizer, removed 12,000 pounds of contaminants in 30 weeks of operation. Total Petroleum Hydrocarbons (TPHs) and BTEX levels were below the Arizona action levels after five months of operation, with total petroleum hydrocarbons (TPHs) and benzene as not detected

in March 1992. Sampling in November 1992 showed that ethyl benzene, toluene and xylene were not detected. System downtime was 1% during this period. After a temporary shutdown period, an attempt to restart the system caused a malfunction in the thermal oxidizer and the destruction of the burner.

- 17. DURATION OF REMEDIATION:-** The Treatment started in October 1991 and was completed in December 1992.
- 18. COST OF REMEDIATION:-** The total cost of the remediation was \$507,185.
- 19. RESULTS:-** The treated soil concentrations indicated that the total petroleum hydrocarbons and BTEX were below the Arizona action levels. 12,000 lb. of contaminants were removed during 30 weeks of operation. The removal rate remained at 40 lb./day after 30 weeks of operation. the soil gas concentration reductions achieved in 6 months for 8 constituents ranged from 72 to 96%.
- 20. TRAINING PROGRAM:-** None.
- 21. OTHER INFORMATION:-** None.
- 22. CONCLUSIONS:-** It was found that the site investigation underestimated the amount of contamination at the site. Due to unexpectedly high concentrations of volatile organic constituents, the carbon supply was exhausted after two days of operation. Finally, the project was a success.
- 23. REFERENCES:-** Abstracts of remediation case studies by EPA, EPA-542-R-95-001, March 1995, pp. 70-71.
- 24. KEY WORDS:-** Contaminated soil, Soil vapor extraction, Total petroleum hydrocarbons (TPHs), Methyl ethyl ketone, BTEX.
- 25. CONTACT PERSONS:-** Jerome Stolinski, CERMO, U.S.Army Corps of Engineers, Omaha District.

CASE STUDY [30] . 2/94

1. **TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Superfund site
2. **LOCATION :-** At the Bofors-Nobel Superfund Site, Michigan.
3. **NATURE OF SOIL:-** Not known.
4. **AREA OF SITE / CONTAMINATED SITE:-** 85 acres.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** Not known.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Details to be collected.
7. **SITE CHARACTERIZATION:-** Not known.
8. **MAJOR CONTAMINANTS:-** The site was found to have as many as 69 different organic compounds and 24 metal species of which benzene, chlorobenzene, tetrachloroethylene and toluene were found to be significant.
9. **SOURCE OF CONTAMINANTS:-** The site was previously identified as a manufacturing site for dyes, detergents, pesticides and herbicides. The chemicals used and the raw materials like sulfur dioxide, aqua ammonia, nitrobenzene, methanol and benzene led to the contamination.
10. **CONCENTRATION OF CONTAMINANTS :-** Benzene registered from undetectable levels to 1,800 ppb, chlorobenzene up to 220 ppb, tetrachloroethylene up to 340 ppb, toluene up to 1,500 ppb, and 2-chloroaniline up to 1,500 ppb.
11. **REGULATIONS:-** Not available.
12. **SPECIFICATIONS:-** Information to be collected.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- Pump and treat method and treating ground water with powder activated carbon.
 - (b) Selected technology:- Ultraviolet oxidation with Ammonia stripping.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Information to be collected.
16. **DESCRIPTION OF TECHNOLOGY:-** After the contamination had been detected at the site, they have excavated some of the land and landfilled at a site which was never used for contaminated soils and installed 13 migration wells to prevent further migration of contaminated ground water. Ultraviolet oxidation was a proven destruction technology especially appropriate in treating volatile and semivolatile organic compounds. The cost is due primarily to the amount of electricity needed to produce ozone, which must be

generated on site since it only had a half life of 25-30 minutes. Still Ultraviolet oxidation was considered the best alternative, because the other efficient alternative, using powder activated carbon, would have cost even more.

Polymer is added to assist in the formation of floc particles that settle and are then pumped to a thickening processor. Water flows by gravity through dual media.

17. DURATION OF REMEDIATION:- The remediation was started in December 1993 and was completed in September 1994

18. COST OF REMEDIATION:- The remediation costs were reported to be \$12.4 millions.

19. RESULTS:- During the first week of contaminated water treatment, crews collected samples at key sites to ensure that the ultraviolet oxidation process met bid specifications. All sample locations were tested for 16 metals, 16 volatile organic compounds and 15 semivolatile organic compounds. The final samplings of water discharged from the site indicated that all the regulated contaminants fell below 5 ppb.

20. TRAINING PROGRAM:- None.

21. OTHER INFORMATION:- None.

22. CONCLUSIONS:- The final samplings of water discharged from the site indicated that all the regulated contaminants fell below 5 ppb which was rendered to be undetectable. This was estimated to be cleaner than the effluent from many municipal water-treatment systems.

23. REFERENCES:- "Greening of Ground Water" by Kevin J.Dulle, Ted H.Streckfuss; "Civil Engineering", April, 1995, pp. 62-65.

24. KEY WORDS:- Contamianted groundwater, Ultraviolet oxidation, Volatile organic compounds.

25. CONTACT PERSONS:- None.

CASE STUDY [31] . 6/92

1. **TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil and groundwater.
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Other site (not Superfund, DOT, RCRA, DOE or DOD)
2. **LOCATION :-** At a Gasoline spill site, California.
3. **NATURE OF SOIL:-** Not known.
4. **AREA OF SITE / CONTAMINATED SITE:-** 800 acres.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** Details not available.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Not known.
7. **SITE CHARACTERIZATION:-** 100,000 cubic yards were heated to at least 200^oF. Four hydrogeologic units and seven hydrostratigraphic layers identified near gas pad. The hydraulic conductivity ranged from 0.45 gpd/ sq.m (5 gpd/sq. ft.) to 100 gpd/ sq.m (1,070 gpd/sq. ft.). Low groundwater velocities kept contamination confined to a relatively smaller area.
8. **MAJOR CONTAMINANTS:-** Benzene, Toluene, Ethyl benzene, Total Xylenes (BTEX).
9. **SOURCE OF CONTAMINANTS:-** Underground storage tanks.
10. **CONCENTRATION OF CONTAMINANTS :-** The concentrations of fuel hydrocarbons in gasoline were as high as 5,100 ppm in saturated sediments near center of vadose zone. Benzene levels in groundwater were greater than 1 ppb found within 91 m (300 ft.) of release point. Benzene levels in soil were as high as 50 ppm.
11. **REGULATIONS:-** The groundwater cleanup levels based on California Maximum cleanup levels were 1 ppb, 680 ppb, 1,750 ppb for benzene, ethyl benzene and xylene respectively. Remediation was required until soil contaminant concentrations were identified as not adversely impacting groundwater.
12. **SPECIFICATIONS:-** Not known.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:- Dynamic underground stripping.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Not known.
16. **DESCRIPTION OF TECHNOLOGY:-** Soil and ground water at the site were found to be contaminated with BTEX and fuel hydrocarbons. It had been decided to treat the contamination at the site using dynamic underground stripping. Dynamic under ground stripping is basically a combination of three technologies which includes steam injection at the periphery of contaminated area to drive contaminants to centrally located vacuum extractions, then electrical heating of less permeable soils and underground imaging to

delineate heated areas. The dynamic underground stripping system used at the site thus employed 6 steam injection or electrical heating wells approximately 44 m (145 ft.) deep, 0.1 m (4 inch) diameter and screened in upper and lower steam zones. It also employed three electrical heating wells approximately 36 m (120 ft.) deep with 0.05 m (2 inch) diameter, one ground water and vapor extraction well approximately 47 m (155 ft.) deep with 0.2 m (8 inch) diameter. The extracted water had been processed through an air cooled heat exchanger, oil- water separators, filters, ultraviolet or hydrogen peroxide treatment unit, air stripping and GAC. The extracted vapors were processed through heat exchanger, demister and internal combustion engines.

17. **DURATION OF REMEDIATION:-** The remediation operation started in November 1992 and was completed in December 1993.
18. **COST OF REMEDIATION:-** The total costs of remediation were \$1,700,000 for before-treatment costs and \$5,400,000 for treatment activities.
19. **RESULTS:-** Over 7,600 gallons of gasoline was removed during the operation. Most of the gasoline was recovered in vapor stream and not from extracted groundwater.
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** None.
22. **CONCLUSIONS:-** Over 7,600 gallons of gasoline was removed during the operation. Potential cost savings of \$4,000,000 were identified for the operation.
23. **REFERENCES:-** Abstracts of remediation case studies by EPA, EPA-542-R-95-001, March 1995, pp. 46-47.
24. **KEY WORDS:-** Contaminated groundwater, BTEX, Dynamic underground stripping.
25. **CONTACT PERSONS:-** Kathy Willis, University of California office of Tech Transfer, 1320 Harbor Bay Parkway, Suite 150, Alameda, CA 94501, Ph:- (510) 748-6595.

CASE STUDY [32] . 4/90

1. **TYPE OF PROJECT:-**
 - (a) Treating contaminated groundwater.
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) DOE site
2. **LOCATION :-** At a U.S. Department of Energy Site, Aiken, South Carolina.
3. **NATURE OF SOIL:-** The subsurface comprised of discontinuous sand and clay layers.
4. **AREA OF SITE / CONTAMINATED SITE:-** The contaminated groundwater extended to a depth of about 150 ft. and covered about 1,200 acres.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** Not known.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Information to be collected.
7. **SITE CHARACTERIZATION:-** The area of volatile organic compound contaminated groundwater has an approximate thickness of 45 m (150 ft.) and covers about 1,200 acres. The aquifer units were characterized to 55 m (180 ft.) below ground surface showing complex hydrogeology and discontinuous sand and clay layers. The hydraulic conductivity was reported to be 2.75 - 22 m/day (9-73 ft./day) and the transmissivity was reported to be 175 to 12,500 gpd/day.
8. **MAJOR CONTAMINANTS:-** Chlorinated Aliphatics.
9. **SOURCE OF CONTAMINANTS:-** Surface impoundment.
10. **CONCENTRATION OF CONTAMINANTS :-** The concentrations of volatile organic compounds in ground water was reported as high as 500 ppm. The ground water trichloroethene concentrations were over 48 ppm. The ground water also contained 117936 to 204120 kg (260,000 to 450,000 pounds) of dissolved organic solvents in concentrations greater than 0.01 ppm. The soil trichloroethene concentrations were found to be over 10,000 μ g/l and also dense nonaqueous phase liquids were present in ground water.
11. **REGULATIONS:-** The regulations were based on permissions based on the South Carolina Department of Health and Environmental Control, Air Quality Control and Underground Injection Control.
12. **SPECIFICATIONS:-** Not known.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:- Insitu Air Stripping.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Not known.
16. **DESCRIPTION OF TECHNOLOGY:-** In the air stripping process, air was injected into a lower horizontal well in the saturated zone and extracted through the horizontal well in the vadose zone. The system installed 7 horizontal wells out of which 2 were used for field

demonstration. The wells were installed both in saturated zone, vadose zone and the targeted contaminated sands. The air had been injected through lower horizontal well below the water table. Here, the treatment was focused on supplementing pump and treat efforts. The insitu air stripping had increased volatile organic compound removal over conventional vacuum extraction from 49 kg (109 pounds) per day to 58 kg (129 pounds) per day. Nearly 7258 kg (16,000 pounds) of volatile organic compounds were removed during the treatment period. A cost analysis performed at the site showed that in situ air stripping can remove volatile organic compounds for approximately 69% of the cost for conventional methods. Installation costs for horizontal wells is greater than for vertical wells. Several implementation concerns were identified for installing horizontal wells at the site.

- 17. DURATION OF REMEDIATION:-** The period of operation started on July 1990 and extended till September 1993.
- 18. COST OF REMEDIATION:-** The total cost for the equipment was \$253,525, site costs were \$5,000, total annual labor costs were \$62,620 and total annual consumable costs were \$157,761.
- 19. RESULTS:-** The substantial changes were measured in ground water volatile organic compound concentrations measured during demonstration. Increased microbial numbers and metabolic activity was exhibited during air injection period. The 139 day demonstration removed as much as 7258 kg (16,000 pounds) of volatile organic compounds.
- 20. TRAINING PROGRAM:-** None.
- 21. OTHER INFORMATION:-** None.
- 22. CONCLUSIONS:-** A cost analysis performed at the site showed that in situ air stripping can remove volatile organic compounds for approximately 69% of the cost for conventional methods. Installation costs for horizontal wells is greater than for vertical wells. Several implementation concerns were identified for installing horizontal wells at the site.
- 23. REFERENCES:-** Abstracts of remediation case studies by EPA, EPA-542-R-95-001, March 1995, pp 58-59.
- 24. KEY WORDS:-** Chlorinated aliphatics, Contaminated ground Water, In situ air stripping.
- 25. CONTACT PERSONS:-** G.E. Turner, DOE, Savannah River Operating Office, environmental Restoration Division, Aiken, SC.

CASE STUDY [33] . 7/92

1. **TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Other site (not Superfund, DOT, RCRA, DOE or DOD)
2. **LOCATION :-** Hermiston, Oregon.
3. **NATURE OF SOIL:-** The subsurface was found to consist of quincy fine sand and quincy loamy fine sand.
4. **AREA OF SITE / CONTAMINATED SITE:-** 187 cubic meters of soil needed remediation.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** Not known.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Not known.
7. **SITE CHARACTERIZATION:-** The site predominantly consisted of quincy fine sand and quincy loamy fine sand.
8. **MAJOR CONTAMINANTS:-** The major contamination was due to explosives which include 2,4,6-trinitrotoluene (U234), hexahydro-1,3,5-trinitro-1,3,5-triazine (U213), and octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (P085).
9. **SOURCE OF CONTAMINANTS:-** Surface impoundment and lagoons.
10. **CONCENTRATION OF CONTAMINANTS :-** The contaminant levels were greater than 100 ppm limited to soils in the first 0.6 to 1.2 m below the surface of the lagoons.
11. **REGULATIONS:-** The regulatory levels for the concentrations of explosives in soil were to be below 30 ppm. The top 1.5 m of the soil below the lagoons was to be excavated, treated, and returned to the excavated area.
12. **SPECIFICATIONS:-** Not known.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:- Composting.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Details to be collected.
16. **DESCRIPTION OF TECHNOLOGY:-** Windrow Composting was used as a treatment technology at this site to treat 187 cubic meters of contaminated soil. Non aerated and aerated windrows were treated for 40 days, using several soil amendments, and tested for residual contamination. The excavated soil was screened and mixed with soil amendments. The treated soil was then mixed with top soil and re vegetated, re deposited in excavated area and landfilled. This is done 3 to 7 times per week, the temperature being maintained at 15 to 60°C, oxygen content up to 21%, Moisture being 30 to 40% and a pH of 5 to 9. 2,4,6-

trinitrotoluene (TNT) was reduced from 1,600 to 4 ppm, hexahydro-1,3,5-trinitro-1,3,5-triazine reduced from 1,000 to 7 ppm, and octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine reduced from 200 to 47 ppm in a 40 day treatment period.

- 17. DURATION OF REMEDIATION:-** The remediation was started in May 1992 and was concluded in November 1992.
- 18. COST OF REMEDIATION:-** The capital cost for treatment activities was \$1,840,000.
- 19. RESULTS:-** After 40-day treatment, the 2,4,6-trinitrotoluene reduced from 1,600 to 4 ppm, hexahydro-1,3,5-trinitro-1,3,5-triazine reduced from 1,000 to 7 ppm, and octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine reduced from 200 to 47 ppm.
- 20. TRAINING PROGRAM:-** None.
- 21. OTHER INFORMATION:-** None.
- 22. CONCLUSIONS:-** The project was a complete success with all the contaminant levels brought down to below regulatory levels.
- 23. REFERENCES:-** Abstracts of remediation case studies by EPA, EPA-542-R-95-001, March 1995, pp 34-35.
- 24. KEY WORDS:-** Contaminated soil, Composting, Explosives.
- 25. CONTACT PERSONS:-** Remedial Project Manager, Umatilla Army Depot Activity, Hermiston, OR.

CASE STUDY [34] . 8/92

1. **TYPE OF PROJECT:-**
 - (a) Treating contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Other site (not Superfund, DOT, RCRA, DOE or DOD)
2. **LOCATION :-** Hastings, Nebraska.
3. **NATURE OF SOIL:-** Not known.
4. **AREA OF SITE / CONTAMINATED SITE:-** 141,450 cubic meters of soil needed treatment.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** Not known.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Details to be collected.
7. **SITE CHARACTERIZATION:-** In the shallow zone, the moisture content was reported to be 26.3%, the air permeability was 1.9×10^{-10} cm², and the total organic content was 270 mg/kg. In the deep zone, the moisture content was reported to be 5%, air permeability was 6.2×10^{-8} cm², and the total organic content was less than 50 mg/kg.
8. **MAJOR CONTAMINANTS:-** Chlorinated aliphatics which included carbon tetrachloride (D019), chloroform (D022), trichloroethylene (D040), 1,1-dichloroethane (U076), 1,1,1-trichloroethane (U226) and perchloroethylene (U068).
9. **SOURCE OF CONTAMINANTS:-** Spills and contaminated aquifers.
10. **CONCENTRATION OF CONTAMINANTS :-** The highest carbon tetrachloride concentration measured in soil gas was 1,234 ppm at 34 m below ground surface.
11. **REGULATIONS:-** The regulatory requirements established in 1992 by EPA and Nebraska Department of Environmental Quality recommended an extraction rate for carbon tetrachloride of 4.5×10^{-4} kg/hr.
12. **SPECIFICATIONS:-** Not known.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:- Soil Vapor Extraction.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Details not known.
16. **DESCRIPTION OF TECHNOLOGY:-** The full scale soil vapor extraction system consisted of 10 extraction wells out of which 5 were deep, 3 intermediate and 2 shallow. EPA and Nebraska Department of Environmental Quality established a recommendation of an extraction rate for carbon tetrachloride of 4.5×10^{-4} kg/hr. The equipment consisted of 5 monitoring wells, an air-water separator, vacuum pump, and vapor phase granular activated carbon unit. The operation of the system continued until the field analytical results were verified through laboratory analysis and confirmation of no rebounding of carbon

tetrachloride. The soil vapor extraction system achieved the 4.5×10^{-4} kg/hr extraction rate within 6 months with the results verified and no rebounding confirmed.

17. **DURATION OF REMEDIATION:-** The operation started in June 1992 and was concluded in July 1993.
18. **COST OF REMEDIATION:-** The total cost of remediation was \$370,000.
19. **RESULTS:-** The Soil Vapor extraction system achieved the cleanup goals of 4.5×10^{-4} kg/hr extraction rate for carbon tetrachloride within 9 months of operation. Approximately 272 kg of carbon tetrachloride extracted, about 20 kg extracted within the first two months of operation.
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** None.
22. **CONCLUSIONS:-** The project was a complete success. The cleanup goals had been reached after only 9 months as against estimated 2 years based on treatability studies.
23. **REFERENCES:-** Abstracts of remediation case studies by EPA, EPA-542-R-95-001, March 1995, pp 66-67.
24. **KEY WORDS:-** Contaminated soil, Chlorinated aliphatics, Soil vapor extraction.
25. **CONTACT PERSONS:-** Diane Easley, U.S.EPA Region 7, 726 Minnesota Avenue, Kansas City, KS 66101, Ph: (913) 551-7797.

CASE STUDY [35] . 5/89

1. **TYPE OF PROJECT:-**
 - (a) Treating contaminated soil and lagoon water.
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Superfund site
2. **LOCATION :-** Superfund Site, Live Oak, Florida.
3. **NATURE OF SOIL:-** Clayey sand.
4. **AREA OF SITE / CONTAMINATED SITE:-** 81,000 cubic yards of soil needed treatment and 200,000 gallons of lagoon water needed treatment.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** Not known.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** To be collected.
7. **SITE CHARACTERIZATION:-** The lagoon had a clay bottom and sandy contents, which ranged from silty clay to fine sand.
8. **MAJOR CONTAMINANTS:-** Polyaromatic Hydrocarbons (PAHs).
9. **SOURCE OF CONTAMINANTS:-** The site was used for wood preserving which caused contamination.
10. **CONCENTRATION OF CONTAMINANTS :-** The contamination levels ranged from 100 to 208 mg/kg.
11. **REGULATIONS:-** A cleanup goal of 100 mg/kg of total carcinogenic indicator chemicals was established.
12. **SPECIFICATIONS:-** Not available.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- No action, On site Incineration, Off site Incineration, Biological treatment.
 - (b) Selected technology:- Land treatment.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Not known.
16. **DESCRIPTION OF TECHNOLOGY:-** A clay liner, which ranged from 1 to 3 ft. in thickness was constructed. Swales were run outside the treatment area to prevent flowing surface water from entering the site. A subsurface drainage system consisted of lateral pipes spaced 50 ft. apart across the treatment area connected to a main collector pipe. A 750,000 gallon retention pond to hold runoff from from the site was constructed. Land treatment was performed in three lifts. A composite sample was collected during each quarterly sampling event until the concentrations of TCICs contained in the soil was less than 100 mg/kg. The land treatment application met the cleanup goal for TCICs in 18 months.

- 17. DURATION OF REMEDIATION:-** The system operated from January 1989 to July 1990.
- 18. COST OF REMEDIATION:-** The total cost for the remediation was \$565,400 corresponding to \$70 per cubic yard of soil treated.
- 19. RESULTS:-** The final concentration of TCICs measured was 23 to 92 mg/kg.
- 20. TRAINING PROGRAM:-** None.
- 21. OTHER INFORMATION:-** This was of one of the early applications of land treatment of creosote contaminated soil at a superfund site.
- 22. CONCLUSIONS:-** The project was a complete success with the contaminant levels brought down to below regulatory levels.
- 23. REFERENCES:-** Abstracts of remediation case studies by EPA, EPA-542-R-95-001, March 1995, pp. 68-69.
- 24. KEY WORDS:-** Contaminated soil, Contaminated lagoon, Land treatment, Creosote, PAHs.
- 25. CONTACT PERSONS:-** None.

CASE STUDY [36] . 8/91

1. **TYPE OF PROJECT:-**
 - (a) Treating contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Superfund site
2. **LOCATION :-** Arsenal Superfund Site, Commerce City, Colorado.
3. **NATURE OF SOIL:-** Silty Clay.
4. **AREA OF SITE / CONTAMINATED SITE:-** 26,000 cubic meters (34,000 cubic yards) of soil.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** Not available.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Not available.
7. **SITE CHARACTERIZATION:-** The unconsolidated deposits beneath the site area consisted of discontinuous sand and gravel lenses, interbedded with silt and clay. In the area of the SVE system, a low permeability clayey sand to clay layer 0.3 to 1 m (1 to 3 feet) thick exists between 9.5 and 11.5 m (32 and 38 feet) below ground surface. The water table is approximately 20 m (65 feet) below ground surface in the site area.
8. **MAJOR CONTAMINANTS:-** Halogenated VOCs primarily trichloroethylene (TCE) (U228).
9. **SOURCE OF CONTAMINANTS:-** The site was used for cleaning and servicing equipment for storing diesel, gasoline, and oil products in aboveground and underground storage tanks.
10. **CONCENTRATION OF CONTAMINANTS :-** The initial TCE levels were 65 ppm.
11. **REGULATIONS:-** No specific regulations or cleanup goals were adopted.
12. **SPECIFICATIONS:-** Not available.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:- Soil Vapor Extraction and activated carbon system for extracted vapors.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Not available.
16. **DESCRIPTION OF TECHNOLOGY:-** The soil vapor extraction system consisted of a shallow soil vapor extraction well, located above the clay layer and a deep extraction well located below the clay layer. The extraction wells were connected by insulated PVC pipe to a liquid vapor separator tank designed to remove condensed water, a sediment filter and a blower. Exhaust air from the blower was discharged to vapor phase granular activated carbon canisters.
The rate of extraction of TCE by the soil vapor extraction system decreased over time. Approximately 16 kgs (35 pounds) of TCE were removed during the first 30 days of operation.

17. **DURATION OF REMEDIATION:-** The treatment started in July 1991 and completed successfully in December 1991.
18. **COST OF REMEDIATION:-** The total cost for the remediation was \$74,600 corresponding to \$2.5 per cubic meter of soil treated.
19. **RESULTS:-** 26,000 cubic meters (34,000 cubic yards) of soil was treated. The results indicated that TCE concentration in vapor monitoring wells were less than 6 ppm prior to start of the test and decreased to less than 1 ppm after completion of the test.
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** None.
22. **CONCLUSIONS:-** TCE levels in the soil vapor at the site were reduced within 5 months of operation from levels upto 65 ppm to levels of less than 1 ppm. Approximately 32 kgs (70 pounds) of TCE were recovered during the cleanup action.
23. **REFERENCES:-** Remediation Case Studies: Bioremediation, PB95-182911, from **Internet**, location, <http://clu-in.com/pubindex.htm#2>.
24. **KEY WORDS:-** Contaminated soil, Bioremediation, Land treatment, VOCs, Trichloroethylene.
25. **CONTACT PERSONS:-** None.

CASE STUDY [37] . 1/87

1. **TYPE OF PROJECT:-**
 - (a) Treating contaminated soil and groundwater.
 - (b) ESI, RI/FS and Site clean-up (HWMP - PHASE II, PHASE III and PHASE IV).
 - (c) Superfund site
2. **LOCATION :-** At the Verona Well Field Superfund Site in Battle Creek, Michigan.
3. **NATURE OF SOIL:-** The soil comprised of fine to coarse grained sand with traces of silt, clay, and pebbles.
4. **AREA OF SITE / CONTAMINATED SITE:-** The site covered an area of 1 acre.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-**The water table is 6.1 m below the grade.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Details to be collected.
7. **SITE CHARACTERIZATION:-** The site was located in the bottom of a wide river valley. The site topography was flat. The lithology of the site consists of fine to coarse grained sand with traces of silt, clay and pebbles. The hydraulic gradient was towards the well field and the hydraulic conductivity was of the order of 10^{-2} to 10^{-3} cm/sec.
8. **MAJOR CONTAMINANTS:-** The primary contaminants were benzene (D018), toluene (U220), xylene (U239), ethyl benzene (U239) (BTEX), tetrachloroethene (U208), trichloroethene (U226) and their breakdown products.
9. **SOURCE OF CONTAMINANTS:-** Contamination of the soil and ground water was thought to have resulted from underground tank leakage and surface spills in the tank truck loading / unloading areas.
10. **CONCENTRATION OF CONTAMINANTS :-** The ground water concentrations were as high as 19,000 $\mu\text{g/l}$ total VOCs. The soil concentrations were as high as 22,000 kg. The NAPL concentration was about 550 liters.
11. **REGULATIONS:-** Not known.
12. **SPECIFICATIONS:-** Not known.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:- Selected ground water extraction for ground water remediation and soil vapor extraction for the soil in the vadose zone. The extracted ground water was treated in a nearby air stripper. Both vapor phase carbon and catalytic oxidation were used to treat soil vapor extraction system off gas.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Not known.
16. **DESCRIPTION OF TECHNOLOGY:-** The installation of 9 ground water extraction wells at the site began in the fall of 1987. The extracted ground water is pumped from the

submersible well pumps to a monitoring building on site where the water discharges into a common header and then flows via gravity to an air stripper located in the well field for treatment. More than 6,400 kg of VOCs have been extracted with the ground water. Ground water concentrations have decreased from 19,000 µg/l total VOCs to 500 µg/l total VOCs. 550 liters of NAPL recovered through dual extraction. Total VOC concentrations in ground water downgradient from the site and outside the contaminated zone have decreased by 50 percent since system startup through natural attenuation.

Full scale operation of soil vapor extraction system began in March 1988. The soil vapor extraction system included 23 vapor extraction wells, an air water separator, offgas treatment equipment, and two system blowers. Each of the vapor extraction well had a throttling valve, sample port, and a vacuum gauge. The wells were connected by means of an above ground surface manifold. During the course of operation, the soil vapor extraction system removed approximately 20,500 kg of VOCs from the site vadose zone. The total VOC loading rate dropped from an initial high of approximately 490 kg of VOCs removed per day to under 0.5 kg per day.

Off gas from the soil vapor extraction system was initially treated using a vapor phase activated carbon adsorption to remove the contaminants from the vapor stream. The system was later replaced with a catalytic oxidation unit. A ground water sparging system using nitrogen as the sparging gas was implemented to address residual NAPL contamination in the capillary zone soils.

17. **DURATION OF REMEDIATION:-** Continuously operated from 1987 to 1991.
18. **COST OF REMEDIATION:-** Information not available.
19. **RESULTS:-** Ground water concentrations have decreased from 19,000 µg/l total VOCs to 500 µg/l total VOCs. 550 liters of NAPL recovered through dual extraction. During the course of operation, the soil vapor extraction system removed approximately 20,500 kg of VOCs from the site vadose zone. The total VOC loading rate dropped from an initial high of approximately 490 kg of VOCs removed per day to under 0.5 kg per day.
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** The lessons that have been learned during the course of system implementation and operation were:
 - Use care when applying site characterization data to design.
 - Understand the site conceptual model before starting remediation and update the site conceptual model, as necessary, during remediation.
 - Consider all the regulations that will apply to the remedial action.
 - Be flexible in selecting and implementing treatment technologies.
 - Evaluate more than just the key contaminants.
 - Plan effective, inclusive coordination with all relevant federal, state and local agencies.
 - Do not underestimate the importance of effective public relations.
22. **CONCLUSIONS:-** The project was a success with some lessons learnt during the application of the remediation program.
23. **REFERENCES:-** McCann, M. , Boersma, P. and Danko, J. , Environmental Progress, Vol. 13, No. 3, August, 1994, pp. 208-213.
24. **KEY WORDS:-** Volatile Organic Compounds, Soil vapor extraction, Groundwater Extraction, Treatment, NAPL.

CASE STUDY [38] . 7/91

1. **TYPE OF PROJECT:-**
 - (a) Treating contaminated soil and groundwater .
 - (b) ESI and Site clean-up (HWMP - PHASE II and PHASE IV).
 - (c) DOT site
2. **LOCATION :-** The expansion project of I-595 through Broward county, Florida.
3. **NATURE OF SOIL:-** Not known.
4. **AREA OF SITE / CONTAMINATED SITE:-** Information not available.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** Not known.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Not known.
7. **SITE CHARACTERIZATION:-** The monitoring program determined that the mounding effect pushed the contaminant plume to the recovery system. The characterization details are to be collected.
8. **MAJOR CONTAMINANTS:-** Benzene (D018) and total volatile organic aromatics.
9. **SOURCE OF CONTAMINANTS:-** The site was previously a gasoline station and the gasoline leaks contaminated the site.
10. **CONCENTRATION OF CONTAMINANTS :-** Not known.
11. **REGULATIONS:-** The regulatory discharge levels were 1 part per billion for benzene and 50 parts per billion for total volatile organic aromatics.
12. **SPECIFICATIONS:-** To be collected.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:- Selected ground water recovery system employing filtration, clarification and carbon adsorption treatment.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Information not available.
16. **DESCRIPTION OF TECHNOLOGY:-** The ground water recovery system consisted of six horizontal drains which are made of corrugated, perforated polyvinyl chloride pipes. the specific discharge capacity of those drains was estimated to be 11.15 L/min. per 1 m of the pipe. The horizontal drains were installed typically at 4.88 - 5.49 m below land surface using a pipe trencher. Five vertical recovery wells recovered deeper elements of the contaminated ground water plume. The treatment method consist of three stages.
Filtration: A filtration system removed suspended solids from the ground water pumped from drains and wells. The system consisted of a clarifier to remove larger particles followed by bag filters to remove fine particles.
Carbon Adsorption: a granular activated carbon system, which consisted of two parallel banks of dual 2.29 m diameter, 4,450 kg carbon adsorbers, operated in series.

Infiltration: a portion of the treated effluent was routed back over the site in designated areas to flush the vadose zone soils.

17. **DURATION OF REMEDIATION:-** The period of operation started in September 1991 and continued till February 1992.
18. **COST OF REMEDIATION:-** The total project costs approximated to \$750,000.
19. **RESULTS:-** The system performed as expected, recovering and treating approximately 132.475 million liters from the site over a period of 90 days. Analytical monitoring showed no treated effluent discharge above required regulatory discharge levels. More than 99% of the benzene and 95% of the total volatile organic aromatics had been removed in three months, keeping the highway project on track.
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** In the initial stages of treatment system operation, the bag filters clogged with fine sand and silt particles. Addition of a clarifier to the system limited this problem.
22. **CONCLUSIONS:-** The treatment system operated efficiently through out the treatment period. Analytical monitoring showed no treated effluent discharge above required regulatory discharge levels. The rapid remediation action saved \$3.3 million over the conventional pump and treat method.
23. **REFERENCES:-** Berry, J.G. and Frantz, L. A. , Civil Engineering, October 1995, pp. 63-65.
24. **KEY WORDS:-** Groundwater, Volatile organic aromatics, Benzene.
25. **CONTACT PERSONS:-** None.

CASE STUDY [39] . 8/93

1. **TYPE OF PROJECT:-**
 - (a) Treating contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Superfund site
2. **LOCATION :-** Superfund site, Reading, Ohio.
3. **NATURE OF SOIL:-** Not available.
4. **AREA OF SITE / CONTAMINATED SITE:-** 12,800 tons of contaminated soil needed treatment.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** Not available.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Not available.
7. **SITE CHARACTERIZATION:-**
8. **MAJOR CONTAMINANTS:-** Volatile and semivolatile organics, PAHs, inorganic metals, sulfur.
9. **SOURCE OF CONTAMINANTS:-**
10. **CONCENTRATION OF CONTAMINANTS :-** The concentration of volatile organics ranged from non detection levels to 140 ppb, that of semivolatile organics ranged from non detection levels to 130 ppb, that of lead ranged from 26 ppm to 1,100 ppm. The soil was determined to contain sulfur in excess of 2% by weight.
11. **REGULATIONS:-** The cleanup goals for tetrachloroethane are 3.24 µg/kg, chloroform was 2.04 µg/kg, and that of benzene was 116 µg/kg.
12. **SPECIFICATIONS:-**
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None
 - (b) Selected technology:- Composting
14. **CONTAINMENT TECHNOLOGY:-** None
15. **RISK ASSESSMENT:-** Not available
16. **DESCRIPTION OF TECHNOLOGY:-** Indigenous bacteria present in petroleum contaminated soil broke down the petroleum hydrocarbons, which are a source of energy for bacteria. The advantage of treating petroleum contaminated soils exsitu is the ability to amend the contaminated soil with nutrients, bacteria and bulking agents. Biomounds with four different soil amendment combinations were constructed for this study.
17. **DURATION OF REMEDIATION:-** Not available
18. **COST OF REMEDIATION:-** Not available

19. **RESULTS:-** Approximately 190 cubic meters of soil was excavated and placed in biomounds for treatment. Mn/DOT successfully treated excavated petroleum contaminated soil by using biomounding treatment.
20. **TRAINING PROGRAM:-** None
21. **OTHER INFORMATION:-** None
22. **CONCLUSIONS:-** The project was successful even though it is still a developing treatment method. The project also has the advantage of being accepted by the local bodies of government with little opposition from public.
23. **REFERENCES:-** Kamnikar Brian, "Biomounds Pass Tests in Minnesota," Soil and Groundwater Clean-up-Bioremediation. <http://www.sgcleanup.com/bio/biomound.html>
24. **KEY WORDS:-** Contaminated soil, Petroleum substance, Composting, Biomounding
25. **CONTACT PERSONS:-** None

CASE STUDY [40] . 9/93

1. TYPE OF PROJECT:-

- (a) Treating saturated contaminated soil .
- (b) Site clean-up (HWMP - PHASE IV).
- (c) Superfund site

2. LOCATION :- Superfund Site, Grand Ledge, Michigan.

3. NATURE OF SOIL:- Silty clay.

4. AREA OF SITE / CONTAMINATED SITE:- 2,300 cubic meters (3,000 cubic yards) of soil.

5. DEPTH OF GROUND WATER / CONTAMINATION:- Not available.

6. ENVIRONMENTAL SITE ASSESSMENT:- Not available.

7. SITE CHARACTERIZATION:- The soil was reported to be difficult to work with under very wet and very dry conditions. The soil also had high moisture content, and the soil moisture contained a high level of dissolved solids.

8. MAJOR CONTAMINANTS:- Pesticides, heavy metals, and dioxins.

9. SOURCE OF CONTAMINANTS:- The site was formerly an agricultural chemicals mixing, manufacturing, and packaging facility.

10. CONCENTRATION OF CONTAMINANTS :- The concentration of contaminants are as follows:

Chlordane	89,000 $\mu\text{g/kg}$
Dieldrin	87,000 $\mu\text{g/kg}$
Hexachlorobenzene	2,600 $\mu\text{g/kg}$
Mercury	34,000 $\mu\text{g/kg}$
Zinc	150,000 $\mu\text{g/kg}$
Pyrene	1,400 $\mu\text{g/kg}$

11. REGULATIONS:- Cleanup goals are as per clean up standards for soil as given below:

Chlordane	1 mg/kg
Dieldrin	0.08 mg/kg
Mercury	12 mg/kg

12. SPECIFICATIONS:- To be collected.

13. TREATMENT TECHNOLOGY:-

- (a) Screening technology:- None.
- (b) Selected technology:- Insitu Vitrification.

14. CONTAINMENT TECHNOLOGY:- None.

15. RISK ASSESSMENT:- Not known.

16. DESCRIPTION OF TECHNOLOGY:- Insitu Vitrification is an immobilization technology designed to treat media contaminated with organic, inorganic and radioactive contaminants. The primary residual generated by In situ Vitrification is the vitrified soil product. The In situ Vitrification system used at the site consisted of 9 melt cells, an air emissions control system and associated equipment. The air emissions control system used at the site consisted of an off gas collection hood, a quencher, a water scrubber, and a thermal oxidizer. The In situ Vitrification system operated by means of four graphite electrodes, arranged in a square and inserted a short distance into the soil to be treated. When power is fed to the electrodes, the graphite and glass frit conducts the current through the soil, heating the surrounding area and melting directly adjacent soil. The electrodes are allowed to progress down into the soil as it becomes molten, continuing the melting process to the desired treatment depth. To increase the economic viability of the treatment at this site, the contaminated soil was excavated and consolidated into a series of nine treatment cells.

17. DURATION OF REMEDIATION:- The treatment was started in May 1993 and was completed in May 1994.

18. COST OF REMEDIATION:- The total costs for the remediation were \$1, 763, 000.

19. RESULTS:- The results indicated a reduction in total waste analysis concentrations from levels as high as 23,000 µg/kg to levels less than 11 µg/kg for chlordane and dieldrin in surface soil samples. Concentrations of metals in a TCLP extract were shown to be reduced from levels as high as 21,000 µg/L to levels less than 5,000 µg/L.

20. TRAINING PROGRAM:- None.

21. OTHER INFORMATION:- This was notable for being the first application of In situ Vitrification treatment at a Superfund site.

22. CONCLUSIONS:- The surface soil samples and gas emission results met the soil cleanup standards and emission standards for this application.

23. REFERENCES:- Remediation Case Studies: Thermal Treatment. PB95-182911, from Internet, location, <http://clu-in.com/pubindex.htm#2>.

24. KEY WORDS:- Contaminated soil, Vitrification, Metals, Dioxins.

25. CONTACT PERSONS:- None.

CASE STUDY [41] . 1/94

1. **TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) ESI and Site clean-up (HWMP - PHASE II and PHASE IV).
 - (c) Superfund site
2. **LOCATION :-** Brockport, New York.
3. **NATURE OF SOIL:-** Not available.
4. **AREA OF SITE / CONTAMINATED SITE:-** Not available.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** Not available.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Site investigations conducted by NYSDEC revealed that the drums were buried throughout the landfill. the sampling of soils was tested for elevated levels of TCE, PCE, VOCs, and SVOCs. A remedial investigation identified source areas and determined the extent of vertical and horizontal migration of contaminants at the site.
7. **SITE CHARACTERIZATION:-** Not available.
8. **MAJOR CONTAMINANTS:-** The contamination is due to the presence of semi volatiles.
9. **SOURCE OF CONTAMINANTS:-** The site was used as a landfill to dispose of construction / demollition debris and hazardous wastes.
10. **CONCENTRATION OF CONTAMINANTS :-** The concentration of petroleum hydrocarbons were extended up to 22,000 mg/kg.
11. **REGULATIONS:-** As per New York State Department of Environmental Conservation cleanup criteria.
12. **SPECIFICATIONS:-** Not available.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:-Selected Ultraviolet biotreatment.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Not available.
16. **DESCRIPTION OF TECHNOLOGY:-** The UVB system installed at the site consisted of a groundwater circulation well. The bioreactor contained granualr activated carbon as biosupport for native micro organisms. The top of the bioreactor was connected to an aerator / stripper with an aboveground ambient air intake pipe. Groundwater entering the lower screen was pumped through the in situ bioreactor. Untreated VOCs leaving the bioreactor were stripped as the water flowed through the stripper / aerator. The treated, aerated and oxygen enriched groundwater was discharged from the well through the upper screen at the water table level. During the system operation, the concentration of target VOCs in

groundwater was monitored in 15 deep and shallow monitoring wells positioned strategically around the treatment system.

17. **DURATION OF REMEDIATION:-**The treatment was adopted for 15 months.
18. **COST OF REMEDIATION:-** Not available.
19. **RESULTS:-** The average concentrations of target compounds was reduced by 49 percent in groundwater. 70% of the soil samples collected met the NY state Department of Environmental Conservation Cleanup criteria. Overall reduction of all nonchlorinated compounds was 88 percent.
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** None.
22. **CONCLUSIONS:-** The overall reduction of all nonchlorinated compounds was 88 percent. The data for chlorinated solvents showed a 52 percent average reduction in total mass.
23. **REFERENCES:-** Susanne M.Borchert, Fayaz S.Lakhwala, James G.Muella, "UVB technology Invigorates Microbes at Superfund Site", Soil and Groundwater Cleanup - Bioremediation, <http://www.sgcleanup.com/bio/uvb.htm>.
24. **KEY WORDS:-** Contaminated groundwater, Chlorinated solvents, Bioremediation.
25. **CONTACT PERSONS:-** None.

CASE STUDY [42] .4/96

1. **TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) ESI and Site clean-up (HWMP - PHASE II and PHASE IV).
 - (c) Other site (not Superfund, DOT, RCRA, DOE or DOD)
2. **LOCATION:-** At an aerospace components manufacturing facility, Southern California.
3. **NATURE OF SOIL:-** The soil at the site include silty sands and sandy to silty clay.
4. **AREA OF SITE / CONTAMINATED SITE:-** Not available.
5. **DEPTH OF GROUNDWATER TABLE/CONTAMINATION:-** The depth to groundwater was 2.7 to 3.0 m.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Soil samples were collected at approximately 0.3, 1.2, and 2.4. m depths from surface and are analyzed for petroleum hydrocarbons. Groundwater was also affected.
7. **SITE CHARACTERIZATION:-** A soil sampling program was conducted to evaluate the extent and concentrations of impacted soil. A geoprobe direct-push sampling rig was used to collect soil samples from 15 soil borings drilled to an approximate depth of 2.4 m.
8. **MAJOR CONTAMINANTS:-** Halogenated hydrocarbons, mainly trichloroethylene and dichloroethene.
9. **SOURCE OF CONTAMINANTS:-** Soil and groundwater had been impacted at the facility from historical releases of petroleum and halogenated hydrocarbons from the underground piping.
10. **CONCENTRATION OF CONTAMINANTS:-** The petroleum hydrocarbons in the diesel fuel range was detected to a maximum concentration of 14,300 mg/kg.
11. **REGULATIONS:-** The local regulatory agency mandated that impacted soil be remediated to a level of 1,000 mg/kg. because the concentrations of halogenated hydrocarbons in groundwater were relatively low, the regulatory agency required quarterly testing and reporting.
12. **SPECIFICATIONS:-** Selected soil samples were analyzed for petroleum hydrocarbons by EPA method 8015 as diesel fuel and for BTEX by EPA method 8020.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology :- None.
 - (b) Selected In situ soil aeration and biopulsing.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Details to be collected.
16. **DESCRIPTION OF THE TECHNOLOGY:-**

- 17. DURATION OF REMEDIATION:-** The project had begun in 1996 and concluded within 3 months.
- 18. COST OF REMEDIATION:-**
- 19. RESULTS:-** The evaluation of remediation activities indicate that approximately 32 kg of diesel fuel present within the impacted zone of soil has been bioremediated.
- 20. TRAINING PROGRAM:-** None.
- 21. OTHER INFORMATION:-** None.
- 22. CONCLUSIONS:-** Treatment was successful.
- 23. REFERENCES:-** Gupta, S. Hari, Marshal, R. T. (1996), "Biopulsing; An In situ Aeration Remediation Strategy" Proceedings, In situ Remediation of the Geoenvironment, GSP 71, ASCE, pp. 516-531.
- 24. KEYWORDS:-** Contaminated soil, Petroleum substance, Bioremediation
- 25. CONTACT PERSONS:-** None.

CASE STUDY [43] . 9/92

1. **TYPE OF PROJECT:-**
 - (a) Treating contaminated soil and UST .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) DOD site
2. **LOCATION :-** Lowry Air Force Base, Denver, Colorado.
3. **NATURE OF SOIL:-** Not known.
4. **AREA OF SITE / CONTAMINATED SITE:-** 3,000 cubic yards of soil needed treatment.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** The depth of groundwater is at 45 feet below the ground surface.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Information not known.
7. **SITE CHARACTERIZATION:-** Thicknesses of unconsolidated alluvium >80 feet occur at the location of the DFAS-DE tanks. A layer of moist, firm sandy clay occupies the top 10 to 15 feet. The next 15 to 80 feet is a medium to coarse-grained sand. Aquifer is a water table aquifer. Groundwater gradient is roughly 0.4%. Approximately 3,000 cubic yards of sandy clay soil excavated from above the tanks was stockpiled separately and used for backfill of the excavation. Clean fill from off site was used to backfill remainder of the excavation.
8. **MAJOR CONTAMINANTS:-** BTEX and heating oil.
9. **SOURCE OF CONTAMINANTS:-** A suspected leak of 10,500 gallons of heating fuel oil was discovered which led to the removal of underground storage tank.
10. **CONCENTRATION OF CONTAMINANTS :-** Ground water benzene concentrations ranged from 1.7 to 3.1 $\mu\text{g/L}$. Concentrations of toluene, ethylbenzene, and xylenes were well below State standards and MCLs. Low TRPH concentrations (0.3 mg/L or less were measured 23 mg/L of TRPH was observed in the soil.
11. **REGULATIONS:-** The Colorado Department of Health (CDH Action Levels are:
Total (Recoverable) Petroleum Hydrocarbons (TRPH): 500 mg/kg
Total Benzene, Toluene, Ethylbenzene, and Xylenes (BTEX): 100 mg/kg .
The MCL standard for benzene is 5 $\mu\text{g/L}$, the MCL for xylenes is 10,000 $\mu\text{g/L}$, but there is no MCL for TPH.
12. **SPECIFICATIONS:-** The USTs were removed in conformance with American Petroleum Institute Recommended Practice 1604 and the National Fire Protection Association Code 30.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:- Land Farming.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Details to be collected.

16. DESCRIPTION OF TECHNOLOGY:- Soil berms, 2 feet wide by 2 feet high, were constructed on plastic sheeting used for the landfarming operation and the edges rolled back over the berms. Contaminated soil was spread on the plastic sheets to a thickness of 15 inches. Orange synthetic mesh fencing 3 to 4 feet high was installed around the landfarm for security and to prevent animal intrusions. The application of agricultural fertilizers to soil used in landfarming operations had C:N:P ratios to 200:10:1 as recommended for hydrocarbon biodegradation. Ammonium nitrate nutrients with this ratio were applied and tilled into the soils once. Optimum moisture for biodegradation ranges from 10 to 15% by weight. Moisture was added to the landfarming soils during the dry summer months to maintain this range. Based on Lowry AFB soil and contaminant conditions, a minimum landfarming treatment period of 12 to 18 months was expected for reduction of heating oil residuals from 3,100 mg/kg to <500 mg/kg.

Assuming that a maximum of 10% by weight of the heating fuel oil will volatilize, 1.9 tons of total volatile hydrocarbons could volatilize to the atmosphere during the anticipated landfarming treatment term. 5,400 cubic yards of petroleum contaminated soil was removed from the excavation. Soil was removed from the tanks to a depth of 35 to 40 feet below ground surface. Soil that was saturated with fuel oil or had olfactory or PID indications of hydrocarbons present was excavated by a track hoe, hauled to a treatment location on an abandoned paved airstrip, and stockpiled on plastic sheets. The stockpiled soils had an average TRPH concentration of 3,100 mg/kg (the maximum observed was 11,000 mg/kg). BTEX was <100 mg/kg. The soil is being remediated using above ground biotreatment (landfarming). In landfarming, soil microbes use petroleum hydrocarbons as their primary carbon source. Soil tilling supplies sufficient oxygen to the soils for biodegradation and produces a homogeneous mixture of soil, moisture, and added nutrients. Nutrients including available nitrogen (N), phosphorous (P), and various trace elements were added once by application of an agricultural fertilizer in aqueous solution. The thickness of the stockpiled soils during treatment was 14 to 18 inches.

17. DURATION OF REMEDIATION:- The treatment began in July 1992 and completed in September 1993.

18. COST OF REMEDIATION:- The total estimated cost was \$60,340 which approximated to \$17 per ton of soil excavated and treated.

19. RESULTS:- 9,000 cubic yards of soil were removed from the excavation. 3,000 cubic yards of this were clean soil removed from over the tanks.

20. TRAINING PROGRAM:-None.

21. OTHER INFORMATION:- Adequate space for landfarming is required. Time is required for biotreatment. For example, it is slower than other treatment method, such as incineration. Soils must be excavated for landfarming to be used.

22. CONCLUSIONS:- Landfarming (above ground bioremediation) appear to have been successful at this site with all the measured levels after treatment being much below the regulatory standards.

23. REFERENCES:- From **internet**, with location [HTTP://128.174.5.51/denix/Public/Library/Remedy/remedy.html](http://128.174.5.51/denix/Public/Library/Remedy/remedy.html).

24. KEY WORDS:- Contaminated soil, UST, Land farming, BTEX, Bioremediation.

25. CONTACT PERSONS:- None.

CASE STUDY [44] . 6/89

1. **TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Other site (not Superfund, DOT, RCRA, DOE or DOD)
2. **LOCATION :-** At a warehouse, New Jersey.
3. **NATURE OF SOIL:-** The subsoil consisted of layers of sandy loam, loam, and silty loam.
4. **AREA OF SITE / CONTAMINATED SITE:-** Approximately 920 cubic meters (1200 cubic yards) of soil needed treatment. The site consisted of 32,000 L (8,400 gal) of diesel fuel spilled into the soil.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** Not available.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Information to be collected.
7. **SITE CHARACTERIZATION:-** The surface and subsoil consisted of layers of sandy loam, loam, and silty loam. Permeability is moderately rapid in the subsoil and the available water capacity was high.
8. **MAJOR CONTAMINANTS:-** Total Petroleum Hydrocarbons (TPH) and Metals.
9. **SOURCE OF CONTAMINANTS:-** The contamination was due to a spill from the dispensing nozzle of an under ground storage tank.
10. **CONCENTRATION OF CONTAMINANTS :-**The results from the sampling and analysis indicated TPH concentrations of 1470 ppm. The concentration of metals was well below the regulatory limits.
11. **REGULATIONS:-** The cleanup levels were based on the New Jersey Pollutant Discharge Elimination System- Discharge to Groundwater (NJPDES-DGW) regulations.
12. **SPECIFICATIONS:-** The regulatory level as per NJPDES-DGW for TPH was 100 mg/kg.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:- Biological Land Treatment.
14. **CONTAINMENT TECHNOLOGY:-**None.
15. **RISK ASSESSMENT:-** Not available.
16. **DESCRIPTION OF TECHNOLOGY:-** Land treatment is described as the managed treatment and ultimate disposal process that involves the regulated application of the waste to a soil. For land treatment of contaminants under aerobic conditions, oxygen transfer into soil is generally considered to be the limiting factor for remediation of the soil. Oxygen transfer into the soil was provided by a soil ripper and it is combined with a bottom plow for effective aeration. Excess water drained from the treatment cell through the draining system was pumped to the holding pools outside the treatment system.

Samples were collected and analyzed on a weekly, monthly, and quarterly basis to assess biological treatment. The soil in the cell was monitored regularly for moisture content, pH, mineral nutrient concentrations, and aerobic bacterial population density. After written approval was received from the NJDEP that the TPH content of the soil was less than 100 mg/kg, the treatment was decided for closure.

17. **DURATION OF REMEDIATION:-** The biological land treatment began in September 1989 and was concluded in November 1990.
18. **COST OF REMEDIATION:-** Information not available.
19. **RESULTS:-** Approximately 920 cubic meters of soil were excavated and treated from the contaminated area. The TPH concentrations were below 100 mg/kg at the closure of the treatment.
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** None.
22. **CONCLUSIONS:-** The project was a success and had operated for one year. Biological land treatment was proved to be a viable option for the remediation of diesel fuel contaminated soils. The diesel fuel contaminated soil was amenable to enhanced land treatment by indigenous microorganisms when the soil was supplemented with mineral nutrients and under proper conditions of moisture and pH.
23. **REFERENCES:-** Troy M.A., Berry S.W., Jerger D.E., "Biological Land Treatment of Diesel Fuel Contaminated Soil", Bioremediation: A Field Experience, Call Number TD 192.5.B557, 1994, pp. 145-160.
24. **KEY WORDS:-** Contaminated soil, Bioremediation, Diesel Fuel, TPH, Land treatment.
25. **CONTACT PERSONS:-**None.

CASE STUDY [45] . 2/88

1. **TYPE OF PROJECT:-**
 - (a) Treating contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Other site (not Superfund, DOT, RCRA, DOE or DOD)
2. **LOCATION :-** Grayling, Michigan.
3. **NATURE OF SOIL:-** The subsoil consisted of mixed sand and intermittent clay.
4. **AREA OF SITE/CONTAMINATED SITE:-** 8,400 cubic meters (11,000 cubic yards) of soil needed treatment.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** The depth of groundwater is reported to be 3.0 to 4.6 m (10 - 15 ft.).
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Information to be collected.
7. **SITE CHARACTERIZATION:-** The subsoil consisted of mixed sands and intermittent clay. The hydraulic conductivity at the site was 10^{-2} to 10^{-3} cm/sec.
8. **MAJOR CONTAMINANTS:-**The contamination was due to the presence of diesel fuel. The major contaminants were BTEX, and total petroleum hydrocarbons (TPH).
9. **SOURCE OF CONTAMINANTS:-** The contamination was due to leaking of diesel fuel from an underground fuel transfer pipe.
10. **CONCENTRATION OF CONTAMINANTS :-** The concentrations of BTEX were 10,500 ppb on an average and that of TPH were 1,700 ppm.
11. **REGULATIONS:-** The cleanup goal for TPH concentration was 10 ppm..
12. **SPECIFICATIONS:-** Information to be collected.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:- Bioremediation using Bioreactors.
14. **CONTAINMENT TECHNOLOGY:-**None.
15. **RISK ASSESSMENT:-** Not available.
16. **DESCRIPTION OF TECHNOLOGY:-**The site provided a typical "ideal" Bioremediation scenario. The bioremediation system was sized to process a 95 to 132 L/min flow rate in the aboveground bioreactor. A series of 6 deep recovery wells were installed along the axis of the groundwater dissolved contaminant plume. Nutrient loading was balanced based on the anticipated carbon loading observed in the site assessment and biofeasibility evaluation. Diesel fuel degrading microorganisms were introduced into the bioreactors to accelerate colonization of the submerged media in the bioreactors. The effluent of the reactors was collected in a tank. Additional nutrients were added, and then the treated effluent containing the nutrients, dissolved oxygen, and acclimated bacteria derived from the

bioreactors was pumped to two sets of horizontal recharge lines laid in the vadose zone. During the period of treatment, 64 million liters of groundwater were processed. Despite exposure to biologically nonconductive temperatures, BTEX removal efficiencies stated above 90% during the project and were generally closer to 100% during the warmer months. The source of residual contamination of TPH is the vadose soil. While treating the soil, samples were collected after 3, 8, and 12 months of system operation. Final concentrations of nitrogen and phosphorus in the soil averaged 1.17 and 0.12 ppm, respectively, indicating that the application of these mineral nutrients was effective in limiting the amount of residual nutrients in the soil.

17. **DURATION OF REMEDIATION:-** The bioremediation system was installed in September 1988 and was completed in April, 1990.
18. **COST OF REMEDIATION:-** The cost for the cleanup ranged from \$300,000 to \$400,000 which averaged to \$39 to \$ 59 per cubic meter.
19. **RESULTS:-** BTEX concentration was reduced in the areas of heaviest contamination from 242,000 ppb to 50 ppb, while TPH concentrations were reduced from 20,500 ppm to less than 10 ppm.
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** None.
22. **CONCLUSIONS:-** Bioremediation was shown to be an effective technology for treating soil and groundwater contaminated by biodegradable chemicals such as petroleum hydrocarbons. There was 99.8% removal of BTEX, and 70.6% of TPH at the conclusion of the treatment.
23. **REFERENCES:-** Lieberman M. T., Schmitt E. K., Caplan J. A., "Remediation of Soil and Groundwater Contaminated With Petroleum Hydrocarbons Using the Bioremediation System", Bioremediation: Field Experience, Call Number TD 192.5.B557, 1994, pp. 477 - 490.
24. **KEY WORDS:-** Petroleum substances, Contaminated soil, Bioreactors.
25. **CONTACT PERSONS:-**None.

CASE STUDY [46] . 7/89

- 1. TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Other site (not Superfund, DOT, RCRA, DOE or DOD)
- 2. LOCATION :-** Detroit, Michigan.
- 3. NATURE OF SOIL:-** The subsoil consisted of mixed sand and homogeneous native silty clay.
- 4. AREA OF SITE / CONTAMINATED SITE:-** The area of the site was extended to 5,570 square meters. 40,500 cubic meters (11,000 cubic yards) of soil needed treatment.
- 5. DEPTH OF GROUND WATER / CONTAMINATION:-** The contamination was extended to 6m depth.
- 6. ENVIRONMENTAL SITE ASSESSMENT:-** Information to be collected.
- 7. SITE CHARACTERIZATION:-** The site investigation has shown that approximately 6m of contaminated fill was underlain by approximately 20 m of relatively homogeneous, native silty clay. The groundwater of the area did not contain significant concentrations of dissolved lead. The lead contamination present in the fill soils appeared to be bound to the soil matrix and not highly mobile.
- 8. MAJOR CONTAMINANTS:-** Lead.
- 9. SOURCE OF CONTAMINANTS:-** The contamination was due to past industrial discharges into the soil.
- 10. CONCENTRATION OF CONTAMINANTS :-** The concentration of lead in the soil was 33,000 ppm.
- 11. REGULATIONS:-** The regulations of the treatment were followed as per Michigan Department of Natural Resources.
- 12. SPECIFICATIONS:-** Information to be collected.
- 13. TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:- None.
- 14. CONTAINMENT TECHNOLOGY:-** In-place Encapsulation using cement-bentonite slurry wall with flyash admixture around the contaminated area followed by capping of the soils at the surface.
- 15. RISK ASSESSMENT:-** The results of risk assessment were to establish a target cleanup level of 1,000 ppm total lead. All soils having total lead concentrations greater than 1,000 ppm were intended to be encapsulated within the cell.
- 16. DESCRIPTION OF TECHNOLOGY:-** The soil-bentonite slurry wall was constructed in-situ using a technology called deep soil mixing. This technology uses a large diameter

mixing blade that is mounted on a drilling rig to construct a continuous, in-situ cutoff wall formed by tangential, overlapping soil-bentonite columns. The in-situ containment cell was constructed using conventional trenched methods with imported soil materials. The fill materials excavated to create the trench was disposed off at a licensed facility. It had been observed that cement-bentonite mixture would produce higher permeabilities than a soil-bentonite mixture, and that the addition of fly ash to the mix would raise the permeability further. The mix design was 16% cement, 11% fly ash, 3% bentonite and 70% water (all by weight). The selected mix resulted in the permeability of the order of 3.0×10^{-6} cm/sec. The slurry wall was designed to be a minimum of 0.6 m thick.

17. **DURATION OF REMEDIATION:-** Information not available.
18. **COST OF REMEDIATION:-** The proposed cost of remediation was \$8,000,000.
19. **RESULTS:-** The remediation was based on both risk assessment and cost effective solution and was successful.
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** None.
22. **CONCLUSIONS:-** The in situ containment technologies employed resulted in the development of lead contaminated area which was put into use as parking lot and for other purposes that protects the public.
23. **REFERENCES:-** Grant J. M., Smits B. S., Swaffar K. M., "In situ Remediation of the Geoenvironment", Geotechnical Special Publication No.71, ASCE.
24. **KEY WORDS:-** Containment, Lead, Contaminated soil.
25. **CONTACT PERSONS:-**None.

CASE STUDY [47] . 1/84

1. **TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) PSA, ESI and Site clean-up (HWMP - PHASE I, PHASE II and PHASE IV).
 - (c) Other site (not Superfund, DOT, RCRA, DOE or DOD)
2. **LOCATION :-** Tacoma Spur Freeway (SR 705), Tacoma, Washington State.
3. **NATURE OF SOIL:-** Not known.
4. **AREA OF SITE / CONTAMINATED SITE:-** Not known.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** Not known.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** To reconstruct the history of the site, newspapers, books, maps, and photos were reviewed. Preliminary subsurface borings were also used.
7. **SITE CHARACTERIZATION:-** A series of 29 soil borings/monitoring wells was used to define types and extent of soil and groundwater contamination. Priority pollutant analyses based on both organic vapor readings and on visual classification were made on selected samples. Analyses findings were compared with the list of contaminants likely to result from coal gasification activities.
8. **MAJOR CONTAMINANTS:-** Polycyclic aromatic hydrocarbons (PAHs) were the contaminants of most concern.
9. **SOURCE OF CONTAMINANTS:-**
 - a) Coal gasification plant.
 - b) Two large buried tanks filled with tar waste.
 - c) Copper contamination from ore spilled in an old train derailment.
10. **CONCENTRATION OF CONTAMINANTS :-** PAH concentrations greater than 1%.
11. **REGULATIONS:-** Washington State dangerous waste regulations (WAC 173-303) classify waste containing 1 percent or more total PAH (as quantified by Washington Department of Ecology's (WDOE's) PAH test) as extremely hazardous waste. Lower concentrations are not officially classified but are generally referred to as problem waste. Problem waste materials fall into a gray area which contains no clear cut regulations to guide disposal: they are not entirely clean, yet at the same time not dirty enough to necessitate the stringent disposal procedures required for extremely hazardous waste.
12. **SPECIFICATIONS:-** Metals, volatile organics, and other contaminant concentrations found were judged to fall below federal and state waste and drinking water classification standards.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:- Fifteen thousand and nine hundred tons (15,900) of extremely hazardous waste (PAH concentration > 1%) was removed and disposed to a hazardous waste facility in Arlington, Oregon.

14. **CONTAINMENT TECHNOLOGY:-** Three on-site concrete vaults were specially designed to store 26,450 tons of problem waste (PAH concentration < 1%).
15. **RISK ASSESSMENT:-** None.
16. **DESCRIPTION OF TECHNOLOGY:-** Not known.
17. **DURATION OF REMEDIATION:-** Not known.
18. **COST OF REMEDIATION:-** The total cost is approximately \$6 million.
Handling and disposal of extremely hazardous waste: \$4 million.
Handling and disposal of problem waste: \$550,000.
Handling and disposal of copper contaminated soil: \$600,000.
Treatment of contaminated water: \$350,000.
Consulting services: \$350,000.
19. **RESULTS:-** The project was successful with the concentration of PAH less than the specified levels.
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** From the experience gained on the Spur Project, WSDOT has developed a Hazardous Waste Response Program, which includes WSDOT "Hazardous Waste Guidelines." The guidelines describe general procedures to be used if hazardous waste is discovered on future WSDOT projects, and address both the design and construction phases of a project.
22. **CONCLUSIONS:-** Separation of the contaminated material into extremely hazardous waste and problem waste sharply reduced the total cleanup costs.
Using the on-site concrete vaults to permanently store problem waste effectively isolated that contamination from its surroundings.
The cost of building the vaults and depositing the problem waste on site was \$6 million lower than the cost of transporting and disposing of the same amount of material at the hazardous waste site in Arlington.
23. **REFERENCES:-** Oscar, R, G., and Mark, G. U., "Washington State DOT Meets the Challenge of Hazardous Waste," Transportation Research Record 1192, pp. 85-93.
24. **KEY WORDS:-** Excavation, Land disposal, Contaminated soil, PAH.
25. **CONTACT PERSONS:-** None.

CASE STUDY [48] . 10/92

1. **TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) ESI, RI/FS and Site clean-up (HWMP - PHASE II, PHASE III and PHASE IV).
 - (c) SDOT site
2. **LOCATION :-** Interstate highway I-595, Fort Lauderdale, Broward County, Florida.
3. **NATURE OF SOIL:-** Sand.
4. **AREA OF SITE / CONTAMINATED SITE:-** Not available.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** The depth of groundwater extended upto 5 ft and the contamination extended up to 50 ft.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Upon reviewing the data provided in the contaminant assessment report (CAR), it was determined that additional investigation was necessary to delineate the horizontal and vertical extents of the affected groundwater and soils.
7. **SITE CHARACTERIZATION:-**
 - 1) In addition to the existing wells, additional monitoring wells were installed to determine the plumes' horizontal and vertical extent.
 - 2) Groundwater samples were collected from newly installed wells and existing wells.
 - 3) The parcels were surveyed, depth to water was measured, and water table contour maps were constructed.
8. **MAJOR CONTAMINANTS:-** Petroleum based contaminants (Benzene, volatile organic aromatics).
9. **SOURCE OF CONTAMINANTS:-** Oil company, gasoline station.
10. **CONCENTRATION OF CONTAMINANTS :-** Benzene: up to 2700 ppb; Volatile organic aromatics: up to 27000 ppb.
11. **REGULATIONS:-** Petroleum contaminated sites in Florida are administered by FDEP under the criteria of Chapter 17-770 Florida Administrative Code (FAC), *Petroleum Contamination Site Cleanup Criteria*. These criteria require that petroleum-contaminated sites undergo a sequence of studies and submittals to FDEP designed to identify the extent of the contamination and the plans for remedial action. The principal documentation required to be submitted is:
Contamination assessment report (CAR), Remedial action plan (RAP), and Site rehabilitation completion report (SRCR).
EPA regulations: 1ppb for benzene and 50 ppb for total VOA.
12. **SPECIFICATIONS:-** None.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:- Horizontal drains and vertical wells for recovery, clarification, filtration, and carbon adsorption for treatment and surface infiltration for disposal.
14. **CONTAINMENT TECHNOLOGY:-** None.

15. **RISK ASSESSMENT:-** None.
16. **DESCRIPTION OF TECHNOLOGY:-** Groundwater recovery: The horizontal drains consisted of corrugated, perforated PVC pipes, 40 to 60 m long and 12.7 cm in diameter. The horizontal drains were installed typically at 4.88 to 5.49 m below land surface using a trencher. The trencher was configured to excavate the trench, place the pipe, and backfill the trench in a single operation. The corrugated pipe was fitted with continuous geotextile filter fabric cover to filter out fine sand particles.
Vertical recovery wells were used to recover deeper elements of the plume of contaminated groundwater. These deep wells were 20.3 cm in diameter and screened from 1.53 to 10.68 m below land surface and from 6.10 to 15.25 m near the middle of the plume. The location of the screened interval was based on the depth of the plume being captured.
Groundwater treatment: The recovered groundwater was pumped from the drains or wells through a filtration system to remove suspended solids. The system consisted of a clarifier to remove the larger particles followed by bag filters to remove the fine particles (>50 μ m). The groundwater was then passed through a granular activated carbon system. A portion of the treated effluent was routed back over the site in designated areas to flush the vadose zone soils.
Treated water discharge: The effluent from the groundwater treatment system was discharged into three recharge ponds. Additionally, five horizontal perforated PVC pipes, paralleling the drain pipes, were installed above the horizontal under drains at a depth of approximately 5 ft to discharge treated effluent.
17. **DURATION OF REMEDIATION:-** 3 months (Mid December 1991-mid February 1992).
18. **COST OF REMEDIATION:-** \$750,000.
19. **RESULTS:-** Groundwater remediation was effective at the site, removing more than 99% of the benzene and 95% of the total volatile organic aromatics.
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** Samples from the monitoring wells and other points of interest were collected and analyzed daily to assess the conditions of the plume distribution. After periods of rainfall, elevated contaminant levels were noted in the effluent and most of the monitoring wells around the center of the plume at the site. These anomalous readings were attributed to desorption of contaminants from the vadose zone soil matrix by infiltration of rainfall. When this phenomenon was discovered, it was decided that the treated effluent would be reapplied to the site by horizontal drains to flush the soil.
22. **CONCLUSIONS:-**
- A method of soil flushing within the vadose zone must be implemented to minimize the rebound effect typical of most pump and treat remedial operations.
 - Given an expedited construction schedule and defined budget, it was imperative that there be frequent and thorough coordination among the regulatory agencies, contracting agency or client, remedial contractor or consultants, and other participating entities.
 - Because of the close and intense coordination required, each participant had a point of contact.
23. **REFERENCES:-** Berry, J. G., and Frantz, L., "Expedited Remedial Action by Florida Department of Transportation at I-595 and Davie Boulevard Corridor Expansion Project: Case History," Transportation Research Record 1475, pp. 99-109.
24. **KEY WORDS:-** Florida DOT, groundwater, benzene, volatile organic aromatics, horizontal drains, vertical wells, clarification, filtration, carbon adsorption.

CASE STUDY [49] . 3/88

1. **TYPE OF PROJECT:-**
 - (a) Treating contaminated soil .
 - (b) ESI and Site clean-up (HWMP - PHASE II and PHASE IV).
 - (c) SDOT site
2. **LOCATION :-** I-287 in northern New Jersey.
3. **NATURE OF SOIL:-** Not available.
4. **AREA OF SITE / CONTAMINATED SITE:-** Area of site is 4-ha.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** Not available.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Not available.
7. **SITE CHARACTERIZATION:-**
 - 1) Preliminary soil sampling was carried out in areas of the USTs and ASTs by the NJDOT during construction.
 - 2) Additional soil sampling in the interiors of the buildings and drum storage areas.
 - 3) Thirteen shallow monitoring wells were installed to obtain ground water samples and was found that there was no threat to the ground water.
8. **MAJOR CONTAMINANTS:-** Petroleum hydrocarbons were detected in the areas around the ASTs and USTs. Contaminants such as base/neutral organic compounds consisting of primarily of polyaromatic hydrocarbons.
9. **SOURCE OF CONTAMINANTS:-** Concrete pipe manufacturing plant (Two above ground storage tanks and four underground storage tanks).
10. **CONCENTRATION OF CONTAMINANTS :-** TPH: 340 to 23000 ppm, 74000 ppm from inside the building
11. **REGULATIONS:-** Followed New Jersey Department of Environmental Protection and energy (NJDEPE) regulations.
12. **SPECIFICATIONS:-** The excavated soils from the remedial activities were analyzed for the federal Resource Conservation Recovery Act (RCRA) waste classification parameters of Extraction Procedure (EP) toxicity metals, corrosivity, ignitability, total petroleum hydrocarbons (TPHs) and reactivity to cyanide and sulfide.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:- The stockpile from the Building 1 interior (25 m³) which contained TPHs at 74000 ppm was manifested, transported, and disposed of as a hazardous waste. The rest of the contaminated soil (13760 m³) was to be placed directly beneath the 70-cm-thick roadway pavement box, which eliminated the potential for infiltration and resultant leaching of the contamination into the environment.
14. **CONTAINMENT TECHNOLOGY:-** Not applicable.

15. **RISK ASSESSMENT:-** A qualitative risk analysis was performed as a part of the soil reuse plan. The analysis evaluated short-term and long-term pathways and exposure rates of the contaminants in relation to the guidelines of the National Institute for Occupational Safety and Health and the American Conference of Governmental Industrial Hygienists.
16. **DESCRIPTION OF TECHNOLOGY:-** There was no treatment technology adopted except that part of the soil was manifested, transported, and disposed of as a hazardous waste and the rest of the soil, which was classified as ID-27 material (contaminated but nonhazardous dry industrial waste), was reused as highway embankment material at \$9/m³.
17. **DURATION OF REMEDIATION:-** Not available.
18. **COST OF REMEDIATION:-** Not available.
19. **RESULTS:-** A soil reuse plan was developed which addressed the types of soil contamination present, proposed method of reuse, proposed construction methods, and health and safety requirements during construction.
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** The NJDOT presented to the NJDEPE's Bureau of Hazardous Waste Classification and Regulation a waste classification sampling plan in November 1988 to characterize the 13,760 m³ soil stockpile. NJDEPE accepted a modified form of the sampling plan because of the large volume of soil to be sampled. The NJDOT plan modified NJDEPE's standard sampling protocol of one five-part composite sample per 75 m³ to one five-part composite sample per 200 m³. The soil stockpile was systematically divided into 72 sampling units, with each unit representing 200 m³ in accordance with the modified sampling plan.
22. **CONCLUSIONS:-** By reusing the contaminated soils within the project area, a savings of approximately \$2,000,000 in disposal costs was realized by NJDOT.
23. **REFERENCES:-** Fekete, A., Caiazza, N., Morgan, L. O., and Dunne, K. P., "Interstate 287 Wetland Mitigation Project: Turning an Environmental Liability into an Environmental Asset," Transportation Research Record 1444, pp. 64-68.
24. **KEY WORDS:-** NJDOT, contaminated soil, Petroleum hydrocarbons, polyaromatic hydrocarbons, disposal, soil reuse.
25. **CONTACT PERSONS:-** None.

CASE STUDY [50] . 1/95

1. **TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) ESI and Site clean-up (HWMP - PHASE II and PHASE IV).
 - (c) Other site (not Superfund, DOT, RCRA, DOE or DOD)
2. **LOCATION :-** Northern New Jersey.
3. **NATURE OF SOIL:-** Not available.
4. **AREA OF SITE / CONTAMINATED SITE:-** Excavation area was approximately 1148 m².
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** Average depth of excavation was approximately 1.83 m.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Three geophysical techniques: Magnetometer (MAG), electromagnetics (EM), and ground penetrating radar (GPR) were used during the preliminary site investigation to assess the amount of buried waste and drums and to delineate their physical extent.
7. **SITE CHARACTERIZATION:-** Field testing kits employing immunoassay technology were used to segregate soil and minimize the number of post excavation samples submitted for laboratory analysis.
8. **MAJOR CONTAMINANTS:-** Polychlorinated biphenyl (PCB).
9. **SOURCE OF CONTAMINANTS:-** Buried drums.
10. **CONCENTRATION OF CONTAMINANTS :-** Above 50 ppm.
11. **REGULATIONS:-** The federal Toxic Substance Control Act (TSCA) regulates PCB wastes as hazardous if their concentration is > 50 ppm. The New Jersey Department of Environmental Protection did not require the remediation of surface soil (0 to 0.61 m) with PCB concentrations below 0.49 ppm on residential sites and or up to 2 ppm on sites designated as industrial. For subsurface soils (below 0.61 m), soil with PCB concentrations up to 100 ppm could remain in place. However, if the soil is excavated and brought to the surface, it is judged a hazardous waste under TSCA if it contains PCB concentrations greater than 50 ppm; solids must be disposed of in a specially designed lined landfill, and liquids, in a specially licensed incinerator.
12. **SPECIFICATIONS:-** None.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:- Fill during highway construction, disposal to a landfill.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** None.

16. **DESCRIPTION OF TECHNOLOGY:-** During phase 1, approximately 9904 Mg of overburden material that was mounded over the buried drums was removed and used as fill during mainline highway construction. In phase 2, the actual hazardous waste remediation, the decomposed drums and drummed wastewere removed from the excavation, loaded directly in dump trucks, and taken to a specially constructed, TSCA-regulated landfill.
17. **DURATION OF REMEDIATION:-** Not available.
18. **COST OF REMEDIATION:-** The actual site remediation cost was \$3.8 million. The use of immunoassay testing kits, up front negotiation of cleanup levels, soil segregation, and soil reuse resulted in a \$1 million savings from the estimated cleanup cost.
19. **RESULTS:-** To compare the results of PCB analysis by field and laboratory methods, six soil samples were analyzed for PCBs by both the field PCB test and by the gas chromatography/electron capture detector method according to the EPA contract Laboratory Program. The results obtained by the field testing method for two samples are greater than those obtained by the laboratory method.
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** Immunoassay testing techniques were selected for PCB analysis because they possess a significant advantage over other field screening tests in that the chemistry is PCB specific. This feature precludes interference from other compounds and from native chlorine, such as that typically found in certain soils and other waste mixtures. Immunoassay technology is a semiquantitative colorimetric method, which uses tubes coated with antibodies that specifically detect PCBs. The test is "competitive," since the immobilized antibodies will bind to the PCB contaminant in a sample, the enzyme conjugate supplied with the test kit, or both in proportion to their relative concentrations. After the used tubes are washed to remove the sample solution, leaving behind the enzyme conjugate and PCB molecule immobilized by the antibodies, a chromogenic substrate that produces a vivid blue color in the presence of horseradish peroxidase is added to the test tubes. Color production is inversely proportional to the concentration of PCB contaminant in the sample: the more enzyme conjugate present, the faster the solution turns color and the darker it becomes. On the other hand, the more sample PCB molecules present, the fewer sites available for the enzyme conjugate and the lighter the solution. Therefore, the depth of the color determines the concentration range of the sample PCB solution.
22. **CONCLUSIONS:-** The geophysical surveys provided a noninvasive technique for defining the limits of the buried drums and approximating the amount of waste and potentially impacted soil before the start of excavation. After the excavation was complete, geophysical surveys helped establish that all of the buried drums had been removed. Field screening immunoassay testing for PCBs allowed for a rapid and inexpensive way to segregate the soils and minimize the number of post excavation samples submitted for laboratory analysis. The site was remediated below the NJDEP proposed cleanup levels. No residual contamination was left on site, as indicated by the results of the postexcavation sample analyses. The environmental solution resolved the contamination issue without modifying the construction ramp and highway design.
23. **REFERENCES:-** Ferrel, S. L., Ivanciu, I., and Sweet, J., "Geophysical and Immunoassay Techniques to Accelerate Hazardous Waste Site Remediation," Transportation Research record 1475, pp. 45-49.
24. **KEY WORDS:-** Buried drums, contaminated soil, polychlorinated biphenyl (PCB), geophysical, magnetometry, ground penetrating radar, electromagnetics, immunoassay testing, Landfill.

CASE STUDY [51] .1/91

1. **TYPE OF PROJECT:-**
 - (a) Treating contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Superfund site
2. **LOCATION:-** Southeastern Wood Preserving Site, Canton, Mississippi.
3. **NATURE OF SOIL:-** Not available.
4. **AREA OF SITE / CONTAMINATED SITE:-** 14,140 tons (10,500 cubic yards) of soil needed treatment.
5. **DEPTH OF GROUNDWATER TABLE/CONTAMINATION:-** Not available.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Excavation was based on a visual assessment of contamination. EPA sampled this material in April 1989, and found it to be contaminated with polynuclear aromatic hydrocarbons (PAHs), at levels of approximately 4,000 mg/kg, The contaminated material from the lagoon was classified as a RCRA K001-listed hazardous waste.
7. **SITE CHARACTERIZATION:-** Various types of debris were present in the contaminated soil and sludge excavated at the site. The debris included large stones, plastic sheeting, concrete, and railroad ties.
8. **MAJOR CONTAMINANTS:-** Polynuclear aromatic hydrocarbons (PAHs).
9. **SOURCE OF CONTAMINANTS:-** Creosote wood preserving, Manufacturing Process, Surface Impoundment/.
10. **CONCENTRATION OF CONTAMINANTS:-** The excavated material at the site contained PAH concentrations of approximately 4,000 mg/kg dry weight for total PAHs and from 1,000 to 2,500 mg/kg dry weight carcinogenic PAHs.
11. **REGULATIONS:-** Cleanup goals were developed based on the results of bench-scale and field pilot studies using bioremediation and a site-specific health-based risk analysis. cleanup goals for this application:
 - 950 mg/kg dry weight soil solids total PAHs; and
 - 180 mg/kg dry weight soil solids of benzo(a)pyrene (B(a)P) - equivalent carcinogenic PAHs.
12. **SPECIFICATIONS:-** At the beginning of this application, soil was classified as RCRA hazardous waste K001. However, in February 1992, soon after full-scale operation began, an LDR treatability variance was obtained so that the soil would not need to be treated to meet the LDR treatment standards for K001.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology :- None.
 - (b) Slurry-phase bioremediation was selected for this application on the basis of cost.

14. CONTAINMENT TECHNOLOGY:- None.

15. RISK ASSESSMENT:- Details to be collected.

16. DESCRIPTION OF THE TECHNOLOGY:- The slurry phase bioremediation system used at Southeastern Wood Preserving included a power screen, a slurry mix tank, four slurry phase bioremediation reactors (bioreactors), and a slurry dewatering unit. This system, shown in Figure 2, was used to separate out the larger particles (greater than 200 mesh, or 0.0029 inches) from the stockpiled soil and sludge, and to biologically treat the remaining soil and sludge particles (less than 200 mesh). As shown on Figure 2, soil and sludge from the stockpile were power-screened to remove debris greater than 0.5 inches such as large stones, plastic sheeting, and railroad ties. The power-screening step removed approximately 450 cubic yards of material. Soil and sludge that passed the power screening step were loaded into a slurry mix tank for soil washing. The mix tank contained three compartments:

- Compartment No. 1 - Water was added to slurry the solids.
- Compartment No. 2 - The slurry was pumped to a shaker screen to remove debris between 12 mesh (0.0661 inches) and 0.5 inches. Approximately 1,500 cubic yards of debris were removed by the shaker screen.
- Compartment No. 3 - A hydrocyclone removed approximately 1,500 cubic yards of materials (sand) and other materials between 200 mesh and 12 mesh.

In addition, nutrients and slurry conditioning chemicals (including a dispersant and defoaming agent) were added and mixed with the slurry in this compartment.

17. DURATION OF REMEDIATION:- The period of operation was between 1991-1994.

18. COST OF REMEDIATION:- The total costs for activities directly attributed to treatment corresponds to \$170 per ton (\$230 per cubic yard) of soil and sludge treated.

19. RESULTS:- The average total PAH concentration was reduced from 8,545 mg/kg to 634 mg/kg, which corresponds to a treatment efficiency of 93 percent. The average B(a)P-equivalent concentration was reduced from 467 mg/kg to 152 mg/kg, or 67 percent. Carcinogenic PAHs showed a similar reduction, from 1,160 mg/kg to 374 mg/kg, or 67 percent.

20. TRAINING PROGRAM:- None.

21. OTHER INFORMATION:- None.

22. CONCLUSIONS:- The technology was successful.

23. REFERENCES:- This case study was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Radian International under EPA Contract No. 68-W3-0001 and U.S. Army Corps of Engineers Contract No. DACA45-96-D-0016.

24. KEYWORDS:- Contaminated soils, Petroleum substances, Slurry bioreactors

CASE STUDY [52] . 10/93

1. TYPE OF PROJECT:-

- (a) Treating saturated contaminated soil .
- (b) ESI, RI and Site clean-up (HWMP - PHASE II, PHASE III and PHASE IV).
- (c) Superfund site

2. LOCATION:- Commerce City, Colorado.

3. NATURE OF SOIL:- Sandy loams, loamy sands.

4. AREA OF SITE / CONTAMINATED SITE:- 684 pounds of soil needed treatment.

5. DEPTH OF GROUNDWATER TABLE/CONTAMINATION:- Not known.

6. ENVIRONMENTAL SITE ASSESSMENT:- EPA conducted a Remedial Investigation (RI) at the site from 1984 to 1988. Soils identified as contaminated with pesticides were excavated and hauled off site for incineration. Additional soil contamination at the site was identified by the vendor as consisting of mixed petroleum and halogenated hydrocarbons, with some of the hydrocarbons classified as semivolatile or non-volatile, including hydrocarbons of aromatic range and heavier hydrocarbons to C-24.

7. SITE CHARACTERIZATION:- The Moisture Content was found to be 3.0 - 30.1%. The RI indicated that the site is underlain by alluvial deposits consisting of high-permeability sands and gravels, interbedded with low-permeability clayey and silty layers. Two groundwater units underlie the site, separated by a relatively impermeable layer 10 to 20 feet thick. The upper deposit is up to 40 feet thick and is primarily unsaturated (i.e., contains little to no groundwater). The lower deposit is up to 44 feet thick and generally exists under confined conditions.

8. MAJOR CONTAMINANTS:- Halogenated volatile organic compounds (VOCs), specifically chloroform, methylene chloride, trichloroethene (TCE), and tetrachloroethene (PCE), and nonhalogenated VOCs, including mixed petroleum hydrocarbons.

9. SOURCE OF CONTAMINANTS:- Boiler feed water draining into a common surface drainage.

10. CONCENTRATION OF CONTAMINANTS:- The maximum soil concentrations of halogenated VOCs:
chloroform - 0.820 mg/kg,
methylene chloride - 5.8 mg/kg,
TCE - 0.087 mg/kg, and
PCE - 9.34 mg/kg.

11. REGULATIONS:- The modified ROD specified soil cleanup standards for the four target VOCs as follows: chloroform -0.165 mg/kg, methylene chloride - 0.075 mg/kg, TCE - 0.285 mg/kg, and PCE - 1.095 mg/kg. No soil cleanup standards were identified for the nonhalogenated VOCs.

12. SPECIFICATIONS:- Not known.

13. TREATMENT TECHNOLOGY:-

- (a) Screening technology :- None.
- (b) Selected soil vapor extraction (SVE).

- 14. CONTAINMENT TECHNOLOGY:-** None.
- 15. RISK ASSESSMENT:-** Details to be collected.
- 16. DESCRIPTION OF THE TECHNOLOGY:-** The soil vapor extraction system used at Sand Creek consisted of 31 vertical wells and 1 horizontal well, and was thermally-enhanced by fluid injection with vacuum extraction (referred to as the FIVE system). The wells were grouped into three sub-areas at the site: SVE-1, SVE-2, and SVE-3. Thirteen vertical wells and the horizontal well were located in SVE-1 (wells 101 through 113 and H12). SVE-2 contained 12 wells (wells 201 through 212) and SVE-3 contained 6 wells (wells 301 through 306). Well H12 is a horizontal well, and all other wells are vertical. For several of the wells in each sub-area, operation of the wells was alternated between vacuum extraction and air injection during the course of remediation. Extracted water was separated from the vapors using an air/water separator. Following separation, extracted vapors were diluted with ambient air (between 12% and 50% by volume) and treated using a catalytic oxidizer. The emissions from the catalytic oxidizer were either re-injected into the soil through the vertical and horizontal wells, or released to the atmosphere. The system included two blowers for air injection, operated one at a time.
- 17. DURATION OF REMEDIATION:-** Six months.
- 18. COST OF REMEDIATION:-** The total actual costs for this application were approximately \$2,140,000. The costs directly attributed to treatment correspond to \$39-65 per cubic yard of soil treated (based on a range of soil quantity treated estimates of 31,440 to 52,920 cubic yards, as provided by the vendor) and \$11.70 per pound of VOC removed (based on 176,500 pounds).
- 19. RESULTS:-** Confirmatory soil borings collected in April 1994 showed that the concentrations for all four target contaminants were less than the cleanup standards set in the ROD. The maximum concentration of target contaminants measured in the confirmation soil borings was: chloroform - 0.0099 mg/kg, methylene chloride - not detected, TCE - 0.10 mg/kg, and PCE - 0.28 mg/kg. Approximately 176,500 pounds of total VOCs were extracted during this application, including 3,250 pounds of the four target contaminants.
- 20. TRAINING PROGRAM:-** None.
- 21. OTHER INFORMATION:-** None.
- 22. CONCLUSIONS:-** The treatment indicated that the SVE system used at Sand Creek met the soil cleanup goals for VOCs within 6 months of operation. Soil concentrations were reduced from as high as 9.34 mg/kg (the maximum concentration shown in the RI for tetrachloroethene) to less than the cleanup goals. The maximum concentration of target constituents measured by the off-site laboratory for the confirmation soil borings was: chloroform - 0.0099 mg/kg; methylene chloride - not detected; trichloroethene - 0.10 mg/kg; and tetrachloroethene - 0.28 mg/kg. Less than 20% of the soil boring samples (i.e., soil borings at specific depths) contained at least one target constituent measured at a detectable concentration.
- 23. REFERENCES:-** This case study was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Radian International under EPA Contract No. 68-W3-0001 and U.S. Army Corps of Engineers Contract No. DACA45-96-D-0016.
- 24. KEYWORDS:-** Contaminated soils, Petroleum substances, Soil vapor extraction

CASE STUDY [53] . 2/96

1. **TYPE OF PROJECT:-**
 - (a) Treating contaminated soil and groundwater .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Other site (not Superfund, DOT, RCRA, DOE or DOD)
2. **LOCATION :-** Blaine, Minnesota
3. **NATURE OF SOIL:-** Not available.
4. **AREA OF SITE / CONTAMINATED SITE:-** Approximately 6.8. kg of contaminants must be removed from soil and groundwater.
5. **DEPTH OF GROUND WATER / CONTAMINATION:-** The depth of groundwater is 3-4.57 m. The depth of contamination was 2.74-3.66 m.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Not available.
7. **SITE CHARACTERIZATION:-** The site rests atop an expansive glacial plain. The sand plain consists of primarily brown, fine to medium grained sand. The sand plain is typically present from ground surface to depths of greater than 24.4 m.
8. **MAJOR CONTAMINANTS:-** Gasoline Constituents such as Benzene, Ethyl Benzene, Toluene and Xylene, and PCE (tetrachloroethylene).
9. **SOURCE OF CONTAMINANTS:-** The site was a former gasoline station.
10. **CONCENTRATION OF CONTAMINANTS :-** Not available.
11. **REGULATIONS:-** Not available.
12. **SPECIFICATIONS:-** Not available.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology:- None.
 - (b) Selected technology:- Radio frequency heating enhanced soil vapor extraction and air sparging
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** None.
16. **DESCRIPTION OF TECHNOLOGY:-** Radio frequency heating provides a tool for accelerating site remediation that augments many other site remediation technologies by supplying thermal energy to soils and groundwater. The in situ application of Radio frequency heating provides a subsurface, focused pattern of thermal energy thereby increasing the vapor pressure and bioavailability of contaminants, enhancing soil permeability and reducing the viscosity of liquids.
The equipment to supply the power for radio frequency heating was contained within a mobile trailer and consisted of a 25 kilowatt radio frequency generator. Additional equipment operating the soil vapor extraction and air sparging systems are housed in a separate mobile remediation unit. On March 5, 1996, the SVE portion of the system was

started with anticipated three week heating period. The two soil vapor vents were set at the same flow rate to maintain a uniform vacuum at the radio frequency heating well.

17. **DURATION OF REMEDIATION:-** Three weeks.
18. **COST OF REMEDIATION:-** Not available.
19. **RESULTS:-** The three week demonstration resulted in the significant decreases in both soil and groundwater impact. These reductions are attributed to accelerated volatilization of hydrocarbons by radio frequency heating. Groundwater concentrations were reduced by one or two orders of magnitude in most sampling locations. The remediation resulted in the removal of approximately 6.8 kg of contaminants from soil and groundwater in the treated zone and a measurable decrease in both soil and groundwater impact.
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** None.
22. **CONCLUSIONS:-** The project was a big success and the radio frequency heating can thus be used to remediate soil contaminated with organic contaminants.
23. **REFERENCES:-** Kasevich S. Raymond, Price L. Stephen, Wiberg Dan, Johnson Mark, "Insitu Radio Frequency Heating for Remediation of Soil and Groundwater Contamination" Proceedings of the conference "Insitu remediation of the geoenvironment", Geotechnical Special Publication No.71, pp. 574-589.
24. **KEY WORDS:-** Contaminated soil and groundwater, Radio Frequency heating, BTEX.
25. **CONTACT PERSONS:-** None.

CASE STUDY [54] . 11/93

1. **TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Other (not Superfund, DOT, RCRA, DOE or DOD)
2. **LOCATION:-** At a Federal Aviation Administration Facility in Oklahoma.
3. **NATURE OF SOIL:-** Red brown shale with layers of limestone.
4. **AREA OF SITE / CONTAMINATED SITE:-** The area of the site was 67, 500 square meters.
5. **DEPTH OF GROUNDWATER TABLE/CONTAMINATION:-** Not known.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Details not available.
7. **SITE CHARACTERIZATION:-** The geology beneath the site consists of a red-brown shale with layers of siltstone. The shale is highly weathered and fissile near the surface. The siltstone occurs in well defined layers generally a few centimeters thick. Fracture sets oriented at approximately 90, 45 and 30 degrees to the horizontal have been observed. Groundwater flow appears to occur within fissures and fractures within the weathered shales and siltstones and is confined by overlying less permeable shales. The results of permeability tests indicated hydraulic conductivity ranged from 10-3 cm/sec to 10-2 cm/sec.
8. **MAJOR CONTAMINANTS:-** BTEX.
9. **SOURCE OF CONTAMINANTS:-** The site has previously served as logistical center, training facility, supply depot, research center, and aircraft maintenance and modification center.
10. **CONCENTRATION OF CONTAMINANTS:-** The average benzene concentration was reported to be 3.8 mg/L, and benzene was the only BTEX compound to exceed state cleanup levels.
11. **REGULATIONS:-** Not available.
12. **SPECIFICATIONS:-** Not known.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology :- None.
 - (b) Selected Pneumatic Fracturing.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Details to be collected.
16. **DESCRIPTION OF THE TECHNOLOGY:-** The injection and extraction well borings used for the treatment were fractured to reduce the effect of preferential flow paths during groundwater circulation. Groundwater low rate was maintained at approximately 4.2 liters per minute. A nutrient amendment was initially prepared using diammonium phosphate. Estimates of the biological activity occurring in the aquifer were obtained through a microbial

enumeration technique. Each well was sampled approximately every 14 days for BTEX, TPH and additional nutrients.

17. **DURATION OF REMEDIATION:-** 3 months.
18. **COST OF REMEDIATION:-** Not available.
19. **RESULTS:-** The results indicated a significant decrease in BTEX concentrations between the injection well and observation wells. By four months, the benzene concentration at one of the observation wells was less than the desired state cleanup goal of 0.05 mg/L.
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** None.
22. **CONCLUSIONS:-** The limitation of the in situ biodegradation system in the difficulty encountered in effectively distributing nutrients and electron acceptors to contaminated sites within the aquifer.
23. **REFERENCES:-** Cleirigh D. O., Christopher M., Coryea H., Vaughn C., "BTEX Biodegradation in Fractured Shale" in Proceedings of the conference "In situ remediation of the geoenvironment", Geotechnical Special Publication No. 71, pp. 489-502.
24. **KEYWORDS:-** Contaminated soils, Biological, BTEX
25. **CONTACT PERSONS:-** None.

CASE STUDY [55] . 8/89

- 1. TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Other (not Superfund, DOT, RCRA, DOE or DOD)
- 2. LOCATION:-** Porter field's Marina Village Project, Detroit, Michigan
- 3. NATURE OF SOIL:-** The site is comprised of clay fill soils containing foundry slag and sand, cinders, brick and other foreign materials.
- 4. AREA OF SITE / CONTAMINATED SITE:-** The area of contamination was reported to be 5,570 sq.m.
- 5. DEPTH OF GROUNDWATER TABLE/CONTAMINATION:-** The depth of contamination was reported to be 6m.
- 6. ENVIRONMENTAL SITE ASSESSMENT:-** During an initial environmental sampling and testing program, an area of lead contamination was encountered within the southwest portion of the site. Subsequent studies indicated the lead levels in the soil ranged up to 33,000 ppm. The lead contamination present in the fill soil appeared to be bound to the soil matrix and not highly mobile.
- 7. SITE CHARACTERIZATION:-** The site consisted of relatively homogeneous clay beneath the contaminated deposits to a depth of approximately 20 m. A hydrogeologic study performed using monitoring wells in the region of the proposed containment cell indicated that the groundwater of the area did not contain significant quantities of dissolved lead.
- 8. MAJOR CONTAMINANTS:-** The contamination was mainly due to Lead.
- 9. SOURCE OF CONTAMINANTS:-** The contamination was due to past environmental activities. The site was used for industrial purposes.
- 10. CONCENTRATION OF CONTAMINANTS:-**
- 11. REGULATIONS:-** The regulations followed were as per those of Michigan Department of Natural Resources (MDNR), Michigan Department of Environmental Quality.
- 12. SPECIFICATIONS:-** The results of risk assessment were used to specify the cleanup levels of 1,000 ppm total lead in the soil. All soils having total lead concentrations greater than 1,000 ppm were intended to be encapsulated within the cell. But the cleanup levels are changed according to MDNR to 50 ppm total lead regardless of the findings of the health based risk assessment.
- 13. TREATMENT TECHNOLOGY:-**
 - (a) Screening technology :- Abandoning the site and leaving the contamination in place
 - (b) Selected containment technology.
- 14. CONTAINMENT TECHNOLOGY:-** Selected In-situ Containment Cell for encapsulation.

- 15. RISK ASSESSMENT:-** A health-based risk assessment was performed to consider site features and conditions, future site usage, exposure pathways, and potential impacts to human health and environment. The results of risk assessment were used to specify the cleanup levels of 1,000 ppm total lead in the soil.
- 16. DESCRIPTION OF THE TECHNOLOGY:-** It had been decided to construct the in-situ containment cell using conventional trench methods with imported soil materials. The fill materials excavated to create the trench were disposed at an appropriately licensed facility. A cement-bentonite mixture would produce higher permeabilities than a soil-bentonite mixture, and that the addition of fly ash to the mix would probably raise the permeability further. The design mix consisted of 16% cement, 11% fly ash, 3% bentonite, and 70% water. The slurry wall was designed to be minimum of 0.6 m thick. The in-situ slurry wall was also designed to be keyed to the native clay to create a greater barrier to lateral groundwater movement out of the cell. An additional component of the in-situ containment cell design was the maintenance of an inward gradient at all times to reduce the potential for leaching of lead outside the cell boundary.
- 17. DURATION OF REMEDIATION:-** Not available.
- 18. COST OF REMEDIATION:-** The proposed cost for treatment was \$80,000.
- 19. RESULTS:-** The containment method worked as expected containing the lead contaminated soil. The remediation resulted in the reclamation of the formerly industrial site and the development of an useful community asset.
- 20. TRAINING PROGRAM:-** None.
- 21. OTHER INFORMATION:-** None.
- 22. CONCLUSIONS:-** Although the discovery of hazardous lead concentrations in soil threatened to force cancellation of the project, open communication and negotiations with the MDNR, an innovative cost-effective remediation was developed which was proved to be a success at the site.
- 23. REFERENCES:-**
- 24. KEYWORDS:-** Contaminated soils, Lead, Containment
- 25. CONTACT PERSONS:-** None.

CASE STUDY [56] . 11/92

1. **TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Other (not Superfund, DOT, RCRA, DOE or DOD)
2. **LOCATION:-** Fuel dispensing area, Watertown, New York.
3. **NATURE OF SOIL:-** The soil subsurface comprised of fine-grained well sorted sand
4. **AREA OF SITE / CONTAMINATED SITE:-**
5. **DEPTH OF GROUNDWATER TABLE/CONTAMINATION:-**
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Laboratory analytical results have indicated that the detected petroleum contamination is gasoline and #2 fuel oil. The free product and the petroleum contaminated soil and groundwater appears to be located in a narrow zone hydraulically down gradient and downstream from the fuel dispensing area. Petroleum hydrocarbons and lead have been detected in surface water and sediment samples collected from the stream at locations downstream the dike.
7. **SITE CHARACTERIZATION:-** The soil subsurface comprised of fine-grained well sorted sand. BTEX, total volatile aromatic hydrocarbons and lead were detected in surface water. The unconsolidated material observed is primarily fine grained well sorted sand. The site is unpaved; infiltration precipitation affects contamination mobilization and migration.
8. **MAJOR CONTAMINANTS:-** BTEX.
9. **SOURCE OF CONTAMINANTS:-** Due to leaks from an underground storage tank
10. **CONCENTRATION OF CONTAMINANTS:-** Not available.
11. **REGULATIONS:-** The regulations are defined as per New York Department of Environmental Conservation. The discharge limits are defined as:
 - Benzene : 3mg/L
 - Toluene : 35 mg/L
 - Xylenes : 190 mg/L
 - Ethylbenzene : 8 mg/L
12. **SPECIFICATIONS:-** Not known.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology :- None.
 - (b) Selected Air stripping and granular activated carbon.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** A preliminary human health risk assessment indicated that petroleum contamination poses an increased lifetime cancer risk of greater than 1×10^{-6} .
16. **DESCRIPTION OF THE TECHNOLOGY:-** Free petroleum product accumulating in the recovery wells is pumped into a product storage tank. Water from the wells is pumped into

the oil/water separator to remove residual free product and is treated by air stripping and granular activated carbon to remove dissolved hydrocarbons. Treated water is then discharged to a publicly owned treatment works.

- 17. DURATION OF REMEDIATION:-** The system operation started in 1992 and was concluded in 1994.
- 18. COST OF REMEDIATION:-** The total cost for the remediation are \$958, 780.
- 19. RESULTS:-** The project was a success with 98% removal of contaminants.
- 20. TRAINING PROGRAM:-** None.
- 21. OTHER INFORMATION:-** None
- 22. CONCLUSIONS:-** Activated carbon efficiency was limited by iron and biomass. Even though there were few limitations, the overall project was a success.
- 23. REFERENCES:-** <http://128.174.5.51/denix/Public/Library/remedy/ftdrum01.html>
- 24. KEYWORDS:-** Contaminated groundwater, Granular activated carbon, Petroleum products
- 25. CONTACT PERSONS:-** None.

CASE STUDY [57] . 3/96

1. **TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Superfund site
2. **LOCATION:-** New York.
3. **NATURE OF SOIL:-**
4. **AREA OF SITE / CONTAMINATED SITE:-** The area of contamination was 446 square meters.
5. **DEPTH OF GROUNDWATER TABLE/CONTAMINATION:-** The depth of contamination was 0.45 m.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** At the EPA's request, discrete samples were analyzed to verify that lateral and vertical migration did not occur as a result of treatment. Samples were collected to evaluate the potential for lateral migration of PCBs from the heated area, and transport and condensation of vapors into the surrounding unheated soil.
7. **SITE CHARACTERIZATION:-** For pre-treatment soil sampling, the site was divided into 30.5 m by 30.5 m grids to delineate the concentrations of PCBs in the soil. The PCBs were found primarily in the top .15 m of soil across the site. Pre treatment samples were collected to verify the average concentration in the test area and determine the concentration variance within the test area.
8. **MAJOR CONTAMINANTS:-** PCB contamination.
9. **SOURCE OF CONTAMINANTS:-** Not available
10. **CONCENTRATION OF CONTAMINANTS:-** The concentrations are as high as 5,000 ppm. The PCB concentration in the treatment zone ranged from 75 to 1, 264 ppm, with a maximum concentration of 5,212 ppm at some locations.
11. **REGULATIONS:-** The regulations are as per Toxic Substances Control Act (TSCA) permit for remediation of surficial soils.
12. **SPECIFICATIONS:-** Three continuous stack tests were performed which were consistent with EPA method 23 procedures to determine the quantities of PCBs, polychlorinated dibenzofuran, polychlorinated dibenzo-p-dioxin, and semivolatile products of incomplete combustion released to the environment from the thermal blanket.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology :- None.
 - (b) Selected in situ thermal desorption.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Details to be collected.

- 16. DESCRIPTION OF THE TECHNOLOGY:-** The in situ thermal desorption process is an integrated system with two key components: the thermal blanket and a vapor treatment system. Thermal blankets are covered over the contaminated soil. Contaminants are vaporized by heating the soil with the blankets. Heating elements in each blanket reach up to 800 to 1,000^o C at the surface. As the heat front moves through the soil, contaminants are vaporized and a vacuum system draws the vapors towards and through the blankets. Most contaminants are destroyed in the soil near the heat source. Remaining vapors are cleaned in a trailer mounted vapor treatment system, which emits only carbon dioxide and water vapor. The remediated site is then ready for re-vegetation.
- 17. DURATION OF REMEDIATION:-** The treatment system began in 1996 and is operated for 4 months.
- 18. COST OF REMEDIATION:-** Not available.
- 19. RESULTS:-** The contaminants were reduced to below 2 ppm. The application suggests that the thermal blanket is effective on contaminants to a depth of about a meter. Post treatment samples demonstrated the cleanup levels of less than 2 ppm from PCBs while meeting ambient air quality standards with respect to air emissions and worker exposure limits.
- 20. TRAINING PROGRAM:-** None.
- 21. OTHER INFORMATION:-**
- 22. CONCLUSIONS:-**The PCBs did not migrate away from the thermal blankets during treatment. Existing or recommended worker exposure levels were not exceeded. The approach was cost effective and intrusive.
- 23. REFERENCES:-** ""Throwing a blanket on the problem" Soil and groundwater cleanup-- from the internet.
- 24. KEYWORDS:-** Contaminated soils, PCB, Thermal desorption
- 25. CONTACT PERSONS:-** None.

CASE STUDY [58] . /92

1. **TYPE OF PROJECT:-**
 - (a) Treating contaminated soil .
 - (b) Site clean-up (HWMP - PHASE IV).
 - (c) Other site (not Superfund, DOT, RCRA, DOE or DOD)
2. **LOCATION:-** Basket Creek Impoundment site, Georgia.
3. **NATURE OF SOIL:-** Not available.
4. **AREA OF SITE / CONTAMINATED SITE:-** Approximately 1,600 cubic yards of soil needed treatment.
5. **DEPTH OF GROUNDWATER TABLE/CONTAMINATION:-**
6. **ENVIRONMENTAL SITE ASSESSMENT:-** Initial activities included sampling to characterize the nature and extent of contamination at the site. The soil was found to be a RCRA hazardous waste by exhibiting the Toxicity characteristic for lead (D008), methyl ethyl ketone (D035), and trichloroethene (D039).
7. **SITE CHARACTERIZATION:-** Details not available.
8. **MAJOR CONTAMINANTS:-** Halogenated volatile organic compounds including trichloroethene (TCE), tetrachloroethene (PCE), and non halogenated volatile organic compounds including toluene, xylenes, methyl isobutyl ketone (MIBK) and methyl ethyl ketone (MEK).
9. **SOURCE OF CONTAMINANTS:-** The site was used for illegal disposal of liquid refinery and other hazardous wastes.
10. **CONCENTRATION OF CONTAMINANTS:-**
 - TCE - below detection limit to 8,600 mg/kg;
 - PCE - below detection limit to 2,700 mg/kg;
 - Toluene - below detection limit to 220,000 mg/kg;
 - Xylenes - below detection limit to 7,300 mg/kg;
 - MEK -below detection limit to 23,000 mg/kg;
 - MIBK - below detection limit to 66,000 mg/kg;
11. **REGULATIONS:-** The cleanup levels ranged from 0.2 to 200 mg/L for all contaminants except total HOCs. The target for total HOCs was 1,000 mg/kg, based on the land disposal restrictions of California List Wastes. In addition EPA and State of Georgia required that the thermal oxidizer maintain a minimum destruction efficiency of 95%.
12. **SPECIFICATIONS:-** Not known.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology :- Off-site incineration, in situ soil vapor extraction, low temperature thermal desorption.
 - (b) Selected Soil Vapor Extraction.
14. **CONTAINMENT TECHNOLOGY:-** None.

15. **RISK ASSESSMENT:-** Details to be collected.
16. **DESCRIPTION OF THE TECHNOLOGY:-**
17. **DURATION OF REMEDIATION:-** The system was run from November 1992 to February 1993, and again from March to April 1993, for a total of 6 months of operation.
18. **COST OF REMEDIATION:-** Approximately \$413 per cubic yard treated, \$275 per ton of soil treated, \$9.20 per pound of VOC removed.
19. **RESULTS:-** A total of 72,000 lbs of total VOCs are recovered from the soil. Toluene was the largest quantity VOC recovered, accounting for approximately 80% of the VOCs recovered. The thermal oxidized achieved a minimum destruction efficiency of at least 95% during system operation, and for three months of at least 98%.
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** None
22. **CONCLUSIONS:-** In situ SVE was rejected because of low permeability of the contaminated soil. Ex situ SVE was adopted. The removal efficiency was 98%.
23. **REFERENCES:-** U.S. EPA, Office of Solid Waste and Emergency Response, Technology Innovation Office, EPA Contract No. 68-W3-001.
24. **KEYWORDS:-** Contaminated soils, VOC, Soil vapor extraction
25. **CONTACT PERSONS:-** None.

CASE STUDY [59] .12/93

1. **TYPE OF PROJECT:-**
 - (a) Treating saturated contaminated soil .
 - (b) RI and Site clean-up (HWMP - PHASE III and PHASE IV).
 - (c) Superfund site
2. **LOCATION:-** Dubose Oil Products Co. site, Cantonment, Florida.
3. **NATURE OF SOIL:-** Not known.
4. **AREA OF SITE / CONTAMINATED SITE:-** 19,705 tons of soil needed treatment.
5. **DEPTH OF GROUNDWATER TABLE/CONTAMINATION:-**
6. **ENVIRONMENTAL SITE ASSESSMENT:-** The RI was conducted in 1988, and revealed contamination above health-based levels in the vault soils, shallow aquifer and benzene, toluene, and xylenes and semivolatile organic compounds including polynuclear aromatic hydrocarbons (PAHs) and phenols (e.g., pentachlorophenol, or PCP).
7. **SITE CHARACTERIZATION:-** Details not available.
8. **MAJOR CONTAMINANTS:-** Polynuclear aromatic hydrocarbons (PAHs), pentachlorophenol (PCP), and volatile organic compounds (VOCs), including benzene, xylene, trichloroethylene (TCE), and 1,2-dichloroethene (DCE).
9. **SOURCE OF CONTAMINANTS:-** The site was a former waste storage, treatment, recycling, and disposal facility.
10. **CONCENTRATION OF CONTAMINANTS:-** The site was found to be contaminated with PAHs (total) at concentrations ranging from 0.578 to 367 mg/kg, PCP ranging from 0.058 to 51 mg/kg, and VOCs ranging from 0.022 to 38.27 mg/kg.
11. **REGULATIONS:-** Soil cleanup goals included PAHs (total) - 50 mg/kg, PCP - 50 mg/kg, benzene - 10 mg/kg, xylenes (total) - 1.5 mg/kg, TCE - 0.05 mg/kg, and DCE -0.07 mg/kg. Leachate discharge standards ranged from 1 to 50 µg/L for the target constituents/parameters.
12. **SPECIFICATIONS:-** Not known.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology :- None.
 - (b) Selected Composting.
14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Details to be collected.
16. **DESCRIPTION OF THE TECHNOLOGY:-** The composting system used at Dubose consisted of a treatment structure, a leachate collection system, an aeration system, an inoculum growth and application system, and an on-site wastewater treatment system. Contaminated soil was treated in batches, with each batch containing from 660 to 2,310 tons of soil. For most of the batches, soil depth ranged from 4.0 to 4.25 feet. Soil was aerated to

maintain a pore space oxygen content of approximately 20 percent, and inoculum was added over a period of two days (typically), until the entire surface area of the soil was moistened. A moisture content of approximately 15% and a carbon: nitrogen: phosphorus ratio of 120:10:2 was maintained during the application. Off-gasses collected by the aeration equipment were treated using granular activated carbon (GAC) adsorbers prior to discharge to the atmosphere.

17. **DURATION OF REMEDIATION:-** Composting activities were performed from May to November 1993,
18. **COST OF REMEDIATION:-** \$7,736,700 corresponding to \$266 per ton of soil treated (19,705 tons).
19. **RESULTS:-** For total PAHs, before-treatment concentrations ranged from 50.8 to 576.2 mg/kg, while after-treatment concentrations ranged from 3.3 to 49.9 mg/kg (average - 19 mg/kg). For PCP, before treatment concentrations ranged from 7.67 to 160 mg/kg, while after-treatment concentrations ranged from 16.5 to 36.3 mg/kg.
20. **TRAINING PROGRAM:-** None.
21. **OTHER INFORMATION:-** None.
22. **CONCLUSIONS:-** Soil cleanup goals for all 19,705 tons of soil treated at the DOPC site were met in this application. Of the 58,559 tons excavated, 19,705 tons required treatment because one or more constituents were measured at concentrations greater than the cleanup goals, including 8,783 tons containing total PAHs at concentrations greater than the cleanup goals, and 10,922 tons containing VOCs (primarily xylenes).
23. **REFERENCES:-** This case study was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Radian International under EPA Contract No. 68-W3-0001 and U.S. Army Corps of Engineers Contract No. DACA45-96-D-0016.
24. **KEYWORDS:-** Contaminated soils, Biological, PAH, VOC
25. **CONTACT PERSONS:-** None.

CASE STUDY [60] . 5/96

1. **TYPE OF PROJECT:-**
 - (a) Treating contaminated soil .
 - (b) ESI, RI and Site clean-up (HWMP - PHASE II, PHASE III and PHASE IV).
 - (c) Other site (not Superfund, DOT, RCRA, DOE or DOD)
2. **LOCATION:-** At an industrial site, New York.
3. **NATURE OF SOIL:-** The subsurface comprised of dense sand and gravel.
4. **AREA OF SITE / CONTAMINATED SITE:-** 4,100 cubic meters of soil needed treatment.
5. **DEPTH OF GROUNDWATER TABLE/CONTAMINATION:-** The depth of groundwater as well as contamination extended to 11 m below surface.
6. **ENVIRONMENTAL SITE ASSESSMENT:-** A facility-wide remedial investigation (RI) was conducted under the purview of consent order with the New York State Department of Environmental Conservation. The findings of RI are summarized as follows:
 - The soil contamination extended over an area of 650 square meters up to 11 m deep, approximately the level of water table in the area.
 - Cadmium contamination was present in concentrations up to 9000 mg/kg, but much of the contamination was detected in concentrations from 10 to 1000 mg/kg.
 - Groundwater in the vicinity is not contaminated.
7. **SITE CHARACTERIZATION:-** The subsurface comprises of dense sand and gravel. The soil in the area requiring remediation are sands and coarse gravel with some silty layers and occasional cobbles.
8. **MAJOR CONTAMINANTS:-** Cadmium.
9. **SOURCE OF CONTAMINANTS:-** The site is a portion of an active chemicals manufacturing facility in Eastern New York. Various historical spill and leaks from process vessels in and around the waste water system resulted in environmental contamination by cadmium.
10. **CONCENTRATION OF CONTAMINANTS:-** Total cadmium concentrations in the soil were approximately 130 mg/kg with Toxicity Characteristics Leaching Procedure (TCLP) leachable cadmium concentrations of 2.2 mg/L.
11. **REGULATIONS:-** The remediation criteria for the site were established on the basis of total cadmium concentrations - 10 ppm for surface soils and 50 ppm for subsurface. The regulations are according to New York state which requires that the soils were to be treated to meet the RCRA (Resource Conservation Recovery Act) TCLP criteria of 1.0 mg/L in the leachate for cadmium.
12. **SPECIFICATIONS:-** TCLP regulatory limit for cadmium is 1.0 mg/L.
13. **TREATMENT TECHNOLOGY:-**
 - (a) Screening technology :- None.
 - (b) Selected stabilization using jet grouting.

14. **CONTAINMENT TECHNOLOGY:-** None.
15. **RISK ASSESSMENT:-** Information not available.
16. **DESCRIPTION OF THE TECHNOLOGY:-** Non -replacement jet grouting was selected as the preferred jet grouting method. Jet mixing consists of drilling or driving a drill stem to the required depth and then injecting grout through horizontal jets at very high pressures. The drill stem is slowly rotated and raised during injection. Construction began with the demolition of the former buildings floor slab footings, tank foundations and manholes. The structures are broken up, excavated and removed from the site. After demolition, a test program was conducted to establish jet grouting parameters, and verify column diameters and material properties. No cadmium was detected in the leachate for the test columns. The regular columns are thus constructed using the jet grouting technique.
17. **DURATION OF REMEDIATION:-** The project was successfully completed in December 1996.
18. **COST OF REMEDIATION:-** Not available.
19. **RESULTS:-** All results after the treatment showed cadmium not detected to a detection limit of 0.048 or 0.004 mg/L. The state approval of the remediation was received within two months after the completion of construction and submission of required reports.
20. **TRAINING PROGRAM:-** Health and safety for the project included measures to protect the construction crew and limit access to the public. All workers were trained in accordance with the OSHA hazard standard 40 CFR 1910.120 and subjected to physicals including blood analysis.
21. **OTHER INFORMATION:-** None.
22. **CONCLUSIONS:-** The in-situ treatment of cadmium contamination was highly successful at this site. The project was completed on low budget, and on schedule.
23. **REFERENCES:-** Steven R. Day, Stephen J. Zarlinski, Peter Jacobson, "Stabilization of Cadmium-Impacted Soils using Jet-Grouting Techniques", Proceedings of the conference In situ Remediation of the Geoenvironment, Geotechnical Special Publication No. 71, pp. 388-4-2.
24. **KEYWORDS:-** Contaminated soils, Stabilization, Jet Grouting, Cadmium
25. **CONTACT PERSONS:-** None.

APPENDIX D

TNRCC DOCUMENTS



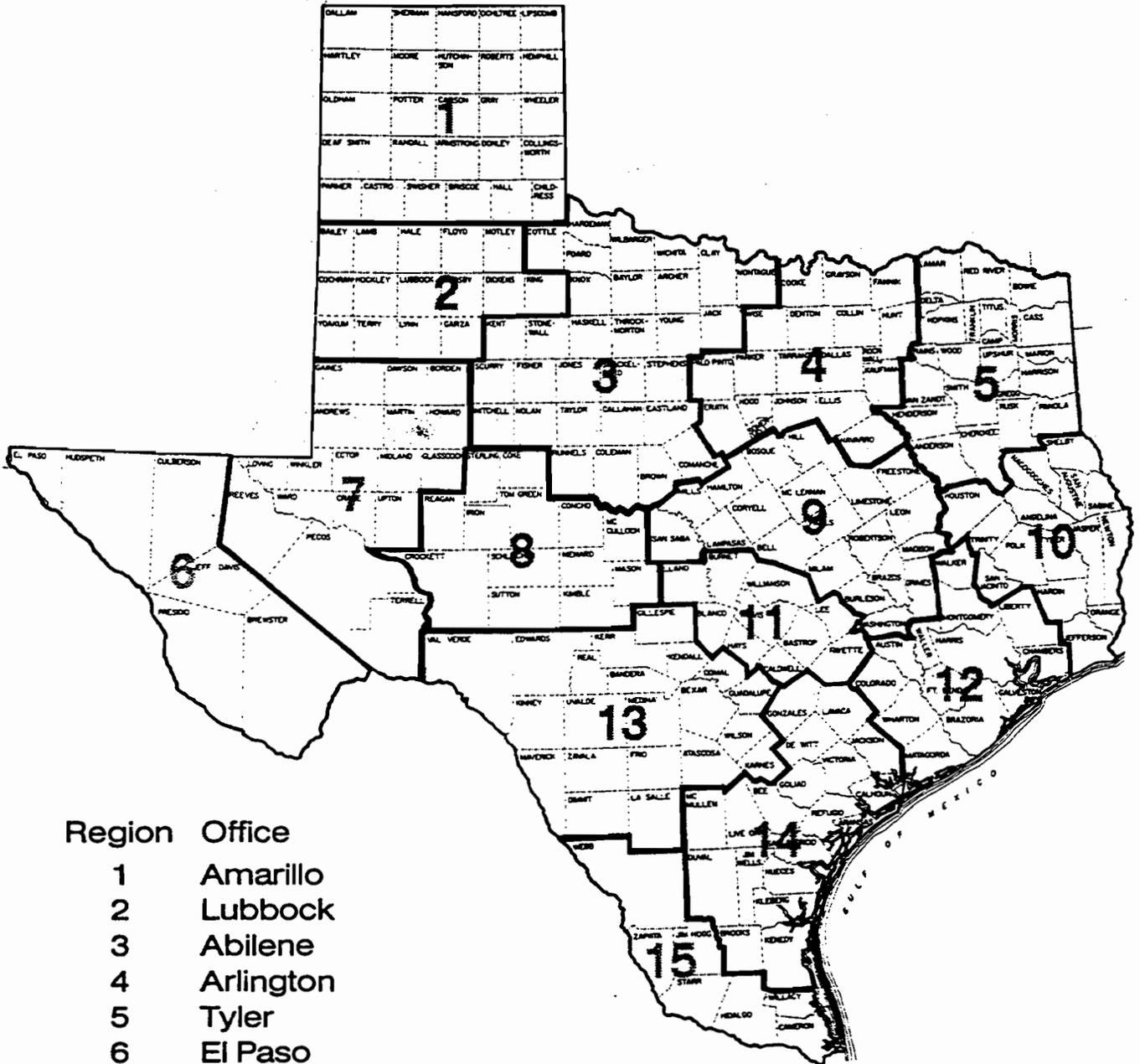
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TNRCC REGULATORY GUIDANCE

Petroleum Storage Tank Division

RG-17

October 1996

SUBJECT: Action Levels for LPST Sites

INTRODUCTION

This document provides guidance for determining when to consider a confirmed release as a Leaking Petroleum Storage Tank (LPST) case. The term **RELEASE** is defined in 30 TAC §334.2 as "any spilling including overfills, leaking, emitting, discharging, escaping, leaching, or disposing from an underground storage tank into groundwater, surface water, or subsurface soils." Therefore, a release is considered to have occurred when any amount of contamination is detected using quantitative analytical methods on soil or water samples, or when non-aqueous phase liquid (NAPL) is present. The release must be reported to the local TNRCC regional office within 24 hours of confirmation. Samples should be analyzed using the analytical methods specified in the TNRCC publication, *Soil and Groundwater Sampling and Analysis* (RG-14).

ACTION LEVELS

The presence of contamination does not necessarily mean that corrective action is necessary. To determine the need for additional corrective action (which includes assessment and/or remediation), compare the contaminant levels to the action levels listed in the "Action Levels and Screening Levels" table on page 2. (The term **ACTION LEVEL** indicates the concentration of constituents in the native soil or water at which some level of corrective action will be required. These action levels are not used as cleanup levels; they are simply levels that signal LPST case designation and the need for additional site evaluation. In general, except when NAPL is present in the tankhold, constituent levels in native soils and groundwater must exceed any of the listed action levels for the release incident to be considered an LPST case. Based on actual site conditions, professional judgement should be used to determine the appropriate application of these levels.

When analytical results obtained from tank removal-from-service or other release determination information indicates that the constituent levels in the native soils and/or water exceed any of the action levels, the release will be considered an LPST case and an LPST ID number will be assigned. When the benzene, ethylbenzene, toluene, and xylenes (BTEX) components are less than the action levels and only the total petroleum hydrocarbon (TPH) level exceeds the TPH screening level, the sample with the highest TPH level should be analyzed for polynuclear aromatic hydrocarbons (PAH) as listed below (remember that PAH analyses have a 14-day holding time). The results should then be compared to the action levels. If the PAH levels (and the BTEX concentrations) do not exceed the action levels, the site will not be considered an LPST site.

ACTION LEVELS AND SCREENING LEVELS			
CONSTITUENTS	SOIL ACTION LEVELS (mg/kg)		GROUNDWATER ACTION LEVELS (mg/L)
	Fine-Grained Soil*	Coarse-Grained Soil*	
Benzene	0.50	0.50	0.005
Ethylbenzene	70	10	0.70
Toluene	100	20	1.0
Total xylenes	560	70	10
Acenaphthene	314	314	0.010
Anthracene	13	13	0.010
Benzo(a)anthracene	0.877	0.877	0.010
Benzo(b)fluoranthene	0.877	0.877	0.010
Benzo(k)fluoranthene	8.77	8.77	0.010
Benzo(a)pyrene	0.0877	0.0877	0.010
Chrysene	7.2	7.2	0.010
Dibenz(a,h)anthracene	0.0877	0.0877	0.010
Fluoranthene	156	156	0.010
Fluorene	247	247	0.010
Indeno(1,2,3-cd)pyrene	0.877	0.877	0.010
Naphthalene	389	389	0.010
Pyrene	99	99	0.010
SCREENING LEVELS			
Total petroleum hydrocarbons (TPH) for middle distillate releases**	500	500	5
Total petroleum hydrocarbons (TPH) for gasoline releases**	100	100	5

* Apply the fine-grained soil standard to sites dominated with clays and silts. Apply the coarse-grained soil standards to sites dominated with sands, gravels, and rock units.

** Apply the middle distillate TPH standard to diesel, kerosene, jet fuel, hydraulic oil, and used oil releases. Apply the gasoline standard to gasoline and aviation gasoline releases. At sites where both gasoline and middle distillate releases have occurred in the same area or tank hold, the gasoline standard will apply.

The listed action levels do not apply and the site should be listed as an LPST site when:

- surface water is known or suspected to be impacted by the release;
- a water well or surface water intake is impacted or threatened;
- buildings or utilities are impacted with vapors;
- nuisance conditions such as odors, or water supply discoloration or taste degradation exist; or
- NAPL is present in the tankhold or in the native soil or groundwater.

Tank owners should complete and submit the *Release Determination Report* (RDR) form (TNRCC-0621) within 20 days from the date of release confirmation. Typically, the next step will be to conduct a risk-based assessment to determine the degree of contamination present, except in cases with minor soil contamination as described below in the *Second Set of Confirmation Samples* section of this document. A proposal for a risk-based assessment (or other appropriate activities) should be submitted with the RDR form.

SECOND SET OF CONFIRMATION SAMPLES

In situations where the release is discovered during a tank removal-from-service activity and analytical results indicate that the contaminant levels only slightly exceed the action levels, even though the site is considered an LPST site (indicate as such on the RDR form), a risk-based assessment may not be warranted. Instead, the tank owner or operator may be allowed, with approval from the appropriate TNRCC regional office staff, to conduct additional investigative steps by collecting a second set of verification samples. This option is available only when:

- The tank removal-from-service activities have just been completed and the tankhold and piping chases have not been filled. The second set of samples must be collected immediately after the results of the initial sampling are received when the sampling locations are easily accessible. However, the tankhold and piping chases must not be left open if they pose a safety hazard in any way;
- No more than two of the native soil samples collected for release determination purposes during a tank removal from service activity exceed action levels. This includes samples collected from the piping chases and from under the dispenser islands as well as samples from the tankhold;
- Verification samples are collected at a location a maximum of five feet vertically (or horizontally if only lateral migration has occurred) from the initial sampling points;
- Groundwater is not present in the excavation;
- Groundwater or surface water is not impacted or threatened;
- There is no indication that the release poses a threat to the public, and the extent (degree of spreading) of the contaminant is minimal;
- Non-aqueous phase liquid (NAPL) is not present in the excavation;
- The tank removal was not initiated in response to a documented impact to a sensitive receptor (water supply well, subsurface utility, spring, etc); and
- The case is not an apparent Priority 1, 2 or 3 (1.1 through 3.5) as described in the *Assessment Report* form (TNRCC-0562).

If all the above conditions are met and the results of this second confirmation sampling indicate contaminant levels are below action levels, the site may be closed.)

If you have additional questions, contact the Petroleum Storage Tank Division staff at (512) 239-2200.



TNRCC TECHNICAL GUIDANCE

MUNICIPAL SOLID WASTE DIVISION

SUBJECT: Suggested Analytical Testing for Special Wastes Disposal

Suggested analytical testing requirement for disposal of special waste at municipal landfills permitted by the Texas Natural Resource Conservation Commission (TNRCC). This testing should take into consideration that generators of special waste can use process knowledge. See the last page for explanation of asterisks and abbreviations.

Description of Waste Items	Treatment or Testing Suggested
Abrasives (sandblasting wastes, steel shots, iron shot dust, spent blast media)	determine what was being blasted, TCLP Inorganic* (not to exceed the level in Appendix 1, Table 1 of Subchapter R**, case-by-case review)
Asbestos (friable and nonfriable) Regulated Asbestos Containing Material (RACM) >1% Asbestos	None, follow TNRCC disposal guideline in 30 TAC §330.136
Asphaltic material (not weathered)	do hazardous waste determination,* TCLP organic not to exceed in Appendix 1, Table 1 of Subchapter R,* TCLP semi-volatile (method 8270 or 8250), recycle!
Asphaltic material (weathered)	ASTM D2887 or D3710, recycle!
Coal ash	TCLP Inorganic* and Dioxins (not to exceed the level in Appendix 1, Table 1 of Subchapter R**)
Commercial garbage and rubbish (uncontaminated)	None
Construction debris (lead base paint contaminated)	hazardous waste determination, TCLP Inorganic* (not to exceed in Appendix 1, Table 1 of Subchapter R**, case-by-case review)
Cooling tower wastes	TCLP Inorganic* (not to exceed the level in Appendix 1, Table 1 of Subchapter R**, case-by-case review)
Creosote wood floor blocks	TPH (<1500 ppm), PNAs (method 8310 or 8270 for hazardous waste determination), case-by-case review
Cured epoxy resin	None
Baghouse dust	TCLP Inorganic (not to exceed the level in Appendix 1, Table 1 of Subchapter R**, case-by-case review)
Beer	None, follow TNRCC disposal guideline
Electroplating wastes	TCLP Inorganic* (not to exceed the level in Appendix 1, Table 1 of Subchapter R**, TPH (<1500 ppm), pH (\leq 2.0 or \geq 12.5), case-by-case review)
Filter cake	TCLP Inorganic* (not to exceed the level in Appendix 1, Table 1 of Subchapter R**, TPH, case-by-case review)

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Description of Waste Items	Treatment or Testing Suggested
Floor sweepings	do hazardous waste determination, TPH, case-by-case review
Fluorescent lamps	hazardous waste determination for TCLP mercury (<0.2 mg/l)*, recycle!
Fly ash	TCLP Inorganic * and Dioxins(not to exceed the level in Appendix 1, Table 1 of Subchapter R**, case-by-case review
Food waste	None, follow TNRCC disposal guideline, compost!
Fuel filter waste fuel	TCLP Lead (<1.5 mg/l), BTEX (<150 mg/kg (ppm) *), TPH (<1500 ppm), alternate
Grease trap waste	* TCLP Inorganic (not to exceed the level in Appendix 1, Table 1 of Subchapter R**, paint filter liquid test, compost!
Grit trap wastes	TPH (<1500 ppm), * TCLP lead (<1.5 mg/l), * TCLP benzene (<0.5 mg/l), paint filter liquid test, case-by-case review
Incinerator ash	TCLP Inorganic * (not to exceed the level in Appendix 1, Table 1 of Subchapter R**
Insulation (nonasbestos)	None
Light ballast	PCBs (not to exceed 50 ppm)
Mercury salts	* TCLP Mercury (<0.2 mg/l), reactivity test, pH (<2 or >12.5)
Molecular sieve	TPH (<1500 ppm) and * TCLP benzene (<0.5 mg/l)
Oil filters from internal combustion engines	Prohibited from land disposal, see 30 TAC §330.136 (c), recycle! , alternate fuel
Paint booth filters	MSDS for paints, TCLP Inorganic * (not to exceed in Appendix 1, Table 1 of Subchapter R**, case-by-case review
Paint-contaminated material	TPH (<1500 ppm), TCLP metals, * TCLP volatiles and semi- volatiles * (not to exceed the level in Appendix 1, Table 1 of Subchapter R**
PCB > 50 ppm (<i>small</i> nonleaking capacitors from industrial facility)	None, TNRCC does not approve the disposal of a nonPCB-containing electrical components. TNRCC allows small PCB ballast generated by routine maintenance to be disposed of in Type 1 municipal landfills as long as the total weight does not exceed 3 lbs. (pounds of ballast per day)
Pesticide containers	None if it is triple rinsed and rendered unusable, recycle!
Railroad ties and telephone poles (used)	None
Railroad ties and telephone poles (new)	TPH (<1500 ppm), cresol test (<200 mg/l (milligrams per liter))
Sludges from industrial process	* Full TCLP (not to exceed the level in Appendix 1, Table 1 of Subchapter R, paint filter liquid test, case-by-case review
Sludges from grinding	TPH (<1500 ppm) base on process knowledge. * TCLP Organic and Inorganic (not to exceed the level in Appendix 1, Table 1 of Subchapter R**, paint filter liquid test, case-by-case review
Sludges from zinc phosphate (electroplating process)	* Full TCLP (not to exceed the level in Appendix 1, Table 1 of Subchapter R (**), * TCLP benzene, flash point (>140 degrees), paint filter liquid test, case-by-case review
Soil contaminated with automotive gasoline	TPH (<600 ppm), * TCLP benzene (<0.5 mg/l), * TCLP lead (<1.5 mg/l), recycle! , remediate

Description of Waste Items	Treatment or Testing Suggested
Soil contaminated with diesel fuel	TPH (600 ppm), * TCLP benzene (<0.5 mg/l) recycle!, remediate
Soil contaminated with home heating oil	TPH (<600 ppm), * TCLP benzene (<0.5 mg/l), remediate, recycle!
Soil contaminated with hydraulic oil	TPH (<600 ppm), * TCLP benzene (<0.5 mg/l), * TCLP Inorganic (not to exceed the level in Appendix 1, Table 1 of Subchapter R**, TOX (<50 mg/kg), PCB (<50 mg/kg), recycle!, remediate
Soil contaminated with jet fuel	TPH (<600 ppm), * TCLP benzene (<0.5 mg/l), remediate
Soil contaminated with kerosene	TPH (<600 ppm), * TCLP benzene (<0.5 mg/l), remediate
Soil contaminated with mineral spirits	TPH (<600 ppm), * TCLP benzene (<0.5 mg/l), remediate
Soil contaminated with motor oil	TPH (<600 ppm), * TCLP benzene (<0.5 mg/l), * TCLP lead (<1.5 mg/l), TOX (<50 mg/kg), recycle!, remediate
Soil contaminated with natural gas condensate	Full TCLP * (not to exceed the level in Appendix 1, Table 1 of Subchapter R), TPH (<600 ppm), remediate
Soil contaminated with other petroleum product	TPH (<600 ppm), * TCLP benzene (<0.5 mg/l), * TCLP lead (<1.5 mg/l), case-by-case review, recycle!, remediate
Soil contaminated with other waste oil	TPH (<600 ppm),* * TCLP benzene (<0.5 mg/l), TOX (<50 mg/kg), PCB (<50 mg/kg), * TCLP Inorganic (not to exceed the level in Appendix 1, Table 1 of Subchapter R**, case-by-case review, recycle!, remediate
Soil contaminated with transformer oil	TPH (<600 ppm), * TCLP benzene (<0.5 mg/l), * TCLP Inorganic (not to exceed the level in Appendix 1, Table 1 of Subchapter R**, TOX (<50 mg/kg), PCB (<50 mg/kg), recycle!, remediate
Soil contaminated with unknown substance	waste determination, pesticides, full TCLP* (not to exceed the level in Appendix 1, Table 1 of Subchapter R**, * TCLP benzene (<0.5 mg/l), TPH (<600 ppm), PCB (<50 mg/kg), case-by-case review, recycle!, remediate
Sorbent materials	do a hazardous waste determination, TPH (<1500 ppm), * TCLP benzene (<0.05 mg/l), case-by-case review, recycle (burn for energy recovery)
Spent lead acid batteries	None, TNRCC does not approve the disposal of lead acid batteries into a municipal landfill. This waste is subject to General Prohibitions under the new rule 30 TAC §330.5 (e)(1) and must be recycled.
Tank sediments	Full TCLP * (not to exceed the level in Appendix 1, Table 1 of Subchapter R**, case-by-case review
Wine	pH factor (≤ 2.0 or ≥ 12.5), may require neutralization
Wood chips case-by-case review	TCLP Inorganic * (not to exceed the level in Appendix 1, Table 1 of Subchapter R**, case-by-case review
Zinc dust	TCLP lead *, zinc ignitability test in water

(Footnotes on back page)

- * A total analysis may be used as a screen prior to Toxicity Characteristic Leaching Procedure (TCLP). If a total analysis (i.e. Total Lead, Total Benzene, etc.) for screening exceeds the limits listed below, then TCLP must be performed and the TCLP results must not exceed the stated limits:

<u>Analyte</u>	<u>Total Limit</u>	<u>TCLP Limit</u>
Benzene	10 mg/kg	0.5 mg/L
Arsenic	36 mg/kg	1.8 mg/L
Barium	2000 mg/kg	100 mg/L
Cadmium (Cd)	10 mg/kg	0.5 mg/L
Chromium (Cr)	100 mg/kg	5.0 mg/L
Lead (Pb)	30 mg/kg	1.5 mg/L
Mercury (Hg)	4 mg/kg	0.2 mg/L
Selenium (Se)	20 mg/kg	1.0 mg/L
Silver (Ag)	100 mg/kg	5.0 mg/L
Xylene	140000 mg/kg	7000 mg/L

Results of the following analyses must be within the limits stated for landfill disposal in a municipal solid waste facility:

TPH	=	< 600 mg/kg (for soils in most landfills)
		< 1500 mg/kg (for soils in 30 specific landfills)
TOX	=	< 50 mg/kg
PCBs	=	< 50 mg/kg
PNAs	=	< 1500 ppm
Chlorides	=	< 3000 mg/kg
Sulfide	=	< 500 mg/kg (vapor) SW846 Method 376.1
Cyanide	=	< 250 mg/kg (vapor) SW846 Method 9010

- ** Approximately 75% of the special waste that is managed in Texas is generated by industrial generators. Although the generation of industrial waste is subject to the industrial and hazardous waste rules (Chapter 355), upon disposal into a municipal solid waste facility, the waste is subject to the municipal solid waste rules (Chapter 330). The same waste streams that are generated by a nonindustrial generator are also special waste. While evaluating the nature of a waste stream, TNRCC applies the values found in 30 TAC Chapter 335 Subchapter R, since these values are the best technical information currently available and the waste stream environmental impact is the same regardless of who generates it.

Abbreviations:

BTEX	-	Total Benzene (B), Total Toluene(T), Total Ethylbenzene (E), Total Xylene (X)
TPH	-	Total Petroleum Hydrocarbon
TCLP	-	Toxicity Characteristic Leaching Procedure
TOX	-	Total Organic Halides (X = Fluorine, Chlorine, Bromine, or Iodine)
PCBs	-	Polychlorinated Biphenyls
PNAs	-	Polynuclear Aromatics
MSDS	-	Material Safety Data Sheet(s)
mg/kg	-	milligrams per kilogram
mg/l	-	milligrams per liter
ppm	-	parts per million
ur/hr	-	microRoentgen
Subchapter R	-	Refers to Title 30 Texas Administrative Code (TAC)
ASTM	-	American Society Testing Materials

NOTE: State law considers landfill disposal as the least desirable method of disposal. State policy established a waste recycling rate of 40% by 1994 (Senate Bill 1340, 72nd Legislature, Regular Session). This requires recycling of all metal items whenever possible.

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TNRCC REGULATORY GUIDANCE

Petroleum Storage Tank Division

RG-43

September 1996 (rev.)

SUBJECT: Groundwater Monitoring and Reporting

INTRODUCTION

This document provides guidelines for groundwater monitoring (sampling and gauging) and reporting at leaking petroleum storage tank (LPST) sites. Groundwater monitoring activities are needed at LPST sites to document any significant changes that may occur in the subsurface conditions. In most instances, one semiannual partial sampling event and two complete gauging events will be adequate to monitor groundwater conditions after the groundwater flow direction and contaminant levels have been documented through quarterly monitoring events. If a responsible party elects to conduct groundwater monitoring activities exceeding those required by this guideline or by the TNRCC case coordinator, the additional activities will not be allowable for reimbursement. Workplans and cost proposals for groundwater monitoring activities should continue to be submitted on an annual basis, but should only include costs to prepare one annual report. If a site is not eligible for reimbursement or a responsible party does not intend to seek reimbursement, only the workplan should be submitted.

SAMPLING

The following are guidelines for the sampling frequency of groundwater monitoring wells. These guidelines should only be considered after the groundwater contaminant levels have been well documented from previous sampling events. Only groundwater samples collected from adequately screened monitoring wells are considered representative of actual groundwater conditions.

- If the results of two successive quarterly sampling events indicate the contaminant concentrations detected in a specific monitoring well are comparable (approximately the same order of magnitude) to the concentrations previously detected, the sampling frequency for that particular well may be reduced to once every 6 months (semiannually).
- If the results of two successive quarterly sampling events indicate that the concentrations of the constituents analyzed (total BTEX, benzene, TPH, PAHs, etc.) have consistently remained at or below the site cleanup goals in a specific monitoring well, then the frequency of analysis for that particular constituent (or group of constituents) in the affected well(s) should be reduced to once per year (annually).
- Monitoring wells that are positioned either upgradient or outside the periphery of the contaminant plume boundary and yield nondetectable contaminant concentrations for two successive quarterly sampling events should be sampled once per year (annually). This does not apply to the monitoring well situated immediately downgradient.
- The monitoring well situated immediately downgradient of the source area must be sampled during every sampling event.

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- Following the installation of additional monitoring wells, all monitoring wells not containing nonaqueous-phase liquid (NAPL) should be sampled. This sampling event will fulfill the requirement for a quarterly, semiannual, or annual sampling event. Thereafter, the newly installed monitoring wells should be sampled on a quarterly basis only until contaminant levels are well documented.
- Regardless of contaminant concentrations, samples should be collected from all on-site and off-site monitoring wells not containing NAPL at least once per year, and these samples should be analyzed for all the appropriate constituents (based upon the substance released).
- The analysis of methyl tertiary butyl ether (MTBE) is necessary right after the installation of a monitoring well. Subsequently, it is necessary only in monitoring wells located downgradient or outside the periphery of a gasoline contaminant plume boundary.
- Monitoring wells that contain NAPL should not be sampled unless the TNRCC specifically requests laboratory analysis of the product to assist in product or source identification.
- The number of wells sampled and the sampling frequency should be reduced to a level sufficient for monitoring plume migration and/or the effectiveness of a remediation system.

GAUGING AND SUBMITTAL OF GROUNDWATER GRADIENT MAPS

The following are guidelines for the gauging frequency of monitoring wells and the submittal of updated, drafted groundwater gradient maps. These guidelines should only be considered once the groundwater flow direction has been well documented from previous gauging events. Except when NAPL is present, the groundwater gauging frequency should coincide with the frequency of groundwater sampling events.

- If the groundwater flow direction at a site has essentially remained the same as that of the previous gauging event, then an updated groundwater gradient map should not be drafted and submitted for the current sampling event. If a site visit is conducted to sample any wells, all existing wells should be gauged and inspected for damage during the visit. Additionally, tankpit observation wells should be gauged for the presence of NAPL during each gauging event, but the groundwater elevations from these wells should not be incorporated into the groundwater gradient map unless the tankpit water is hydrologically continuous with the native groundwater.
- Following the installation of additional monitoring wells, all monitoring wells should be gauged, and an updated, contoured groundwater gradient map should be constructed, drafted, and submitted. Unless the direction of groundwater flow changes significantly, an updated, contoured groundwater gradient map needs to be drafted and submitted only on an annual basis.
- When NAPL is present, the gauging frequency should be based on product thicknesses and method of product recovery.

REPORTING

Following the completion of groundwater monitoring activities for a period of one year, an annual groundwater monitoring report that contains the results of all sampling and gauging events for that year should be prepared and submitted to the TNRCC. The report should summarize the monitoring events for the past year and provide a discussion of any significant changes that may have occurred in the subsurface conditions. Annual monitoring reports should contain the following information:

I Report Summary

- A brief and concise overview of all information contained in the report.

- A brief description of the groundwater monitoring activities covered by the report that includes the degree of contamination encountered.

II. Chronology of Events

- The dates and brief descriptions of all significant events that have occurred since a problem was suspected at the facility. Begin with the first date a problem was suspected and continue through the most recent activity described in the report.
- After submittal of the initial report chronology, each subsequent chronology of events should be a continuation of the previous chronology.

III. Tables and Maps

- A cumulative list of analytical results. The results should be tabulated such that each sampling date is listed under each monitor well in chronological order from oldest to most recent. Each chemical must be specified (e.g., benzene, toluene, ethylbenzene, total xylenes, etc).
- A cumulative list of groundwater-level measurements and NAPL thickness measurements (when phase-separated product is present). This list should include surveyed top-of-casing elevations, depth-to-water measurements, calculated groundwater elevations, and the date of measurement. If product is present, the apparent product thickness and correction factor used to adjust the apparent thickness should be indicated. The results should be tabulated such that each measuring event is listed under each monitor well in chronological order from oldest to most recent.
- An updated hydrocarbon distribution map for each complete sampling event. This map should portray the dissolved-phase contaminant concentrations for benzene, total BTEX, and TPH, any other constituent specifically requested by the TNRCC, or phase-separated product thickness for each well.
- Groundwater gradient map(s).
- An account of the disposition of any recovered NAPL and contaminated groundwater. If these wastes/materials are transported off-site for disposal, treatment, storage, or recycling, then copies of signed receipts from receiving facilities or any uniform hazardous waste manifests (if required) must be submitted.

IV. Conclusions and Recommendations

- A discussion of any trends or changes noted in analytical results or site conditions and a summary of any ongoing assessment or remediation activities. If applicable, provide a brief discussion of the effectiveness of the current remediation system and a proposal for any recommended system modifications.

V. Quality Assurance/Quality Control Procedures

- A description of the standard quality assurance/quality control (QA/QC) procedures that are practiced in order to ensure that samples collected are representative of actual conditions and that analytical results are valid.
- A concise discussion of the specific sampling techniques employed during the collection of all groundwater samples.
- A description of the EPA-approved methods used to extract and analyze the samples submitted to the laboratory. Reference the maximum recommended sample holding time for each type of analysis performed.

VI. Appendices

- Copies of signed laboratory reports providing the results of all sample analyses, including QA/QC laboratory data sheets confirming the use of blanks, surrogates, spike recoveries, and any other required QC measures taken to ensure the validity of the data.
- Copies of all corresponding chain-of-custody documentation.
- A detailed description of sample collection, preservation, and analytical procedures for all samples collected during that year.
- A cumulative list of groundwater-level measurements and product thickness measurements, when applicable.
- Waste/material disposition records.

A case coordinator may request the submittal of groundwater monitoring information on a more frequent basis if deemed necessary, based on site-specific conditions. Cumulative tables of analytical results and groundwater elevation data should be maintained throughout the annual monitoring cycle and attached to any proposals or reports submitted to the TNRCC for review. These cumulative tables should include the most current groundwater monitoring results and should be made available to the TNRCC during the course of the annual monitoring cycle if specifically requested by the case coordinator.

GROUNDWATER MONITORING AND REMEDIAL ACTION

Please note that the change to just annual reporting applies to routine groundwater monitoring only. Groundwater sampling, gauging, and reporting associated with remedial action performance monitoring or operation and maintenance monitoring may require different frequencies as set forth in other guidance documents or as directed by the case coordinator. Such monitoring programs should be developed and proposed as part of proposed remedial action plans. Therefore, if a site has entered the remediation phase, and the groundwater monitoring and reporting frequency has already been approved, the approved activities should be completed. Future monitoring and reporting frequencies should be determined based on available guidance or as approved by a case coordinator, based on site-specific conditions. In most cases, groundwater monitoring results will be reported annually in a remediation system performance report.

FINAL MONITORING

The following are reporting requirement guidelines for final groundwater monitoring activities. Final monitoring should only be implemented once the responsible party has documented, and the TNRCC has concurred, that either a) the site appears to be adequately cleaned by the remediation system and the remediation system can be shut off or b) the documented contaminant levels are at or below the site cleanup goals for all monitoring wells.

- All on-site and off-site monitoring wells should be sampled and gauged on a three-month (quarterly) basis.
- Following the completion of four groundwater monitoring events, an annual groundwater monitoring report that contains the results of all four sampling and gauging events should be prepared.
- After the annual groundwater monitoring report has been completed, submit a *Site Closure Request* form (TNRCC-0028) if collected soil and groundwater monitoring data confirms that the site has been remediated to the site cleanup goals. If no further corrective action or monitoring is warranted, the TNRCC will grant approval for site closure. A *Final Site Closure Request* form (TNRCC-0030) should then be completed and submitted to the TNRCC to document actual site closure activities.



TNRCC REGULATORY GUIDANCE

Municipal Solid Waste Division

RG-29

September 1996

SUBJECT: What Is "Special Waste"?

To Find Out, Answer These Questions

To find out whether you have a special waste, answer the following questions.

- By process knowledge or chemical analysis, is the waste contaminated with any hazardous substances found in Title 40 Code of Federal Regulations (CFR), Part 261, Appendix VIII?
- Is it large or bulky; a liquid; a containerized liquid; or a containerized gas?
- Is it noxious or likely to attract disease vectors?
- Before or during disposal, will it require treatment or special handling (e.g., immediate burial, worker protection, solidification, bio-remediation, analysis, engineering controls or any other special preparation to receive the waste) because of its quantity, concentration, or physical or chemical characteristics ?
- Is it a regulated medical waste or a waste from a health-care-related facility?
- Is it a substance controlled by the Drug Enforcement Agency (DEA) or the Food and Drug Administration (FDA)?
- Does it contain, or is it contaminated with, PCB's?
- Is it a waste resulting from the exploration, production, or development of oil, gas, or geothermal resources (from facilities regulated by the Railroad Commission of Texas— RRC)?
- Is it reactive, corrosive, ignitable, or toxic?
- Is it contaminated with any petroleum hydrocarbons?
- Was the waste generated outside Texas, other than household waste?
- Is the waste specifically listed under 30 TAC Section 330.2, relating to the definition of special waste?

If you answered "yes" to any of the above questions, and the waste is to be disposed of in a landfill permitted by TNRCC's Municipal Solid Waste (MSW) Division, then your waste is a special waste and requires approval from TNRCC before acceptance of the waste into a municipal solid waste landfill.

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To receive authorization for disposal, please submit form TNRCC-0152 with appropriate analytical reports to the Technical Assistance Team, Permits Section/MC 124, Municipal Solid Waste Division, P.O. Box 13087, Austin, Texas 78711-3087. For more information call (512) 239-6781

“When in doubt, it is a special waste.”

Wastes That Do *Not* Require Approval before Disposal

The following specific special wastes do not require agency approval before disposal, with the noted provisions.

- wastes from health-care-related facilities that have been treated in accordance with the specific procedures in 30 TAC Sections 330.1001-1009, relating to medical waste management;
- dead animals that are covered immediately with three feet of other solid waste or two feet of soil;
- nonregulated asbestos-containing material;
- regulated asbestos-containing material in approved Type I facilities provided the conditions outlined in 30 TAC Section 330.136(b)(3), relating to disposal of regulated asbestos-containing material, have been met;
- empty containers that held pesticides, herbicides, fungicides, or rodenticides and that have been triple rinsed and rendered unusable—provided that the containers are covered by the end of the same day they were received;
- empty containers that cannot be triple rinsed but not exceeding 220 pounds (100 kilograms) monthly from a single generator, in Type I facilities;
- hazardous waste from CESQGs (Conditionally Exempt Small Quantity Generators) but not exceeding 220 pounds (100 Kg) from a single generator per month, in Type I facilities;
- sludges, grit trap waste, grease trap waste, or liquid wastes from municipal sources—provided that the waste has been, or is to be, treated to pass the paint filter test (EPA Method 9095), in Type I facilities that have been approved to process liquids;
- certain specific wastes generated by facilities regulated by the Railroad Commission of Texas (see TNRCC publication RG-3 for details);
- petroleum-contaminated soils that meet the requirements of the current TNRCC soils policy;
- nonhazardous auto shredder fluff; and
- wastes that do not require special handling.

Regulations covering the management of special waste may be found in Title 30 Texas Administrative Code (TAC) Section 330.136 and Section 330.137. The definition of “special waste” may be found in 30 TAC Section 330.2, relating to definitions.



TNRCC REGULATORY GUIDANCE

Municipal Solid Waste Division

RG-4

September 1996

SUBJECT: Asbestos Wastes Disposal

DEFINITIONS

Friable and Nonfriable Asbestos-Containing Materials

Materials containing asbestos can be in two forms: friable and nonfriable

Definition: friable asbestos-containing material, when dry, can be crushed to a powder by hand pressure, and includes:

- blown-in insulation,
- some pipe wrapping, and
- some ceiling tiles.

Definition: nonfriable asbestos-containing materials when dry, cannot be crushed to a powder by hand pressure.

- Category I nonfriable asbestos-containing material includes:
 - gaskets,
 - packing,
 - resilient floor covering, and
 - asphalt roofing products.
- Category II nonfriable asbestos-containing material includes:
 - transite shingle,
 - transite pipe, and
 - any nonfriable asbestos-containing material not defined as Category I.

Regulated and Nonregulated Asbestos-Containing Materials

The Texas Natural Resource Conservation Commission (TNRCC) recognizes two types of asbestos-containing materials. See 30 Texas Administrative Code (TAC) 330.2 (Definitions).

Definition: regulated asbestos-containing material, as defined in 40 Code of Federal Regulations (CFR) Part 61, is:

- friable asbestos-containing material that contains greater than 1 percent asbestos using the method specified in Appendix A of Subpart F in 40 CFR Part 763, Section 1;
- nonfriable asbestos-containing material that contains greater than 1 percent asbestos but has been subjected to sanding, grinding, cutting, or abrading, or that has a high probability of being reduced to powder in the course of demolition or renovation; or
- any asbestos-containing material from outside the boundaries of Texas.

Definition: nonregulated asbestos-containing material is:

- any material containing less than 1 percent asbestos, or
- any nonfriable asbestos-containing material not identified as regulated above.

Management of an asbestos-containing material depends on its regulatory status.

MANAGEMENT OF REGULATED ASBESTOS-CONTAINING MATERIAL

Regulated asbestos-containing material [see 30 TAC 330.136(b)(3) pertaining to friable asbestos-containing material]

- Must go to an approved landfill, which:
 - must notify the TNRCC Office of Air Quality and the Texas Department of Health (TDH) Toxic Substances

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- ▶ Control Division of intent to accept asbestos-containing material (see Guidance Document EPA 340/1-90-016);
 - ▶ must coordinate with the generator for receipt of the waste;
 - ▶ must accept the waste only in a wetted condition;
 - ▶ must accept the waste only in undamaged containers or bags as approved by the TNRCC;
 - ▶ must place bags or containers at or below grade level or not in an area that may be subject to erosion or weathering; and
 - ▶ must place, not dump, the bags or containers and cover immediately.
- Requires a TNRCC Manifest (TWC 0311) for the following generators:
 - ▶ industrial generators, including manufacturing facilities, agricultural activities, and mining operations; and
 - ▶ nonindustrial generators, such as schools and churches; commercial, retail, and service businesses; and oil and gas exploration, development, or production.
 - Requires TNRCC authorization for disposal for the following generators:
 - ▶ wastes generated under Railroad Commission of Texas (RRC) jurisdiction, and
 - ▶ wastes generated outside the boundaries of Texas.

MANAGEMENT OF NONREGULATED ASBESTOS-CONTAINING MATERIAL

Nonregulated asbestos-containing material [see 30 TAC 330.136(b)(4)]

- May go to any municipal solid waste landfill, which:
 - ▶ must place the waste on the active working face of the landfill, and
 - ▶ must cover it immediately.
- Does not require a manifest.
- Does not require TNRCC authorization for disposal, unless it falls under RRC jurisdiction.

FOR MORE INFORMATION

For more information on asbestos-containing material disposal or authorization for disposal of special wastes, please contact:

Technical Assistance Team, Permits Section/MC 124

Municipal Solid Waste Division, TNRCC

P.O. Box 13087

Austin, Texas 78711-3087

Phone (512) 239-6781 Fax (512) 239-6717



TNRCC TECHNICAL GUIDANCE

MUNICIPAL SOLID WASTE DIVISION

SUBJECT: Disposal of Special Wastes Associated with Development of Oil, Gas, and Geothermal Resources

Recommendations for the management of wastes associated with the exploration, development or production of oil, gas, or geothermal resources regulated by the Railroad Commission of Texas (RRCT) in landfills permitted by the Municipal Solid Waste (MSW) Division of the Texas Natural Resource Conservation Commission (TNRCC). See the last page of table for explanation of asterisks and abbreviations.

Description of Waste Items	RCRA Exempt	RRCT Minor Permit Required for Disposal in TNRCC Landfill	Treatment or Testing Recommended	TNRCC Approval Necessary for Landfill Disposal <i>(at MSW Permitted Sites)</i>
Asbestos and asbestos-contaminated waste material	YES	YES	comply with federal & state regs. for asbestos, remove asbestos from metal, recycle metal	NO for sites that are approved to take asbestos
Bags, paper	NO	NO	NONE [bags must be empty]	NO
Brush & vegetation from clearing land, uncontaminated	NO	NO	NONE, compost	NO
Buckets, detergent	NO	NO	NONE [must be empty]-recycle if possible (scrap metal)	NO
Buckets, grease	NO	NO	NONE [must be empty]-recycle if possible (scrap metal)	NO
Concrete, contaminated from plants, compressor stations and other oil & gas facilities	NO	YES	testing determined on case-by-case basis	YES
concrete, uncontaminated from facilities	NO	NO	NONE if uncontaminated	NO
Containers, empty	NO	NO	NONE [must be empty]-recycle if possible (scrap metal)	NO
Drill cuttings	YES	YES	only cuttings, MSDS for additives, chlorides	YES
Barrels/drums 5-gallon buckets	NO	NO	NONE-recycle as scrap metal	NO
Fiberglass tanks and pipe	NO	NO	must be empty & clean, cut up or shredded	NO

Description of Waste Items	RCRA Exempt	RRCT Minor Permit Required for Disposal in TNRCC Landfill	Treatment or Testing Recommended	TNRCC Approval Necessary for Landfill Disposal (at MSW Permitted Sites)
Filters, amine	YES	YES	drain, air dry for 48 hours TPH, TCLP benzene*	YES
Filters, cooling tower	YES	YES	drain, air dry, TCLP	YES chromium*
Filter media, dehydration	YES	YES	drain, air dry 48 hours TPH, TCLP benzene*	YES
Filters, gas condensate	YES	YES	drain, air dry 48 hours TPH, TCLP benzene*	YES
Filters, glycol	YES	YES	drain, air dry 48 hours TPH, TCLP benzene*	YES
Filters, saltwater	YES	YES	drain, air dry 48 hours, pH and total chlorides, TPH	YES
Filters, waste oil (1) entire unit is inside metal container	NO	YES	separate & recycle oil & metal parts	(1) Subject to 31 TAC330.136(c)
(2) replaceable inside units (paper/fiber)	NO	YES	recycle, waste-to-energy drain for at least 24 hrs., TCLP lead & benzene*	(2) YES
Iron sponge	YES	YES	allow to oxidize completely to prevent threat of combustion	YES
Metal plate, metal pipe, metal cable	NO	NO	NONE-recycle as scrap metal	NO
Molecular sieves	YES	YES	cool in non-hydrocarbon, inert atmosphere; hydrate in ambient air 24 hours; TPH; TCLP benzene*	YES
Muds, drilling	YES	YES	TCLP Barium*, TPH, BTEX* treatment to reduce hydrocarbons may be required	YES
Muds, drilling sacks of unused	NO	YES	MSDS return to vendor or use at other site if usable	YES
Mud additives, unused	NO	YES	(Barium), MSDS approval for small quantities only	YES
"Pigging waste" from gathering lines	YES	YES	TPH, TCLP benzene*, TCLP metals*, NORM, MSDS for corrosion inhibitors, TCLP arsenic*	YES
"Pigging waste" from transmission lines	NO	YES	TPH, TCLP benzene*, NORM, MSDS for corrosion inhibitors, TCLP arsenic*	YES

Description of Waste Items	RCRA Exempt	RRCT Minor Permit Required for Disposal in TNRCC Landfill	Treatment or Testing Recommended	TNRCC Approval Necessary for Landfill Disposal (at MSW Permitted Sites)
Pipe scale & other deposits removed from piping and equipment	YES	YES	TPH, TOX, TCLP metals*, NORM	YES
Pipe dope, unused	NO	YES	MSDS-may contain lead re-use if possible	YES
Plastic pit liners	YES	YES	determine type of contamination, clean well	NO
Pumps, junked, valves, etc.	NO	NO	NORM, <i>recycle</i>	NO
Rags/gloves, soiled	NO	NO	NONE	NO
Sand, produced	YES	YES	TPH, TCLP benzene*, NORM TCLP arsenic*	YES
Soils, hydrocarbon bearing (crude oil)	YES	YES	TPH, TCLP benzene* see TNRCC policy on contaminated soils	YES
Soils, hydrocarbon bearing (lube oil)	NO	YES	TCLP cadmium, chromium, lead*; TPH; TCLP benzene*; PCB's	YES
Sulfur, ferrous elemental sulfur & soil contaminated with sulfur	NO	YES	if uncontaminated recover & sell as raw material	YES requires approval on a case-by-case basis
Sorbent pads (crude oil & other exempt wastes)	YES	YES	TPH, TCLP benzene* (TPH usually too high, treat for recovery/reuse)	YES TPH is usually too high for LFs
Sorbent pads (lube oil & other non-exempt)	NO	YES	TPH, TCLP benzene* TPH is usually too high for LFs	YES
Tank seals, rubber	NO	YES	drain, <i>recycle</i> (tire recycling facility)	YES
Tower packing	NO	YES	recycle. TCLP chromium	YES
Water treatment backwash solids	YES	YES	NORM, TCLP metals*	YES
Wooden pallets	NO	NO	NONE unless contaminated	NO

*A less expensive alternative to TCLP Analysis is a Totals Analysis. If a total analysis (i.e. Total Lead, Total Benzene, etc.) exceeds the limits listed below, then TCLP must be performed, and the TCLP results must not exceed the stated limits for MSW landfill disposal:

<u>Analyte</u>	<u>Total Limit</u>	<u>TCLP Limit</u>
Benzene	10 mg/Kg	0.5 mg/L
Arsenic	36 mg/Kg	1.8 mg/L
Barium	2000 mg/Kg	100 mg/L
Cadmium	10 mg/Kg	0.5 mg/L
Chromium	100 mg/Kg	5.0 mg/L
Lead	30 mg/Kg	1.5 mg/L
Mercury	4 mg/Kg	0.2 mg/L
Selenium	20 mg/Kg	1.0 mg/L
Silver	100 mg/Kg	5.0 mg/L

Results of the following analyses must be within the limits stated for landfill disposal in a Municipal Solid Waste facility:

TPH	=	1500 mg/Kg (for soils, other wastes on case-by-case review)
TOX	=	50 mg/Kg
PCBs	=	<50 mg/Kg
Chlorides	=	case-by-case review
NORM	=	below regulatory limit

Explanation of abbreviations:

LF	=	Landfill
MSDS	=	Material Safety Data Sheet(s)
MSW	=	Municipal Solid Waste (Division of TNRCC)
NORM	=	Naturally Occurring Radioactive Materials
PCB	=	Polychlorinated Biphenyls
RCRA	=	Resource Conservation and Recovery Act
RRCT	=	Railroad Commission of Texas
TCLP	=	Toxicity Characteristic Leaching Procedure
TOX	=	Total Organic Halides (X = Fluorine, Chlorine, Bromine, or Iodine)
TPH	=	Total Petroleum Hydrocarbons (EPA method 418.1 with known standard)

NOTE: The TNRCC considers landfill disposal as the least desirable method of waste management.

State policy established a waste recycling rate of 40% by 1994 (Senate Bill 1340, 72nd Legislature, Regular Session). This requires recycling of all metal items whenever possible! Areas where recycling may be readily available are noted in italics.

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TNRCC REGULATORY GUIDANCE

Petroleum Storage Tank Division

RG-018

May 1996

SUBJECT: Leaking Storage Tanks— What Should I Do?

If your storage tank is leaking, this is what you should do:

Act on Hazards

- Evacuate the area immediately if there is a fire or explosion hazard.
- Extinguish open flames (No Smoking).
- Take the leaking system out of service.
- Turn off electrical equipment if safe to do so.
- Stop any immediate threats or impacts to human health and safety. Call the local fire department and request a test for explosive conditions. The fire department can help you decide what other actions or precautions you should take to eliminate hazards.

Report the Leak or Spill

- Report all spills, leaks or suspected leaks.
- Contact the local TNRCC regional office in your area within 24 hours of discovering or suspecting a leak or spill. A list of all TNRCC regional offices is included inside.

Find the Leak

- Use your senses--do you see or smell it?
- Check product pumps for proper operation.
- Check inventory records for product losses.
- If necessary, have the tanks and lines professionally tested.
- Check tank pit observation wells for product.

Stop the Release

- If the piping is leaking, discontinue use of the dispenser serviced with the leaking piping.
- If the tank is leaking, remove the product from the tank.

Do not put any more product in the system.

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Begin Cleanup

- Contact the TNRCC for guidance regarding the cleanup of the spill or release.
- Air emissions must have prior TNRCC registration.
- Contact professionals to help you clean up the leak or spill. Please refer to the PST pamphlet titled *Selecting an Environmental Consultant* and the rules in Title 30, Texas Administrative Code, Chapter 334, Subchapter J, for the requirements for consultants. Single copies may be obtained free of charge by contacting the TNRCC's Agency Publications at (512) 239-0028.
- Comply with TNRCC directives and reporting requirements.

File Report

- A release report (form number: TNRCC-0621) should be filed with the TNRCC within 20 days of discovery or suspicion of a leak or spill to document all initial actions taken to investigate, stop and clean up the leak or spill.