ARCS V

Remedial Activities at Uncontrolled Hazardous Waste Sites in Region V

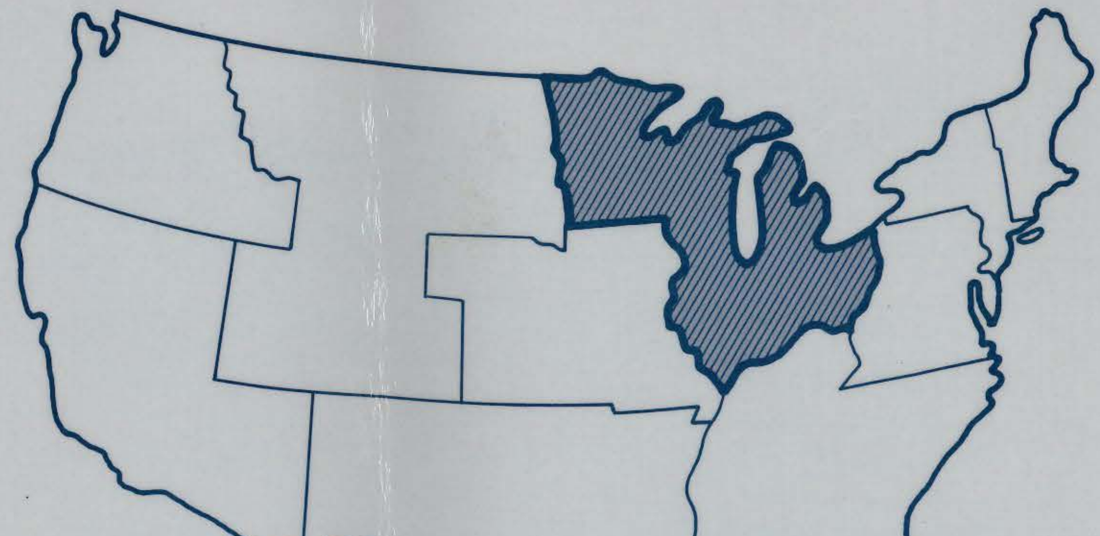
EPA United States Environmental Protection Agency

PUBLIC COMMENT
FEASIBILITY STUDY REPORT

MOSS-AMERICAN SITE
Milwaukee, Wisconsin

WA 15-5LM7.0 / Contract No. 68-W8-0040

May 24, 1990



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GLT595/078.51

CONTENTS

CONTENTS (Continued)

CONTENTS (Continued)

FIGURES

GLT938/092.51

ACRONYMS AND ABBREVIATIONS

AOC	area of contamination
API	American Petroleum Institute
ARAR	Applicable or Relevant and Appropriate Requirement
BATEA	best available technology economically achievable
BOD	biological oxygen demand
BTX	benzenes, toluenes and xylenes
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act (Superfund)
CFR	Code of Federal Regulations
cfs	cubic feet per second
cm/s	centimeters per second
CLP	Contract Laboratory Program
CORA	cost of remedial action
CWA	Clean Water Act
CY	cubic yard
cu yd	cubic yard
DNR	Department of Natural Resources
FEMA	Federal Emergency Management Agency
FIS	Flood Insurance Study
FS	Feasibility Study
ft	feet
FWQC	Federal Water Quality Criteria
GAC	granular activated carbon
GC	gas chromatograph
gpm	gallons per minute
K001	creosote process waste (as defined by RCRA)
lb	pound
LDR	Land Disposal Restrictions
MCL	maximum contaminant level
mi	mile

µg/kg	micrograms per kilogram
mg/l	milligrams per liter
MSL	mean sea level
mg/kg	milligrams per kilogram
MMSD	Milwaukee Metropolitan Sewerage District
MW	monitoring well
NCP	National Contingency Plan
ND	not detected or none detected
NEIC	National Enforcement Investigations Center
NPL	National Priorities List
O & M	Operation and Maintenance
OSEWR	Office of Solid Waste and Emergency Response
PAH	polyaromatic hydrocarbon
PCB	polychlorobiphenyl
POTW	Privately Owned Treatment Works
QA/QC	Quality Assurance/Quality Control
RA	remedial action
RAP	Remedial Action Plan
RCRA	Resource Conservation and Recovery Act
RD	remedial design
RfD	Reference Dose
RI	Remedial Investigation
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act
SB	soil boring
SDWA	Safe Drinking Water Act
sq ft	square feet
SS	surface soil
TAL	Target Analyte List
TBC	To-Be-Considered criteria or guidelines

TCL	Target Compound List
TOC	total organic carbon
U.S. EPA	United States Environmental Protection Agency
U.S. ACE	United States Army Corps of Engineers
VOC	volatile organic compound
WDNR	Wisconsin Department of Natural Resources

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EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

INTRODUCTION

This Feasibility Study Report presents the results of developing and evaluating remedial action alternatives for the Moss-American site in Milwaukee, Wisconsin. The U.S. EPA will use this report in its evaluation of remedial action alternatives for the site in accordance with the Comprehensive Environmental Response Compensation and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA), otherwise known as the Superfund Law. The U.S. EPA will recommend a remedial action alternative in its Proposed Plan, which will be issued separately.

SITE DESCRIPTION AND HISTORY

The Moss-American site is the former location of Moss-American Co., Inc., a 23-acre creosoting facility where railroad ties and other wood products were treated and stored. The wood preserving facility property is bounded roughly to the north by the Chicago & North Western Railroad (which runs parallel to but just south of Brown Deer Road), to the west by Granville Road, to the east by a north-south line located approximately 3,500 feet east of 107th Street, and to the south by the Wisconsin & Southern Railroad tracks (see Figure 1).

The site includes a 5-mile reach of the Little Menomonee River that extends from the northernmost edge of the site (Brown Deer Road) to its confluence with the Menomonee River. Public lands are adjacent to most of the river in this stretch and form the Little Menomonee River Parkway. Privately-owned land borders the river in very few locations.

The creosoting process used at the plant consisted of impregnating wood products with a mixture of 50 percent No. 6 fuel oil and 50 percent coal-based creosote. Freshly-treated wood was stacked on railcars and drip racks and was later transferred to the treated wood storage area. Figure 2 shows the main features of the site, including the processing area, storage area, a discharge trench to the Little Menomonee River with settling ponds, and two landfills.

The plant was first established in 1921. From 1921 to 1941, liquid process wastes were discharged directly into the Little Menomonee River. After 1941, a series of settling ponds and a coke filter were installed for process wastewater treatment. In 1970 the Wisconsin Department of Natural Resources (WDNR) issued an administrative order that required the Moss-American Company to divert its process water to the sanitary sewer, and the company complied with that request in 1971. During the 1970s, numerous studies were conducted on the river downstream from the site. Most of these studies were conducted after three children received skin irritations while wading in the river approximately 3 miles downstream from the site of the creosoting facility. These studies identified the Moss-American site as the source of the chemicals causing the irritations. Plant facilities were demolished in 1978 and some oil-saturated soil was removed from the site. In 1983 the U.S EPA placed the site on the National Priority List of hazardous waste sites.

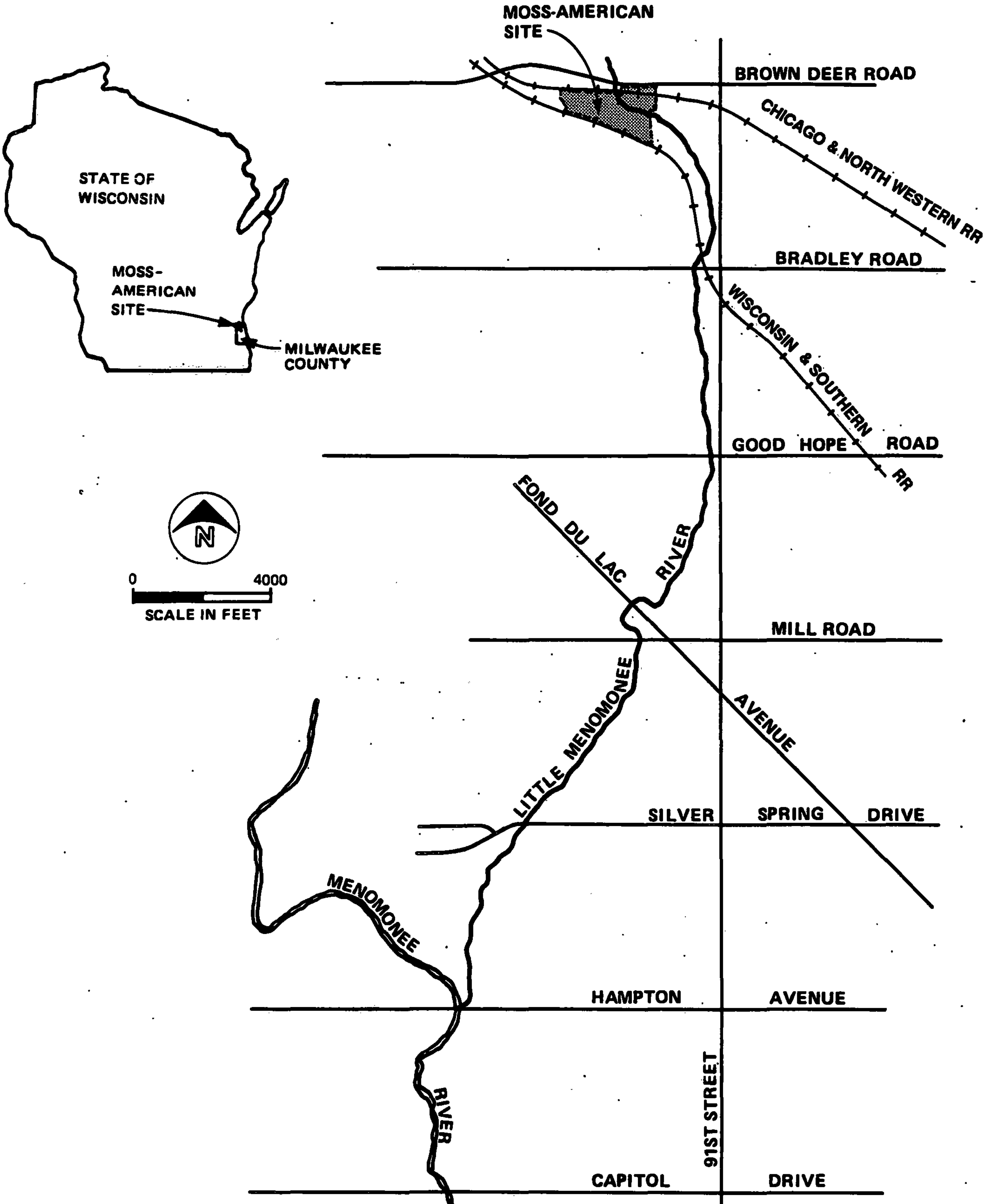
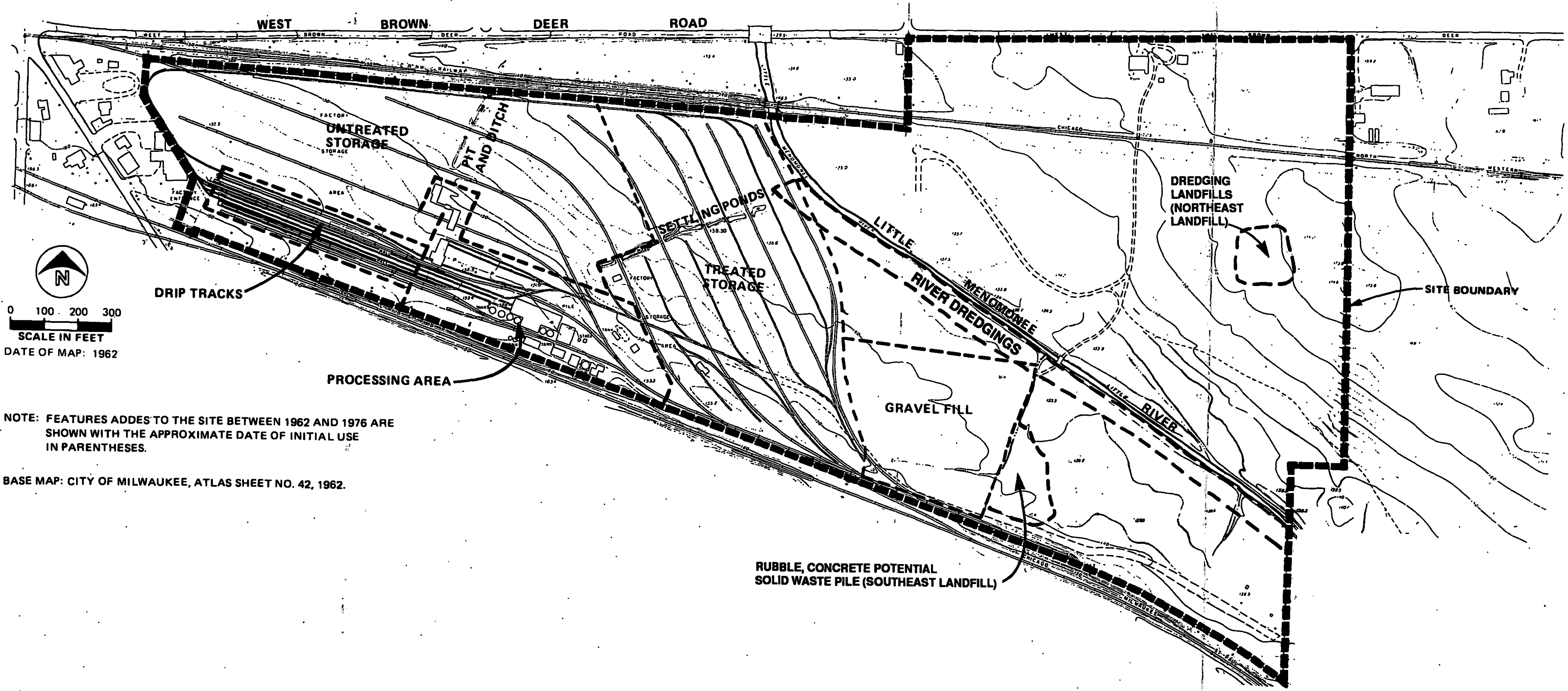


FIGURE 1
LOCATION MAP
MOSS-AMERICAN FS
EXECUTIVE SUMMARY



NOTE: FEATURES ADDES TO THE SITE BETWEEN 1962 AND 1976 ARE SHOWN WITH THE APPROXIMATE DATE OF INITIAL USE IN PARENTHESES.

BASE MAP: CITY OF MILWAUKEE, ATLAS SHEET NO. 42, 1962.

FIGURE 2
HISTORICAL LAND USE
MOSS-AMERICAN FS
EXECUTIVE SUMMARY

SUMMARY OF THE REMEDIAL INVESTIGATION

To characterize the nature and extent of contamination and to assess risks posed to human health and the environment, a remedial investigation (RI) was conducted from November 1987 through the summer of 1988. The results of this investigation are presented in the RI report (January 1990) and are summarized below.

SITE CHARACTERISTICS

The Moss-American site is relatively level, sloping gently to the river. The upper 10 feet of soil consists of varying amounts of fill, alluvial deposits, and weathered clay till. Below the weathered clay is a clay confining layer which separates the shallow aquifer from the deeper regional aquifers. About a quarter of the site is in the 100-year flood plain and exhibits marsh characteristics.

The depth to groundwater varies between zero and 15 feet below the ground surface. The general direction of shallow groundwater flow is toward the river. Based on measured hydraulic conductivities, the average velocity of groundwater in the shallow aquifer is estimated to be about 7 feet per year and the average groundwater flow from the site to the river is estimated to range from 2 to 10 gallons per minute. During extended dry-weather conditions, flow from the river into the ground has been observed.

Much of the Menomonee River within the study area is channelized. The channel characteristics are consistent, with an average water depth of 1 to 2 feet and a base width of 20 feet. Average annual flows in this section of the river are 10 to 17 cfs. The sediments are typically a silty clay, soft in some areas and hard in others. Much of the river is bordered by woodlands.

NATURE AND EXTENT OF CONTAMINATION

Soil

Numerous organic contaminants were detected in the onsite soil. The most prevalent contaminants are polycyclic aromatic hydrocarbons (PAHs), which are common constituents of creosote. The most contaminated areas include the process area, a portion of the treated wood storage area, the northeast landfill, and the southeast landfill. Figure 2 delineates areas based on historical land use. Most soil contamination exists in the upper 4 feet of the soil column, where total PAH concentrations detected were as high as 32,000,000 μg/kg (3.2 percent). A general trend of decreasing concentrations of contaminants with increased depth was observed across the site. The vertical extent of contamination extends 10 to 15 feet below grade in the process area and drip track area, about 10 feet below grade in the northeast landfill, about 20 feet below grade in the southeast landfill, and 1 to 2 feet in the remaining contaminated areas of the site. Deep migration of contaminants below the process area and settling ponds may have occurred. Observations during the RI are inconclusive with regard to the vertical extent of contamination in these two areas.

Groundwater

Groundwater contamination was observed in the monitoring wells near the settling ponds and downgradient from the process area. PAHs were the principal organic contaminants observed in the groundwater. Three monitoring wells contained pure phase product. Few or no contaminants were detected at most of the monitoring wells where no pure phase was observed. Total dissolved PAHs were measured as high as 11,000 µg/l in wells near locations where pure phase was observed. Groundwater contamination was not detected at depths below 20 feet below ground.

Sediments

Sediment contamination was found throughout the reach of the river between the site and its confluence with the Menomonee River. Contaminants detected in the sediment were similar to those in the soil with PAHs being the primary contaminants of concern. Total PAH concentrations in sediments were as high as 5,900 µg/kg, and individual PAH concentrations were as high as 4,600,000 (for phenanthrene). Background sediment sampling results indicate that background levels for total PAHs lie between 6,900 and 24,000 µg/kg. More than 70 percent of the sediment samples collected in the Little Menomonee River downstream from the original property during the RI exceeded this range of concentrations. Results from sediment sampling on the Menomonee River upstream of its confluence with the Little Menomonee River indicate that the Little Menomonee is not the only source of contaminants discharged to the Menomonee River.

SUMMARY OF RISK ASSESSMENT

The risk assessment evaluated potential threats to public health and the environment from the Moss-American site in the absence of remedial action. Potential threats to public health were estimated by making assumptions regarding the length and frequency of exposure. The U.S. EPA is generally concerned with carcinogenic risks that could exceed an excess lifetime cancer risk of 1×10^{-6} to 1×10^{-4}. A risk of 1×10^{-6} means that exposure to site contaminants could cause one additional case of cancer per 1 million people; a risk of 1×10^{-4} means that site contaminants could cause an additional 100 incidence of cancer per 1 million people. Noncarcinogenic risks were also considered but are not presented here because they were determined to be insignificant compared to the carcinogenic risks.

Two exposure settings were developed to evaluate human health risks from contaminated soil under current site conditions. One assumed that exposure to onsite contaminants would be infrequent and of short duration, such as those experienced by occasional trespassers. The excess lifetime carcinogenic risk associated with contaminated soil under this setting is estimated to be 2×10^{-4} for the highest detected concentrations and 4×10^{-6} for average concentrations. The major chemicals contributing to the risk are PAHs. The other setting assumed that a residence could be built on the site and exposure would be more frequent and occur over a longer period of time. The excess lifetime carcinogenic risk for this assumption is estimated to be 3×10^{-2}, based upon the highest detected concentrations, and 1×10^{-4} based upon average contaminant concentrations.

To evaluate potential risks to human health from the contaminated river sediments, exposure through occasional recreational use of the river was assumed. For these exposure conditions, the excess lifetime carcinogenic risk was estimated to be 1×10^{-4} for the highest detected concentration and 6×10^{-6} for average sediment concentrations. As with the soil, the magnitude of the carcinogenic risk was largely due to the presence of PAHs.

The effects of acute dermal exposure to creosote are also a concern. Skin irritations resulting from contact with sediment from the Little Menomonee River have been documented. The potential of sediments causing skin irritation is assumed to continue to exist, but this risk cannot be quantified.

Exposure of birds, terrestrial wildlife, and aquatic plants and animals can occur through direct contact, or ingestion of contaminated surface soils or contaminated sediments in the Little Menomonee River. Many types of wildlife use the river and the river corridor as a food and water source.

The Risk Assessment concluded that repeated exposure to site contaminants in onsite soils and the sediments of the Little Menomonee River could result in unacceptable risk to public health and the environment. Potential exposure to contaminated groundwater is not considered a health risk because currently it is not, and is unlikely to be a source of drinking water in the future. The groundwater is, however, an ongoing source of contamination of river sediments.

Based on the magnitude of these risks, a Feasibility Study was considered warranted to develop and assess remedial alternatives that could mitigate potential exposure to the site and river.

DEVELOPMENT OF REMEDIAL ALTERNATIVES

REMEDIAL ACTION GOALS

The first step in developing remedial alternatives was the development of remedial action goals. Two sets of goals were developed. General goals are contained in the Superfund Law and apply to all Superfund sites. The law states that the remedial actions "shall attain a degree of cleanup of hazardous substances, pollutants, and contaminants released into the environment and of control of further release at a minimum which assures protection of human health and the environment" (CERCLA, Section 121[d]). The law also mandates that:

- Preference be given to technologies that significantly reduce the volume, toxicity, or mobility of hazardous substances
- The selected remedy comply with all applicable federal and state environmental regulations pertaining to the site

Site-specific goals take into account the unique characteristics of the site and are based on the exposure conditions for which protection will be provided. Site-specific goals are established for individual media groups called "operable units." Operable units are expected to require similar or special remedial actions based upon similarities in physical characteristics of the media. The Moss-American site was divided into three operable units: the onsite soil, the river sediment, and the groundwater.

For the soil operable unit, the site-specific goals were to minimize direct contact, inhalation, or ingestion of soil contaminants that present unacceptable levels of risk to human health, and to minimize the threat to human health resulting from the migration of contaminants from the soil into groundwater and eventually the river. Figure 3 outlines the areas of soil believed to have contaminant concentrations of greater than the concentrations associated with a 1×10^{-6} excess lifetime cancer risk. The volume of soil in these areas is estimated to be about 210,000 cubic yards.

Site-specific goals for the sediment operable unit include minimizing contact that could result in unacceptable levels of risk, minimizing the downstream migration of contaminated sediments, and minimizing acute and chronic effects on aquatic life posed by contaminated sediments. The volume of sediment that has carcinogenic PAH concentrations that exceed background levels is estimated to be 26,000 cubic yards.

Site-specific goals for the groundwater operable unit include preventing contact with or ingestion of groundwater that exceeds maximum contaminant levels (MCLs) or presents cancer risks exceeding 1×10^{-6}, and to prevent release of contaminants through the shallow aquifer to the Little Menomonee River. The lateral extent of contaminated groundwater is shown in Figure 3.

DESCRIPTION OF ALTERNATIVES

During the process of developing alternatives, a range of alternatives in terms of cost and effectiveness that satisfied the general and site-specific goals was presented. Alternatives that relied primarily on containment of the wastes and alternatives that relied primarily on treatment of the wastes were developed. The process by which alternatives are developed began with evaluating and screening a wide range of possible technologies to select those technologies most likely to be effective. Then, those technologies were combined into complete alternatives. Following is a description of each alternative.

Alternative 1—No Action

Alternative 1 assumes no corrective action will be taken at the site and no restrictions will be placed on site use. The risks to human health estimated in the base line risk assessment (described before) would remain unchanged.

Alternative 2—Containment of Sediment, Soil, and Treatment of Groundwater

The objective of Alternative 2 is to achieve the remedial action goals through in-place containment of the wastes. A new river channel would be dug parallel to the existing river from the site to its confluence with the Menomonee River, and the soil removed from the new excavation would be used to cover the old stream bed. Contaminated soil onsite (i.e., about 210,000 cubic yards on the original property) would be contained in place under a vegetated soil cover. An estimated 40,000 to 50,000 cubic yards of contaminated soil on the original property in the flood plain would be moved

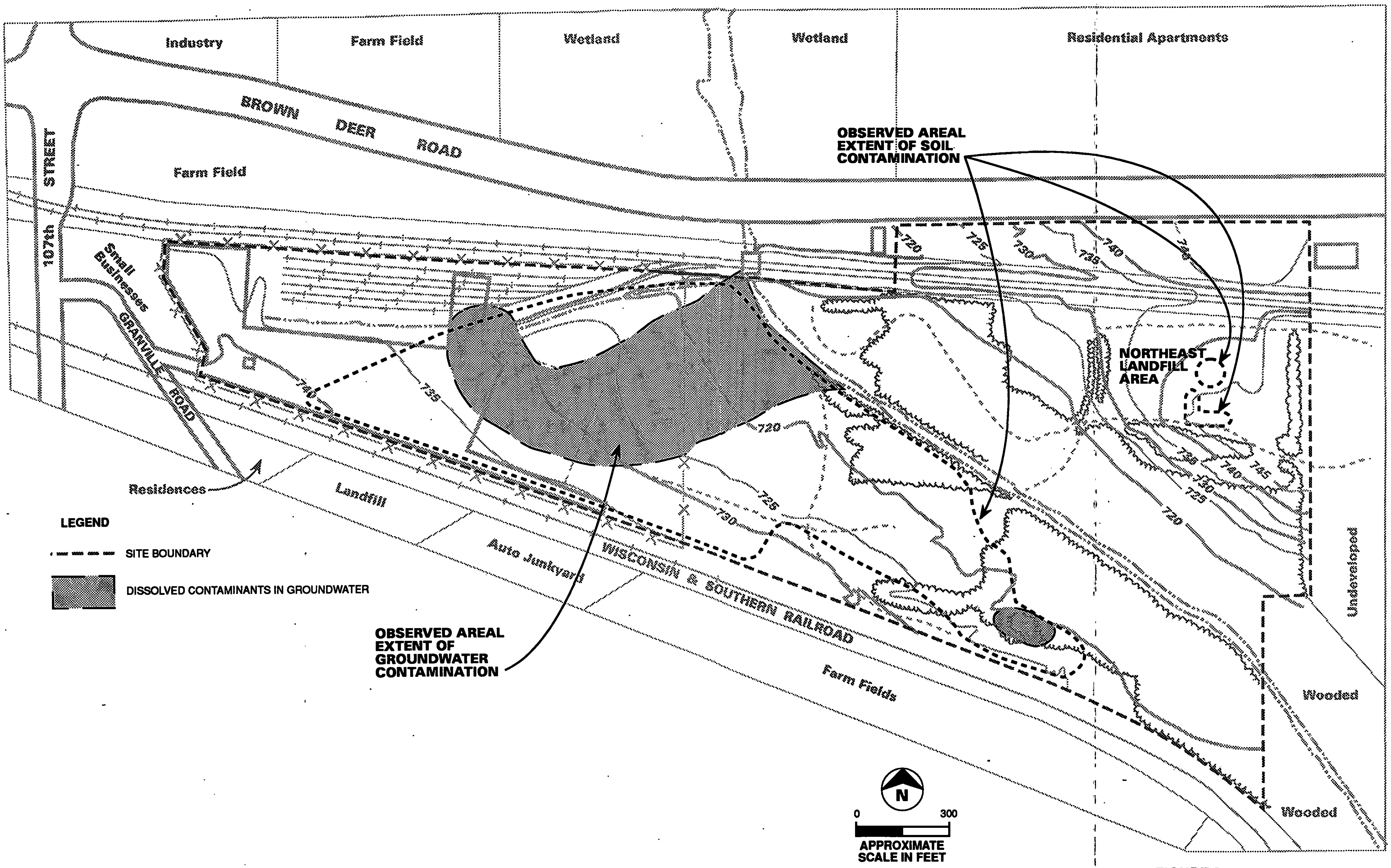


FIGURE 3
EXTENT OF SOIL AND GROUNDWATER CONTAMINATION
MOSS-AMERICAN FS

GLO65564.AS EXT OF SOIL/GRDWTR CONTAM 3-20-90 out of the flood plain and consolidated with other contaminated soil before containment. Contaminated groundwater would be collected with an interceptor trench near the river, treated onsite, and discharged to the Little Menomonee River unless it could be discharged to the POTW following pretreatment with an oil/water separator. Groundwater collection or monitoring may be required for more than a 100 years. Contaminated soil in the Northeast Landfill would be removed and incinerated at an offsite RCRA facility.

Alternative 3A—Partial Removal and Slurry Biotreatment of Contaminated Sediment and Soil, Containment of Remaining Sediment and Soil, and Treatment of Groundwater

The objective of Alternative 3A is to attain the goals of protecting human health and the environment by removing and treating the most highly contaminated soil and sediment. This alternative would remove and treat sediment and soil that is observed to contain visible traces of creosote and place the treatment residues with the remaining contaminated soil under a vegetated soil cover. A large fraction of the contaminant mass is associated with the soil and sediment having visible traces of creosote. Removal of this contaminant source from river sediments would further limit the potential of exposure to contaminated soil and migration of contaminants from sediment contained in place. Contaminated groundwater would be collected and treated onsite and discharged to the Little Menomonee River unless it could be discharged to the sanitary sewer. Because the majority of the contaminant source would be removed, it is estimated that the period of groundwater treatment would be less than 10 years. Sediment and soil treatment would be performed onsite using slurry bioreactors and soil washing equipment. These materials would be treated until contaminant levels are reduced to below the health-based targets (1×10^{-4} excess lifetime cancer risk) and the levels of constituents restricted under the Land Disposal Restrictions (LDRs) are reduced to below the levels established in a Treatability Variance. It is estimated that 6,500 cubic yards of sediment and 80,000 cubic yards of soil would be removed and treated and then contained onsite under a soil cover along with the remaining contaminated soil. Residues produced from the biotreatment of contaminated soil from the Northeast Landfill would be disposed of offsite in a RCRA landfill to comply with LDRs. Oversize material (e.g., railroad ties) removed from areas of contaminated soil would be disposed of offsite in a special waste landfill. Concurrent with the removal of the sediment, a new river channel would be dug and the remaining contaminated sediment contained in place. While significant reductions in contaminants would occur, some residual risk greater than 1×10^{-6} could still be associated with ingestion of the treated soil and sediment. Thus the treated soil and sediment would be placed under a soil cover to prevent direct contact and deed restrictions would be imposed.

Alternative 3B—Partial Removal and Land Treatment of Soil and Sediment, Containment of Remaining Soil and Sediment, Treatment of the Groundwater

Alternative 3B is similar to 3A except that the land treatment technology would be used instead of slurry bioreactors to biologically treat the 6,500 cubic yards of visibly contaminated sediment and the 80,000 cubic yards of visibly contaminated soil. In this alternative, the contaminated soil and sediment would be spread out over two lined, 5-acre cells and periodically tilled to enhance the biodegradation of contaminants. Treated soil and sediment would be stockpiled onsite until all material was treated. While significant reductions in contaminants would occur (treatment levels would be the same as for Alternative 3A), some residual risk greater than 1×10^{-6} could still be associated with ingestion of the treated soil and sediment. Thus the treated soil and sediment would be placed under a soil cover to prevent direct contact and deed restrictions would be imposed. This alternative presumes that discharge of contaminated groundwater to the POTW is not available, and that contaminated groundwater would be collected, treated onsite, and discharged to the river. As under Alternative 3A, residues generated from the treatment of soil from the Northeast Landfill would be disposed of offsite in a RCRA landfill, and oversize debris would be disposed of offsite in a special waste landfill.

Alternative 4—Removal and Slurry Biotreatment of Sediment, Containment of Soil, and Treatment of Groundwater

The objective of Alternative 4 is to biologically treat all the contaminated sediment with contaminant levels exceeding background levels for PAHs and contain the contaminated soil onsite. As for Alternative 3A, sediment and soil would be treated by a slurry bioreactor. Unlike Alternative 3A, no contaminated soil, other than from the Northeast Landfill, would be treated and the existing river alignment would remain the same because sediment posing an unacceptable risk to human health and the environment (above background levels) would be removed. This volume of sediment is estimated to be about 33,000 cubic yards. The volume of soil to be treated is estimated to be 1,000 cubic yards. Groundwater management would be as proposed for Alternative 2. Treatment residues from the Northeast Landfill would be managed as in Alternative 3A.

Alternative 5—Slurry Biotreatment of Soil and Sediment, Containment of Soil, and Treatment of the Groundwater

Alternative 5 combines actions from Alternatives 3A and 4. Under this alternative contaminated sediment exceeding background levels for PAHs and visibly contaminated soil would be treated onsite. The volume of soil and sediment requiring treatment is estimated to be about 110,000 cubic yards. As with Alternative 3A, Alternative 5 would utilize soil washing to reduce the amount of contaminated soil to be treated in the slurry bioreactor. Contaminated soil would be washed to remove contaminants from the coarse-grained soil, and contaminated fine-grained soil and sediment would be treated in the slurry bioreactors. After the contaminated soil and sediment have been treated, they would be placed under a soil cover onsite. Because it is derived from a separate area of contamination, treated soil from the Northeast Landfill would be disposed of offsite in a RCRA landfill. Oversize material would be disposed of in a special waste landfill. Contaminated groundwater would be removed, treated and discharged to the river as per the preceding alternatives. Because sediment with contaminant concentrations greater than background levels would be removed under this alternative, the river would not be rechannelized but some stabilization of river banks and channel modifications may be necessary.

Alternative 6—Incineration of Soil and Sediment

The objective of Alternative 6 is to provide an alternative that minimizes the need for long-term maintenance. Contaminated soil and sediment (total of about 160,000 cubic yards) would be incinerated onsite in a mobile treatment unit. The contaminated soil to be removed would include soil having contaminant concentrations exceeding the 1×10^{-6} excess lifetime cancer risk targets except for soil below the seasonal low water table that has carcinogenic PAH concentrations less than 10 ppm. The treated residues (ash from the incinerator), including residues from treatment of soil from the Northeast Landfill, would be contained onsite under a soil cover. The residual risk associated with the ash is expected to be less than 1×10^{-6} and it is assumed that the material would be delisted. Because source material would be removed, groundwater collection and treatment would not be required except for dewatering during the construction phase.

ALTERNATIVE EVALUATION

The final step of the FS is the evaluation of alternatives. Each alternative underwent a detailed evaluation to demonstrate its fulfillment of the Superfund Law requirements and to assist decisionmakers with the selection of a site remedy. The alternatives were evaluated according to seven criteria:

- Short-term effectiveness
- Long-term effectiveness
- Reduction in toxicity, mobility, and volume of contamination
- Implementability
- Estimated cost
- Compliance with applicable regulations
- Overall protection

With the exception of Alternative 1, all the alternatives are expected to protect human health and the environment. The most significant differences are the cost, the time until implementation of the remedy is complete, and the amount of contaminated material that is treated as opposed to being contained. A summary of the evaluation of alternatives is presented on Table 1.

PROPOSED PLAN

The Proposed Plan, a document to be issued by the U.S. EPA, will present the U.S. EPA's preferred remedial action alternative and solicit public comments on the Feasibility Study in accordance with Superfund Law. Changes to the preferred alternative or a change from one preferred alternative to another may be made if public comment or additional data indicate a better fulfillment of the criteria. The final remedy will be documented in the U.S. EPA's Record of Decision after considering the public's response to the Proposed Plan.

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SUMMARY OF COMPARATIVE ANALYSIS FOR ALTERNATIVES

EVALUATION CRITERIA	SUMMARY OF COMPARATIVE ANALYSIS
SHORT-TERM EFFECTIVENESS	All alternatives except Alternatives 1 and 2 present some nuisance to the community from increased vehicular traffic to transport large volumes of contaminated sediment on residential roads. Alternative 6 may be most visible to the community because of the onsite incinerator and smokestack. No alternative is expected to pose health risks to the community. Excavating contaminated material would pose some health risks to workers under all alternatives. The risks from Alternative 2 are expected to be the least because the contaminated material would be covered in place. Greater risks would occur under Alternatives 5 and 6 because larger volumes of contaminated soil would be excavated. The greatest potential risk to workers could be associated with Alternative 3B, under which long-term tilling of contaminated material would take place. All potential risks to workers should be mitigated through proper health and safety measures. All alternatives would result in the destruction of the local aquatic ecology and would require re-establishing the aquatic habitats after remediation. The approximate time required to implement each remedial action (not including predesign and design activities) is estimated as follows: Alternative 2 — 1 to 2 years Alternative 3A — 3 to 4 years Alternative 3B — 8 to 15 years Alternative 4 — 1 to 2 years Alternative 5 — 4 to 6 years Alternative 6 — 4 to 5 years The time estimates may be refined after pilot-scale studies are complete. These estimates do not include the time to achieve groundwater goals. For Alternatives 2 and 4, removal of groundwater contaminants to meet Wisconsin groundwater and surface water quality standards could require more than 100 years of groundwater extraction and treatment. Alternatives 3A, 3B, and 5 are anticipated to require groundwater collection and treatment for a period of less than 10 years because the majority of source material would be removed. Alternative 6 would achieve protection of groundwater and surface water in the short-term through source removal.

SUMMARY OF COMPARATIVE ANALYSIS
FOR ALTERNATIVES

EVALUATION CRITERIA	SUMMARY OF COMPARATIVE ANALYSIS
LONG-TERM EFFECTIVENESS	The greatest long-term residual risk is associated with Alternative 2 because little of the contaminant mass would be destroyed. Conversely, the long-term residual risk is least with Alternative 6 because it achieves the greatest reduction in soil and sediment contaminants. Alternative 6 is considered the most reliable because it does not rely on containment of contaminants onsite. Residual risks associated with Alternative 6 are expected to be less than 10^{-6}. Alternatives 3A and 3B significantly reduce residual risk since they remove and treat the highly-contaminated soil and sediment. Alternative 4 removes and treats more contaminated sediment, but the residual risk from onsite soil is greater than for 3A and 3B. Residual risk for Alternative 5 is comparable to that of 3A and 3B.
REDUCTION OF TOXICITY, MOBILITY, AND VOLUME	Alternatives 3A, 3B, 4, and 5 would reduce concentrations of contaminants of concern by more than 90% for all the treated material. Contaminant levels for constituents restricted by the Land Disposal Restrictions would be reduced by 95% or to 20 mg/kg to comply with ARARs. These contaminants were not the major contributors to risk, however. Treated residues from 3A, 3B, 4, and 5 could still pose cancer risks greater than 1×10^{-6} if replaced onsite. Alternative 2 would not reduce the toxicity of any of the contaminated material other than the Northeast Landfill, but could result in a decrease in contaminant mobility if an effective admixture is blended into grossly contaminated sediments before in place containment. Alternative 6 could reduce contaminant concentrations by 99.99% and produce residues having cancer risks less than 1×10^{-6}.
IMPLEMENTABILITY	The most difficult aspect of implementation of all alternatives (except Alternative 1) is the work on the river and the extensive diversions that would have to take place. This aspect is the most complicated for Alternatives 3A through 6 since sediment must be removed and transported. For Alternative 6, a test burn of the incinerator would have to be completed to demonstrate compliance with emission standards. Some start-up problems may be encountered with the biological treatment alternatives because these are still innovative technologies. Startup problems will be minimized by identifying them during pilot studies conducted during the RD that will determine specific performance parameters.

SUMMARY OF COMPARATIVE ANALYSIS
FOR ALTERNATIVES

EVALUATION CRITERIA	SUMMARY OF COMPARATIVE ANALYSIS
ESTIMATED COST	The estimated total present worth of each alternative is: Alternative 2 — $18,000,000 Alternative 3A — $26,000,000 Alternative 3B — $26,000,000 Alternative 4 — $20,000,000 Alternative 5 — $24,000,000 Alternative 6 — $89,000,000 The additional level of protection per dollar afforded by Alternative 6 is considered marginal. Alternatives 2 through 5 have similar costs, given the margin of error in this level of cost estimating. Alternatives 3A and 3B provide significant increases in the level of protection over Alternatives 2, 4, and 5 for roughly equal cost.
COMPLIANCE WITH APPLICABLE REGULATIONS	All alternatives are expected to meet state and federal requirements with the exception of state ARARs pertaining to the use of soil covers for containment of treated soil. Since slurry bioreactors or land treatment would probably not achieve treatment standards specified in the land disposal regulations, this FS assumes these alternatives will comply with a treatability variance. While the placement of treated residues back onsite would constitute a disposal action triggering RCRA or land ban requirements, the residues can be replaced into the area of contamination in a unit that does not meet Minimum Technology Requirements, and therefore would be in compliance with federal ARARs. This FS also presumes that the state ARARs for final cover will be waived, and a hybrid closure implemented.
OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT	All alternatives can achieve health based goals for protection of human health, and can achieve the goals set for protection of aquatic life. Those alternatives that most reliably protect human health and the environment are those that treat the most waste (Alternatives 5 and 6). However, those alternatives also involve the greatest nuisance to the community during the remedial action and the greatest threat to workers.

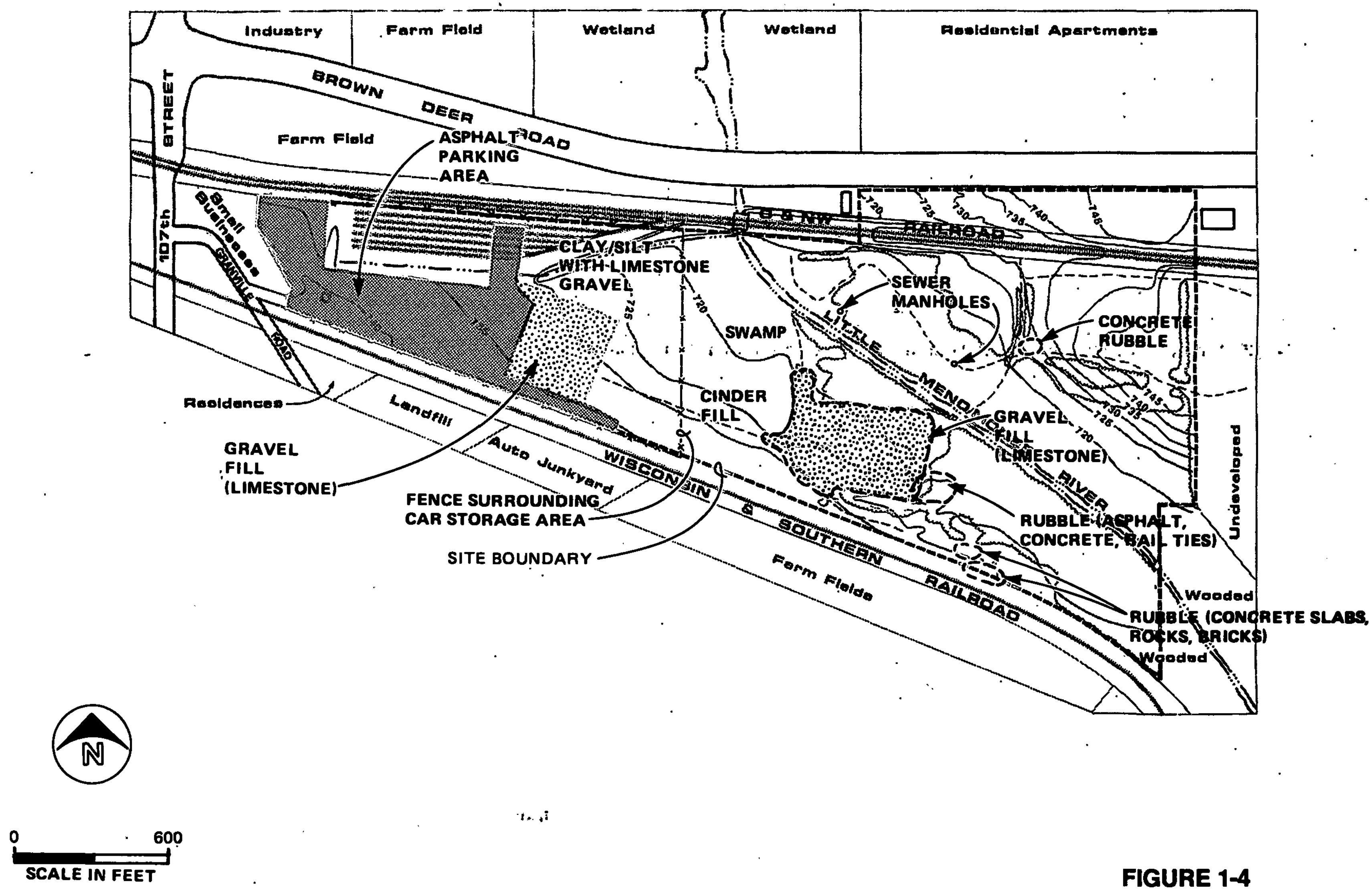


FIGURE 1-4
EXISTING CONDITIONS: 1987
MOSS-AMERICAN FS

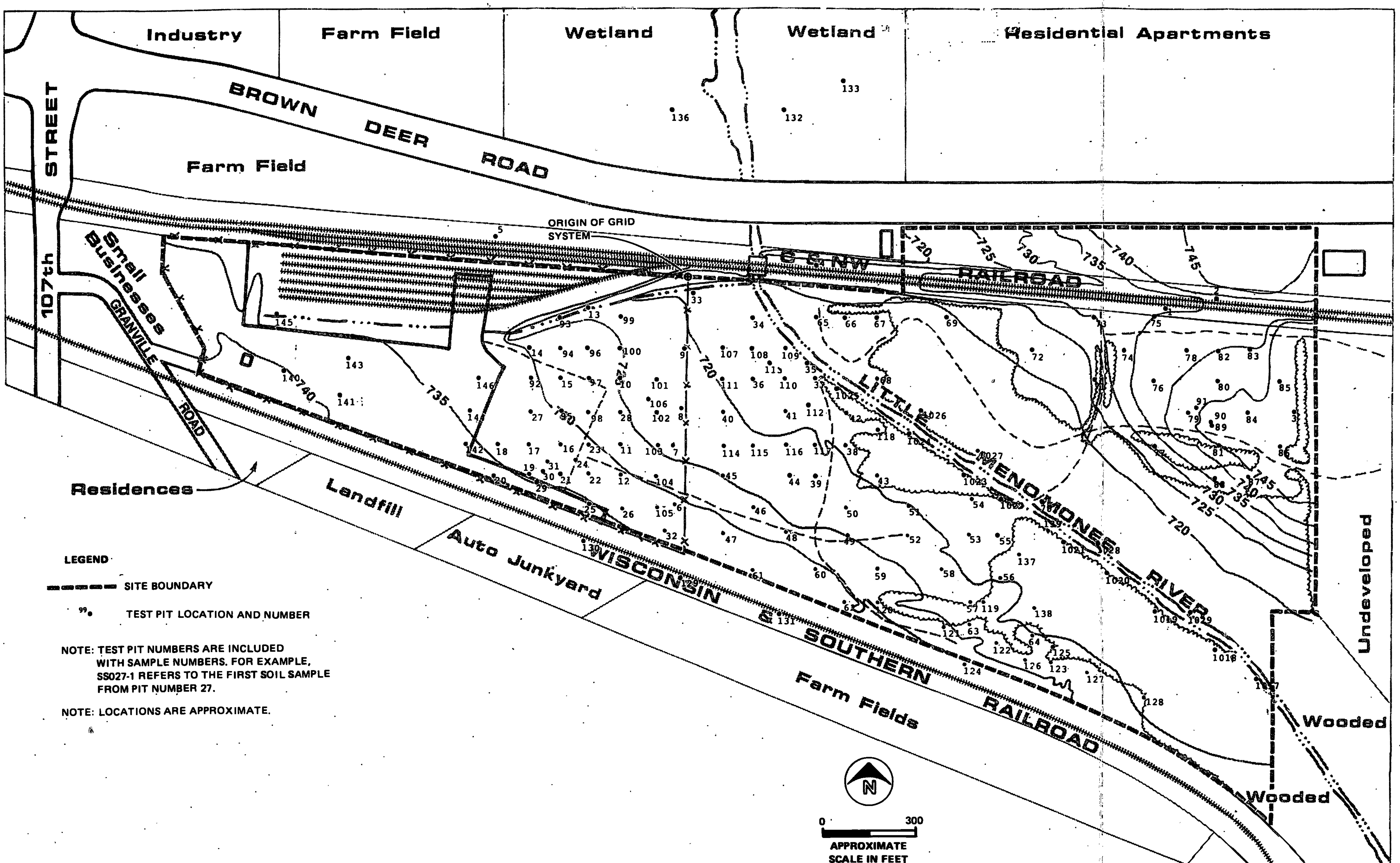


FIGURE 1-5
SURFACE SOIL SAMPLING LOCATIONS
MOSS-AMERICAN FS

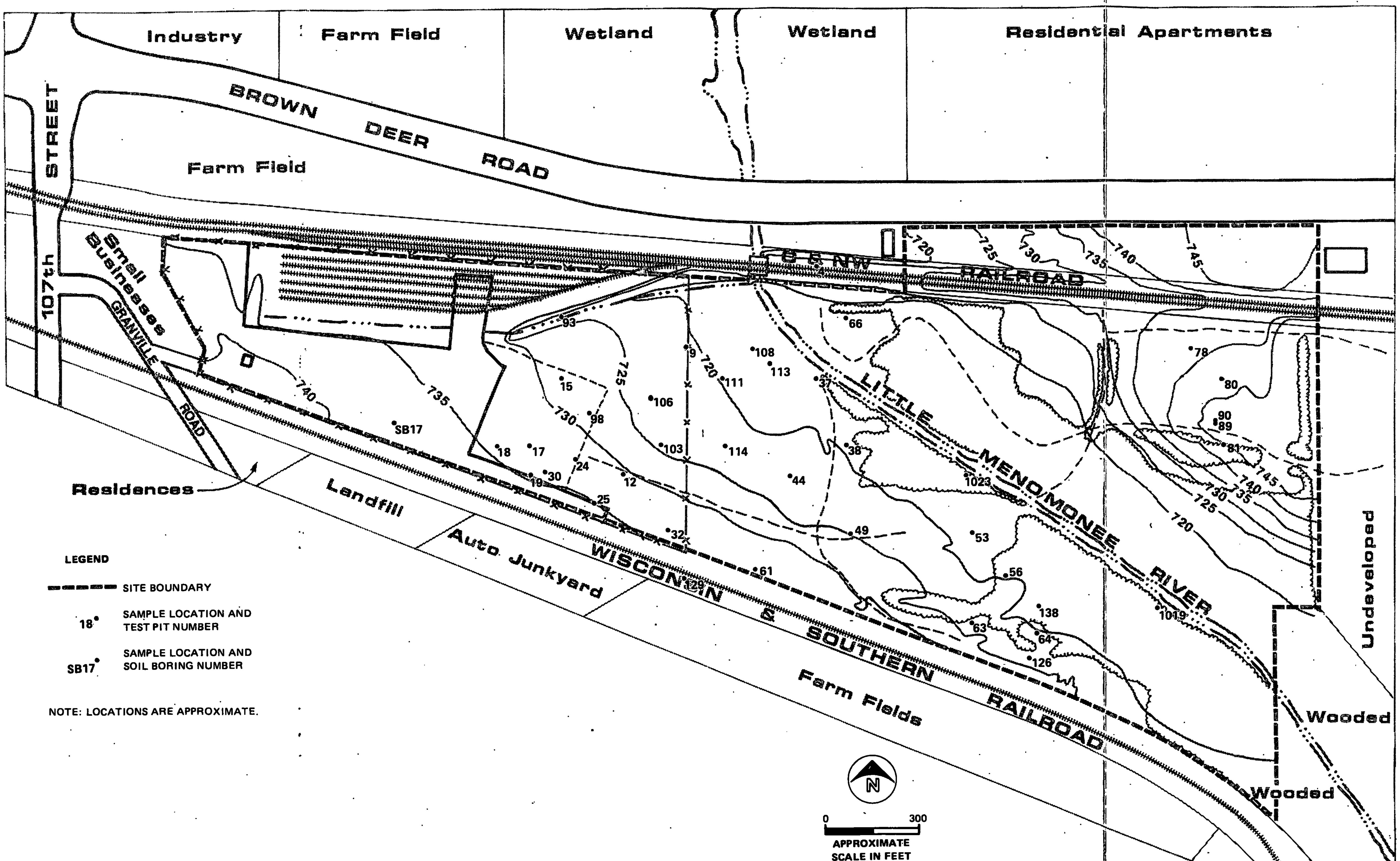
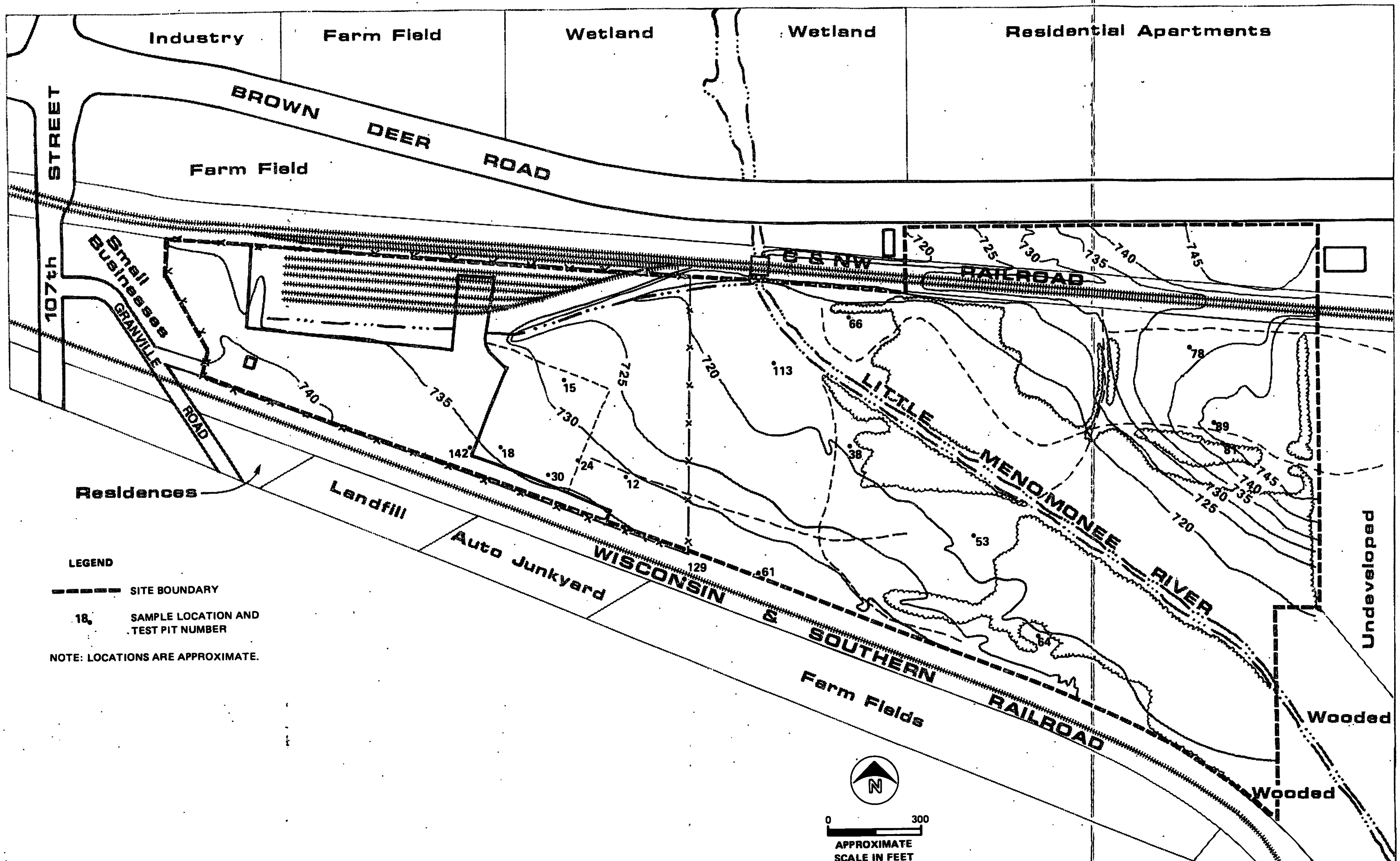


FIGURE 1-6
SAMPLING LOCATIONS FOR PAH AND PHENOLIC ACID COMPOUND ANALYSIS
MOSS-AMERICAN FS



LEGEND

SITE BOUNDARY

18 SAMPLE LOCATION AND TEST PIT NUMBER

NOTE: LOCATIONS ARE APPROXIMATE.

FIGURE 1-7
SAMPLING LOCATIONS FOR CLP ANALYSES
MOSS-AMERICAN FS

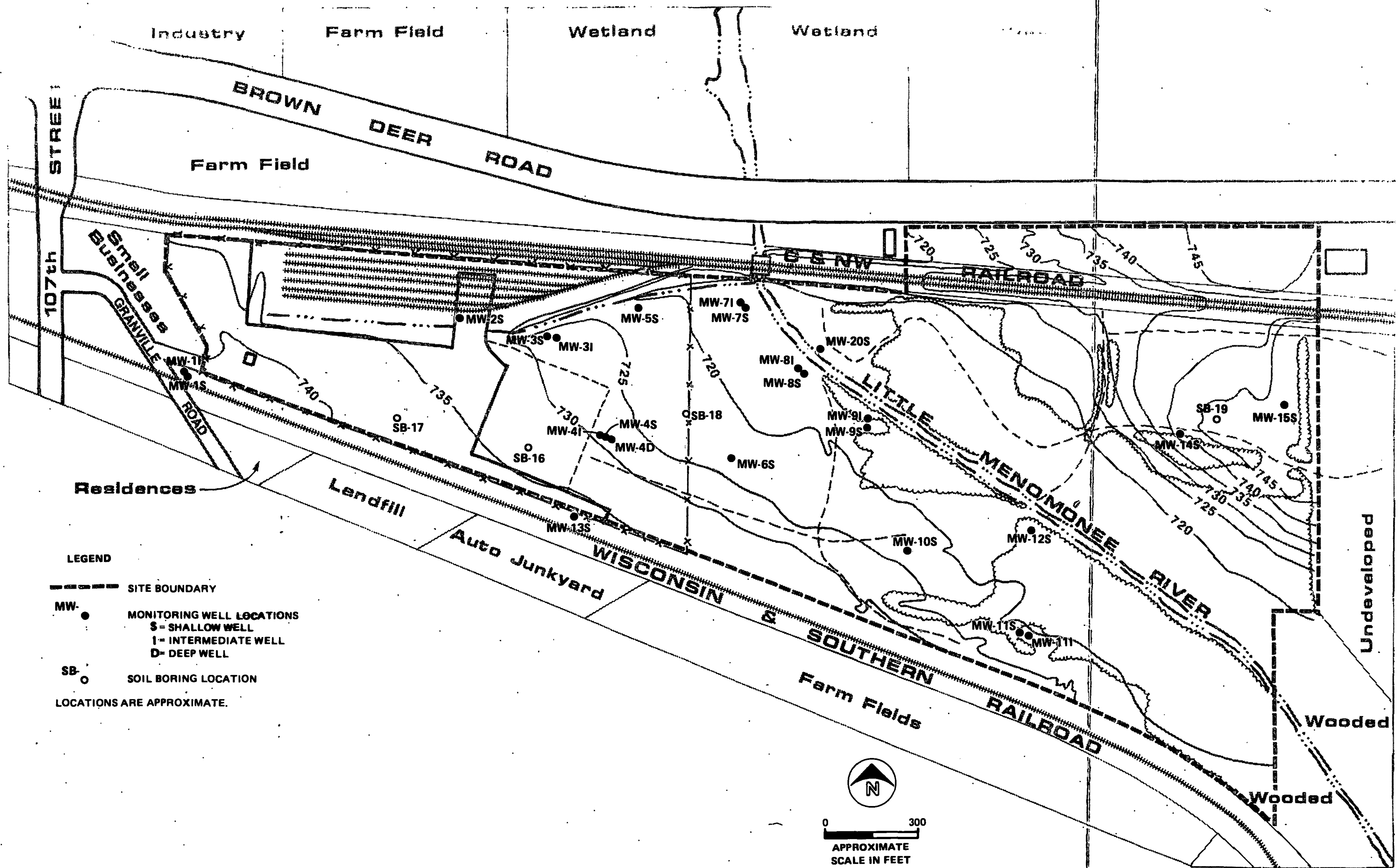


FIGURE 1-8
MONITORING WELL AND SOIL BORING LOCATIONS
MOSS-AMERICAN FS

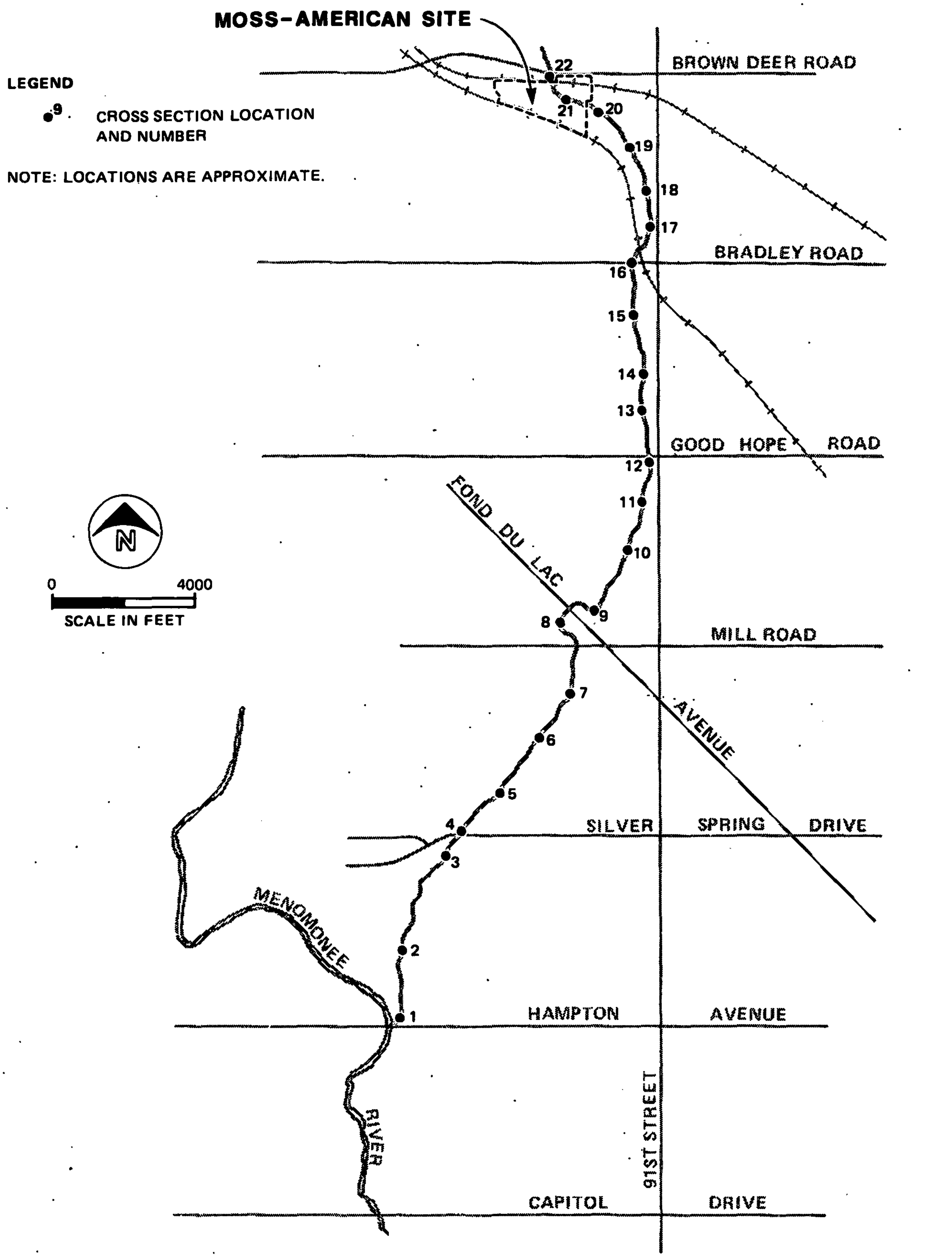


FIGURE 1-9
RIVER CROSS SECTION LOCATION MAP
MOSS-AMERICAN FS

Chapter 1
INTRODUCTION

Chapter 1
INTRODUCTION

Between 1921 and 1976, a wood preserving plant was operated at what is known as the Moss-American site in Milwaukee, Wisconsin. The plant preserved railroad ties, poles, and fence posts with creosote. In 1971 the site received national attention when several youths were burned by creosote-contaminated sediments downstream from the site. A series of investigations and remedial actions were undertaken until 1977; on the basis of the results of those investigations, the U.S. EPA placed the Moss-American site on the National Priority List (NPL) of uncontrolled hazardous waste sites in 1983.

Sites on the NPL are eligible for remedial action under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980. The authority to list, investigate, and remedy hazardous waste sites under CERCLA was extended by the Superfund Amendments and Reauthorization Act (SARA) of 1986. The U.S. EPA is authorized to act when 1) there is an actual or substantial threat of release of hazardous substances into the environment, or 2) there is a release or substantial threat of release into the environment of any pollutant or contaminant that may present an imminent and substantial danger to public health or welfare [CERCLA Section 104(a)]. Pursuant to Section 105 of CERCLA and to Section 311 (c) (2) of the Clean Water Act, the National Contingency Plan (NCP) [40 CFR Part 300] was prepared to establish procedures and criteria for responding to releases of hazardous substances. Section 300.430 of the NCP outlines the Remedial Investigation/Feasibility Study (RI/FS) procedure for determining the nature and extent of contamination at the site and the appropriate extent of remedy for the site.

The U.S. EPA has undertaken and completed the first phase of the RI/FS process. The RI report, completed in January 1990, presented the nature and extent of chemical contamination at the site and evaluated the risks posed to human health and the environment. Environmental problems at the site were related to prior management of creosote-treated products and wastewater. The U.S. EPA concluded that unacceptable human and environmental health risks are associated with the site and recommended that an FS be performed to determine an appropriate remedy for the site.

PURPOSE AND ORGANIZATION OF REPORT

This FS report documents the analyses and evaluations used to develop remedial action alternatives for the Moss-American site. The U.S. EPA, in consultation with the Wisconsin Department of Natural Resources (DNR), will use this information to select a remedial action alternative in its Record of Decision (ROD) in accordance with the NCP. The criteria for remedy selection under CERCLA Section 121 require that Superfund remedial actions 1) protect human health and the environment, 2) comply with applicable or relevant and appropriate requirements (ARARs) of federal and state environmental laws, 3) be cost-effective, and 4) use permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable.

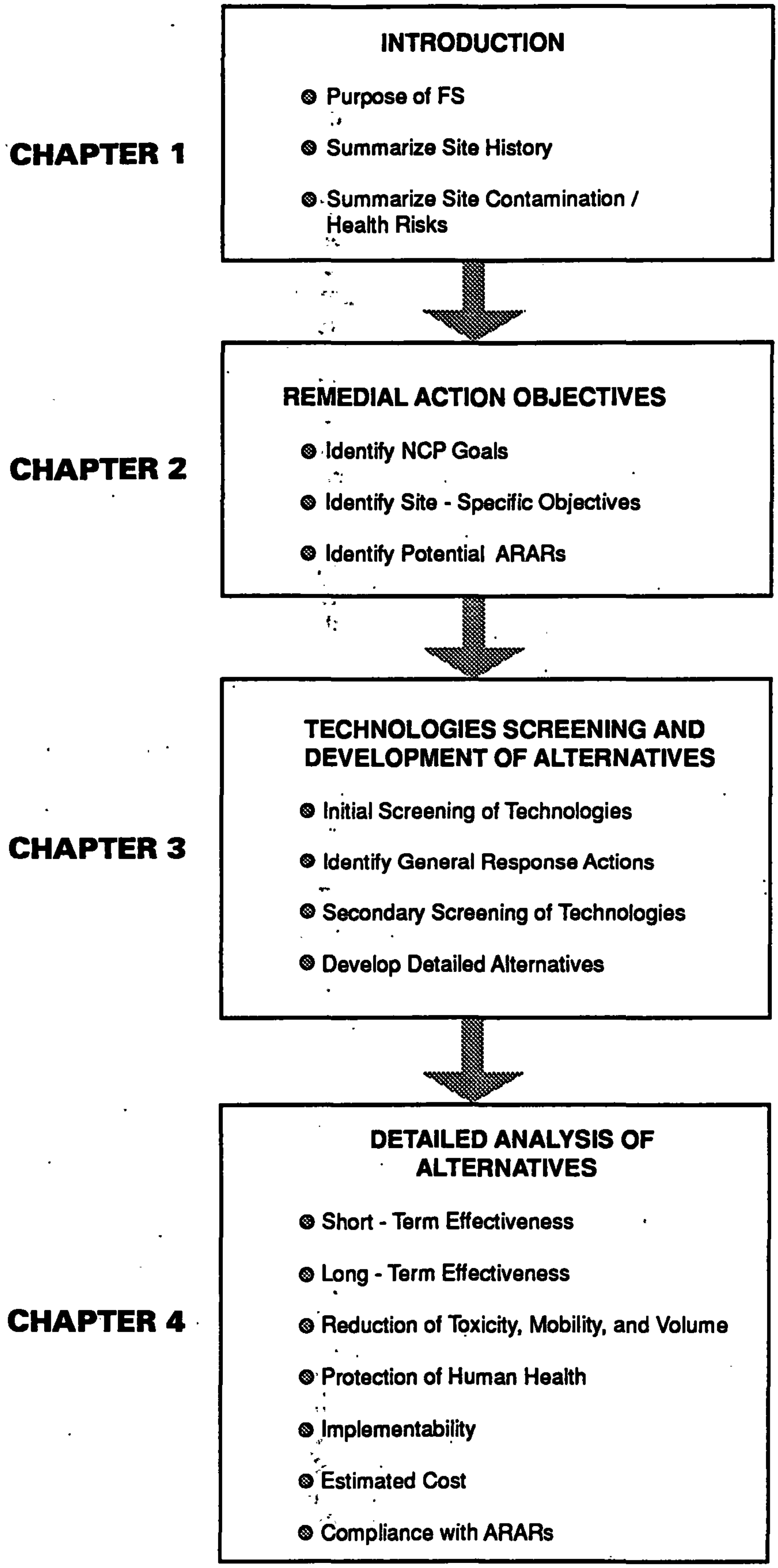
The logical progression and structure of the main body of this FS report is shown in Figure 1-1. Chapter 1 presents a summary of the site history, previous investigations, and health risks posed by the site. Chapter 2 outlines remedial action objectives for the site that are intended to provide adequate protection of human health and the environment. Chemical-specific remedial objectives were developed for soil, sediment, and groundwater based on risk-based concentrations of contaminants in those media, ARARs, and background concentrations. Chapter 3 identifies general response actions that address remedial action goals. Remedial technologies were screened to reduce the number of technologies considered in the detailed alternatives. These remaining technologies were assembled into remedial action alternatives that achieve some or all of the remedial action goals, and provide a range of levels of remediation and a corresponding range of costs. Chapter 4 presents a detailed analysis of these alternatives. The detailed analysis addresses seven specific evaluation criteria as per the NCP. Two additional criteria to be used in the evaluation of alternatives and the selection of a remedy—state acceptance and community acceptance—are addressed following public comment on the FS.

SITE DESCRIPTION AND HISTORY

The Moss-American site is the former location of Moss-American Co., Inc., a 23-acre creosoting facility where railroad ties and other wood products were treated and stored. It includes a 5-mile stretch of the Little Menomonee River extending southward from the wood preserving facility property. The facility property is bounded roughly to the north by the Chicago and North Western Railroad just south of Brown Deer Road, to the west by Granville Road, to the east by a north-south line approximately 3,500 feet east of 107th Street, and to the south by the Wisconsin & Southern Railroad tracks. The site location is illustrated in Figure 1-2.

The portion of the Little Menomonee River considered to be part of the site extends from the northernmost edge of the site (Brown Deer Road) to the confluence with the Menomonee River. It flows through the 23-acre property, eventually discharging to the Menomonee River approximately 5 miles downriver from the site. The public property adjacent to the Little Menomonee River includes the Little Menomonee River Parkway. Privately-owned property fronts the river in very few locations.

Topography near the site is slightly to moderately rolling with drainage toward the south. Depth to groundwater varies from zero feet in wet areas near the river to more than 15 feet in the northeasternmost portion of the site. The water table slopes toward the Little Menomonee River on both sides of the river. The bedrock is buried by approximately 100 feet of glacial till and outwash deposits. Soils onsite are classified by USDA as "loamy sand." They consist of a few feet of fill which is underlain by 10 to 20 feet of weathered silty clay or alluvial silts and sands. The total thickness of the surficial soils varies up to 20 feet. At depths greater than 20 feet, the surficial soils are underlain by a dense silty clay till, which restricts deep migration of groundwater and pure phase.



GLO65564.AS FIG 1-1 12-28-89

FIGURE 1-1
FS REPORT
FLOW DIAGRAM
MOSS-AMERICAN FS

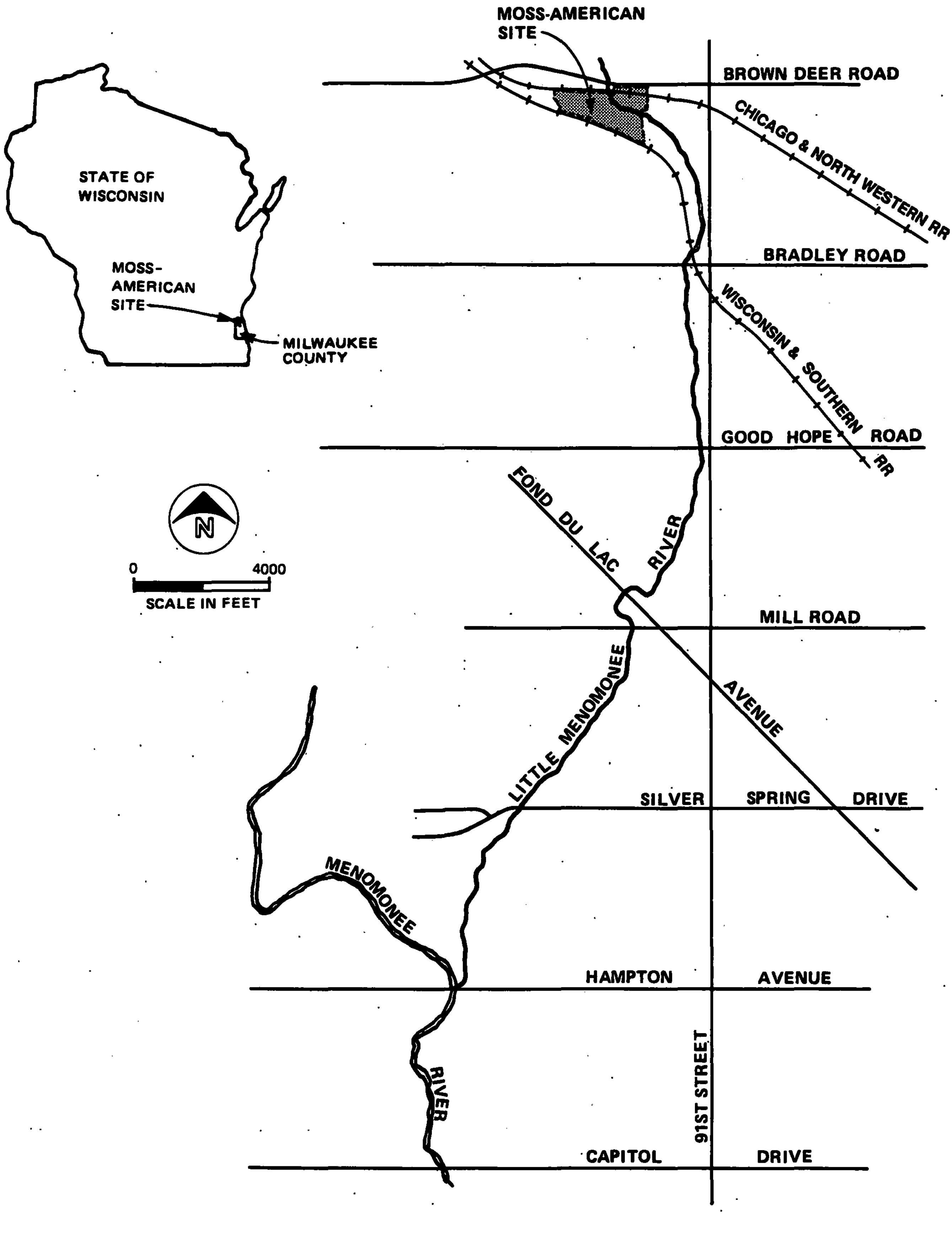


FIGURE 1-2
LOCATION MAP
MOSS-AMERICAN FS

A chronology of activity at the site is summarized in Table 1-1. In 1921 the T. J. Moss Tie Company established a wood preserving plant on the site. The plant preserved railroad ties, poles, and fence posts with creosote. Kerr-McGee purchased the T. J. Moss facility in 1963 and in 1965, after purchasing the American Creosote Company, consolidated the two companies to form the Moss-American Company. The name was changed again in 1974 to Kerr-McGee Chemical Corporation—Forest Products Division. All operations at the plant ceased in 1976, and site buildings and equipment were subsequently dismantled and removed.

The creosoting process consisted of impregnating the wood products with a mixture of 50 percent No. 6 fuel oil and 50 percent coal-based creosote. Freshly treated wood was stacked on railcars, parked on drip tracks, and later transferred to the treated wood storage areas. Processing and storage areas at the site as they appeared in 1962 are shown in Figure 1-3. The processing area consisted of the retort building, vertical tanks for creosote and fuel oil storage, and several smaller support buildings.

Between 1921 and 1941, liquid wastes from the site were discharged directly to the Little Menomonee River. A series of settling basins and a coke filter were installed for waste treatment in 1941, and in 1954 a Public Health Engineer noted that the coke filter was not in place. At that time, the wastewater passed through an oil-water-sludge separator and was discharged to a 700-foot ditch that discharged to the river. The ditch included one settling pond (see Figure 1-3) and hay filters installed at the head of culverts that passed under the tracks at 70- to 150-foot intervals. Subsurface drains added in 1952 drained to an open ditch along the northern property boundary and then to the river.

In 1966 the Milwaukee Metropolitan Sewerage Commission advised Moss-American that oil leaking from the drainage ditch and settling ponds was not permitted and they should be dredged and the pond walls rebuilt with uncontaminated clay. Moss-American complied with that request.

The Wisconsin DNR issued an Administrative Order in 1970 requiring that Moss-American divert its process water discharge to the Milwaukee Sanitary Sewerage System. The company completed the diversion project in 1971, and discharges to the river were limited to water-softener wastes and stormwater runoff.

In 1971 the site received national attention when a group of children received skin irritation from wading in sediments more than 3 miles downstream of the site. Subsequent studies identified creosote from the Moss-American facility as the source of the chemicals. In response to this incident, the settling ponds and 1,700 feet of river adjacent to the site were dredged to remove creosote and creosote-contaminated soils, and an underground clay wall was placed between the settling ponds and the river. Dredgings from the settling ponds were landfilled in a field east of the river (referred to as the northeast landfill), and the ponds were backfilled with clean soil. River dredgings were spread and buried along the west bank of the river.

Between 1970 and 1977, several investigations were conducted (U.S. EPA, U.S. ACE, and private interest groups) to assess the source of creosote contamination in Little Menomonee River sediments. The studies did not quantify individual compounds or evaluate the extent of contamination. Most of these investigations were performed

Table 1-1 (Page 1 of 5)
SITE CHRONOLOGY

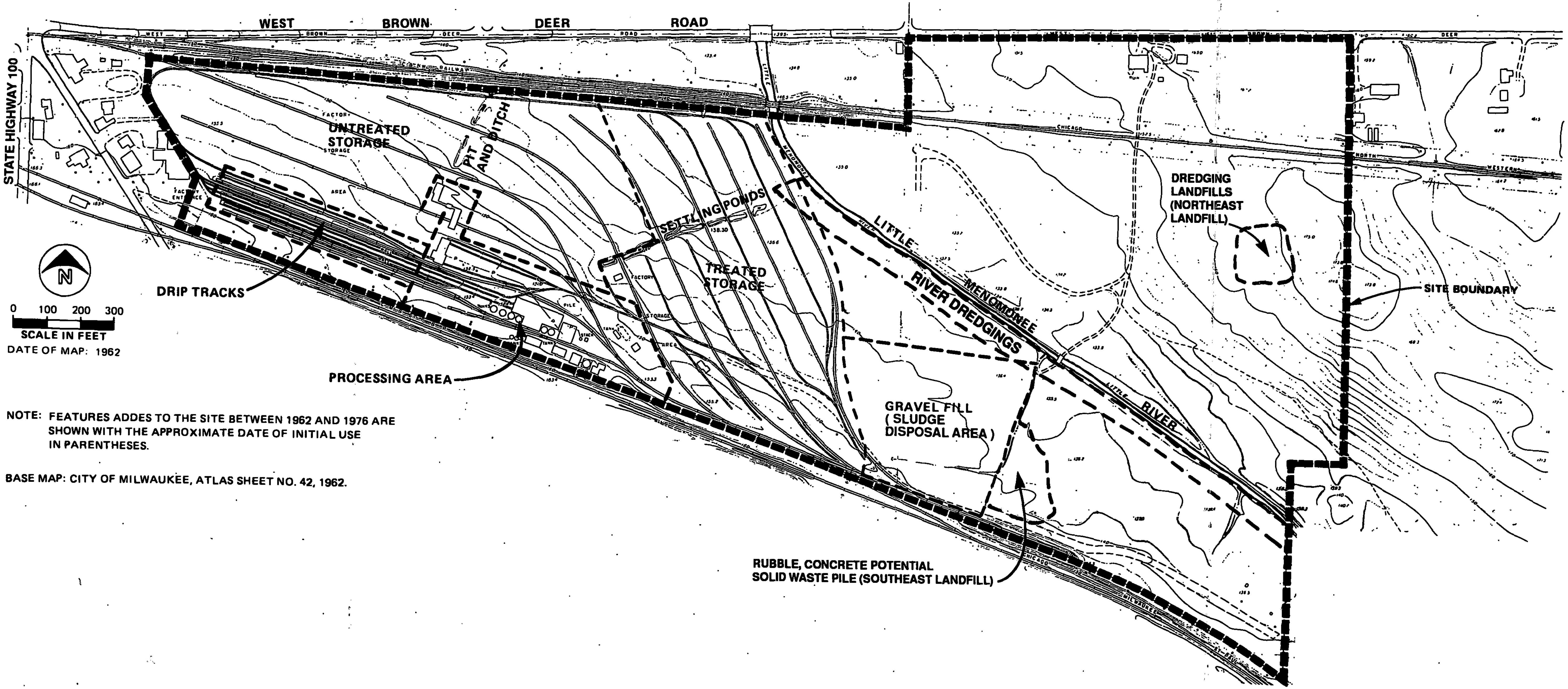
Date	Event
1921	T.J. Moss Tie Company starts operations.
1941	A series of three overflow/underflow settling basins followed by a coke filter is installed for waste treatment.
1952	20 acres of plant yard is covered with gravel and used to store untreated wood. Another 10 acres is covered with cinders and were used to store treated wood products.
6/54	Observations by the Public Health Engineer: Process wastewater passes through an oil/water/sludge separator. Before discharge to a ditch, the water was to pass through a coke filter. This filter was not in operation. The outlet ditch was 700 feet long and passed underneath railroad tracks every 70 to 150 feet. At the head of each culvert passing under the tracks was a 20-foot-wide settling pond. The Public Health Engineer suggested construction of additional settling ponds between all the tracks and better maintenance of facilities.
1963	Kerr-McGee purchases T.J. Moss Tie Company.
1964	Kerr-McGee purchases American Creosote Company.
1965	T.J. Moss Company and American Creosote Company are combined to form Moss-American Company.
3/66 and 6/66	Milwaukee Metropolitan Sewerage Commission collects river and water samples above and below Moss-American effluent. Results indicate discharge of undesirable quality.
8/11/66	Sewerage Commission advises the need to repair a pond leaking oil to the Little Menomonee River.
1968	Fire at a landfill upstream of the site causes the river to become anoxic. A biological survey indicates sterile conditions above and below the site. Contaminated water is found to be entering the Little Menomonee River from the Moss-American site.
8/31/70	Limnetics, Inc. identifies the Moss-American site as a source of creosote contamination.

Date	Event
1971	Under a DNR order to abate pollution, two more coke filters are added, flow is diverted to the metropolitan sewers, the drainageway and ponds are cleaned, and a 75-foot underground "clay wall" is constructed parallel to the Little Menomonee River. Pond dredgings are reportedly mixed with clay and disposed of in four trenches on property east of river.
1971	500 yards of riverbed, from discharge site to downstream property line, are dredged by Kerr-McGee. 1,700 feet of riverbed, from 75 feet above old ditch to east property line, are dredged later in the year. Dredgings are reportedly placed along west bank of river.
4/10/71	Kerr-McGee terminates drainage of process water from the Moss-American facilities to the Little Menomonee River and starts discharging to the metropolitan sewer.
6/5/71	Citizens' group attempts cleanup of trash in river. Some suffer skin irritation due to creosote in river.
6/12/71	Sediment samples taken from Little Menomonee River containing a black substance are analyzed by infrared spectroscopy and identified as creosote.
7/12/71	U.S. Army Corps of Engineers collects and analyzes five sediment and two river water samples in vicinity of site.
10/72	Bio-Test conducts test of equipment to remove, separate, and decontaminate spilled hazardous material from the bottom of waterways. Approximately 500 feet of the Little Menomonee River is dredged.
7/73	Rexnord conducts pilot test of equipment used to clean river bottoms. Approximately 500 feet of the Little Menomonee River is dredged, and dredgings are disposed of in sanitary landfill.
1973	U.S. EPA finances special project to use Little Menomonee River as testing base for river cleanup. 4,000 feet of the river is dredged, and dredgings are disposed of in sanitary landfill.

Date	Event
1973	"The Creosote Problem in the Little Menomonee River" is published by Citizens for Menomonee River Restoration, Inc.
1974	EPA commences legal action against Moss-American.
6/75	Report titled "Stream Segment Survey Report of the Little Menomonee River" assessing the extent of creosote in the Little Menomonee River is released. The Kerr-McGee, Forest Products Division property is identified as the source of creosote.
9/5/75	Followup inspection of Kerr-McGee facility is performed. Skimmer and absorbent booms are installed across drainage ditch, but booms do not cover entire width of ditch. The other ditch is filled in and a catch basin is dug across it.
9/11/75	Kerr-McGee is notified of shortcomings observed during 6/75 and 9/75 site visits.
10/23/75	Kerr-McGee responds to 9/11/75 letter requesting further contact with Kerr-McGee be made through U.S. Attorney's office.
6/76	Operations at Moss-American cease.
1976	Southeastern Wisconsin Regional Planning Commission recommends dredging new channel and filling in old channel with dredgings from new one.
3/23/77	U.S. EPA conducts visual inspection of Little Menomonee River below Moss-American site. No oil slicks, odor, or visual leachate from the stream banks were observed.
4/6/77	U.S. EPA, NEIC, and DNR conduct tour of Moss-American plant and Little Menomonee River.
4/77	National Enforcement Investigations Center (NEIC) investigation of Little Menomonee River. Sixty water and 59 sediment samples were collected and analyzed. Evidence of creosote contamination is detected as far downstream as the confluence with the Menomonee River.

Date	Event
6/23/77	Soil sampling performed for Kerr-McGee indicates phenol concentrations ranging from 15 to 2,027 mg/kg.
10/27/77	Analytical tests of fish samples taken from the Little Menomonee River. Dioctyl adipate in the range of 10 to 35 ppm was found in all samples. Dioctyl phthalate was also detected.
11/77	Report titled "The Potential for Pollution in the Little Menomonee River from the Kerr-McGee/Moss-American Plant Site" is released.
3/78	Moss-American offers to deed a portion of the site to Milwaukee County if the County drops its $500,000 suit against them.
1978	All buildings, storage tanks, and process vessels are demolished, contaminated residue is removed, and surface is backfilled and graded.
7/78	U.S. EPA case against Moss-American is dropped.
3/80	Kerr-McGee sells a 23.3-acre parcel to Chicago and North Western Railroad. The railroad uses the parcel as an auto loading and storage area.
1983	Moss-American site is placed on NPL.
8/29/83	Milwaukee County supervisor requests to review technical data and analytical measurements form Moss-American site because of concern about substances other than creosote.
3/9/84	Hazard Ranking Score calculated to be 32.14.
1984	Milwaukee County Task Force on Pesticides and Herbicides issues a report and makes policy recommendations on the Moss-American site.
1985	PRPs are invited to participate in the Superfund investigation at the site. All refuse initial invitation.
1986	U.S. EPA conducts field sampling and analyses of river sediments for hexane extractables.

Date	Event
1988	U.S. EPA conducts RI into the nature and extent of contamination at the site.
1989	U.S. EPA conducts bench-scale treatability tests on contaminated sediment and collects additional background sediment samples.



NOTE: FEATURES ADDES TO THE SITE BETWEEN 1962 AND 1976 ARE SHOWN WITH THE APPROXIMATE DATE OF INITIAL USE IN PARENTHESES.

BASE MAP: CITY OF MILWAUKEE, ATLAS SHEET NO. 42, 1962.

FIGURE 1-3
HISTORICAL LAND USE
MOSS-AMERICAN FS

before closure of the plant, demolition and removal of buildings, surface preparation of the parking lot, and construction of the additional railroad sidings.

The plant facilities were demolished in 1978. Some oil-saturated soils (450 cubic yards) were excavated and shipped to the Nuclear Engineering Landfill in Sheffield, Illinois. Excavated areas were backfilled with reportedly clean fill material.

Currently, 65 acres of the site are owned by Milwaukee County and held as undeveloped park land; 23 acres are owned by the Chicago and North Western Railroad and used as an automobile loading and storage area. The latter contains an asphalt parking lot used as an automobile storage and loading area. The site is surrounded by both urban and rural uses. Current onsite land use practices are illustrated in Figure 1-4.

HISTORY OF FEDERALLY FUNDED INVESTIGATIONS

Between May and July 1988 the U.S. EPA conducted an RI of the nature and extent of contamination in the soil, groundwater, and river sediment and evaluated the site hydrogeology.

Onsite investigations began in May and included collection of soil samples, installation of groundwater monitoring wells, and excavation of test pits. Extractable organic analysis was used as a screening tool to determine the horizontal extent of creosote and related contaminants across the site that could present a risk to human health. A large number of extractable organic samples (nearly 200) made it possible to identify contaminated areas and select sample locations for further analysis of polycyclic aromatic hydrocarbon (PAH) and phenolic compounds. Results of 40 PAH and phenolic compound analyses were then used to select 16 locations for collection of samples that were analyzed for chemicals that comprise the Target Compound List (TCL) and Target Analyte List (TAL), dioxin, and select physical parameters that could influence the treatability of the soil. Locations of surface soil samples are illustrated in Figures 1-5, 1-6, and 1-7.

Thirty onsite subsurface soil samples were submitted to Contract Laboratory Program (CLP) laboratories for analysis of TCL/TAL compounds, dioxin, and selected treatment parameters. The borings were located on the basis of contaminant distribution as determined by the surface soil screening results and test pit logs. The samples were selected from depths corresponding to the screened intervals of the monitoring wells that were subsequently installed. One hundred eighty-three split-spoon samples were analyzed for extractable organic concentrations. The screening results were not used to select the CLP samples because both sets of samples were collected simultaneously. Subsurface soil sampling locations are illustrated in Figure 1-8.

Twenty-four groundwater wells were installed to monitor contaminant migration from areas of soil contamination, background groundwater quality, and the quality of groundwater entering the Little Menomonee River. The nature and extent of groundwater contamination and vertical and horizontal groundwater gradients and the direction of groundwater movement were determined from the well data. Well tests were performed to estimate aquifer properties. Fifteen monitoring wells were installed to a depth generally between 15 and 20 feet and were screened in the surficial water-bearing zone. One well was 28 feet deep and screened in the unweathered till. Deeper wells (40 to 50 feet) were installed at seven of the shallow-well locations to measure vertical hydraulic gradients and to provide deeper groundwater samples downgradient of contaminated areas. One well was installed to a depth of 55 feet (at MW-4) to investigate for deep contamination immediately downgradient of the process area. The locations of groundwater monitoring wells are illustrated in Figure 1-8.

Sediment sampling in the Little Menomonee River took place in May 1988. One hundred and four samples were collected in soft sediment, which ranged in thickness from 1 to 3 feet, at 300-foot intervals along the river and screened for extractable organic concentrations at the onsite laboratory. The screening results, along with visual observations, were used to select locations for cross section sampling and locations for collection of samples to be analyzed for TCL/TAL compounds. The cross section locations are shown in Figure 1-9.

Surface water samples were collected and analyzed for compounds on the TCL/TAL and for selected treatment parameters.

Background sediment samples were collected during October of 1989. The maximum probable background concentration of carcinogenic PAHs was estimated from these samples to be about 18 mg/kg. Results of the background sampling are summarized in detail in Appendix J.

MAJOR FINDINGS OF THE RI

PHYSICAL DESCRIPTION

Topography

The property is relatively flat, sloping gradually toward the river. Elevations range from 714 to 750 feet (above MSL), and slopes range from 3 to 10 percent. Most of the site is open space, with wooded areas located in the southeastern part of the site. The riverbanks generally are wooded.

Climate

Average daily temperatures range from 8° to 32°F in January and February and from 55° to 83°F in July and August. Average annual precipitation is between 29 and 30 inches, with monthly averages ranging from 1.1 inches in February to 3.8 inches in June and July.

Hydrogeology

The site overlies a surficial water-bearing unit of weathered till (mostly silty clay) and alluvium (fine sands and silts) with an average saturated thickness of about 10 feet, which overlies a confining layer of dense silty clay till. Based upon boring logs taken to depths of 60 feet, the confining layer overlies the regional dolomite aquifer and is believed to be at least 30 feet thick. The water table is generally about 5 to 10 feet deep and the confining layer is at a depth of about 20 feet beneath the ground surface. The water-bearing unit does not yield sufficient water wells to consider it a true aquifer. A cross section of the site geology is illustrated in Figure 1-10.

Generally, groundwater on the site flows toward and into the Little Menomonee River. However, based upon observations of river flow in July 1988, it appears that the river water may flow into the ground during dry weather conditions. Horizontal groundwater gradients in the surficial aquifer range from 0.015 to 0.026 ft/ft, and estimated hydraulic conductivities range from 10^{-3} to 10^{-4} cm/s. The flow of groundwater from the original property (west of the river) toward the river is estimated to be between 2 and 10 gpm. Although observations made during the RI suggest that onsite groundwater recharges the river, the hydraulic relationships between the groundwater and river (particularly downstream from the original property) are not well understood. Figure 1-11 illustrates the water table and flow in relation to site topography.

HYDROLOGY

The reach of the Little Menomonee River from Brown Deer Road to its confluence with the Menomonee River is addressed in this study. Much of the river has been channelized in the past and therefore exhibits some consistent channel geometry. Channel characteristics along the site are relatively constant with the following dimensions:

Top Width	25 to 35 feet
Bottom Width	5 to 10 feet
Channel Depth	5 to 10 feet
Base Flow Water Depth	1 to 2 feet

The typical base flow water depth is 1 to 2 feet and 20 feet wide. The average slope of the river in the vicinity of the site is 2.5 feet per mile. The sediments are typically a silty clay, soft in some areas and hard packed in others. Most of the studied section of the river is part of the Little Menomonee River Parkway.

Continuous stream flow records for the reach of the Little Menomonee River under study are not available. Peak flow rates were estimated in the Federal Emergency Management Agency (FEMA) study conducted in 1987. Peak flow rates for the Little Menomonee River just north of the site at the Brown Deer Road bridge are:

- 10-year 330 cfs
- 50-year 500 cfs
- 100-year 580 cfs
- 500-year 770 cfs

Velocities for the 100-year storm vary from 0.6 to 0.2 foot per second at the site. Conversely, extremely dry conditions during the summer of 1988 resulted in short-term flows near zero at gauging stations upstream of the site.

FEMA has estimated the 100-year flood plain for the stream reach through the Moss-American site. Approximately one quarter of the site is contained within the 100-year flood plain (Figure 1-12). The flood plain elevation is established at 719.2 feet at the upstream site limits and 718.7 feet at the downstream limits.

NATURE AND EXTENT OF CONTAMINATION

In this FS report the term "contaminated" means that concentrations of specific organic compounds or inorganic chemicals in the media exceed background levels. Contamination itself does not require attention in this FS. Typically, media that have been contaminated by sources unrelated to site actions are not addressed in an FS. Contamination resulting from site-related activities is determined by comparing observed levels of contaminants in media believed to have been affected by site-related actions to the observed background levels. The RI determined background concentrations for contaminants in soil and groundwater (see Appendix J).

The RI report documented the contamination of soil, sediment, and groundwater with organic compounds that can be categorized into four groups: carcinogenic polycyclic aromatic hydrocarbons (PAHs); noncarcinogenic PAHs; chlorinated volatile organic compounds (VOCs); benzene, ethylbenzene, toluene, and xylenes (BTXs).

Soil

The extent of soil contamination was estimated from concentrations of extractable organic compounds determined using field screening methods, from concentrations of contaminants determined from CLP analyses, and from visual observations. The major soil contaminants found during the study were PAHs. The highest PAH concentrations in soil were found in areas previously identified as contaminated by extractable organic screening and historical usage. The most contaminated areas are the process area, a portion of the treated storage area, the northeast landfill, and the southeast landfill (see Figure 1-3). Total PAH concentrations were found as high as 32,000,000 µg/kg (3.2 percent). Individual PAH concentrations were measured as high as 4,600,000 µg/kg (0.46 percent). The observed horizontal extent of soil contamination is circumscribed in Figure 1-13. Portions of the site in the vicinity of what was the pit and ditch in the untreated storage area were investigated to a limited extent. The limited information obtained suggests that the extent of contamination does not extend into the northwest portion of the site. Additional investigations during the remedial design may be required to verify this.

Soil contamination is generally greatest near the surface and decreases with depth (except in the landfills). Most of the soil contaminants are located in the upper 2 to 4 feet of soil, although pure phase (creosote) was observed as deep as 18 feet in the process area. Because the water table at the site is fairly shallow (0 to 15 feet below ground), a large fraction of the contaminated soil probably resides between the seasonal high and low water tables. Deep soil contamination (up to 55-feet deep) was observed at three locations.

The RI focused on areas that may have been affected by site operations. Therefore the wooded areas and a small field east of the river that according to aerial photographs were not disturbed, were not included in the investigation.

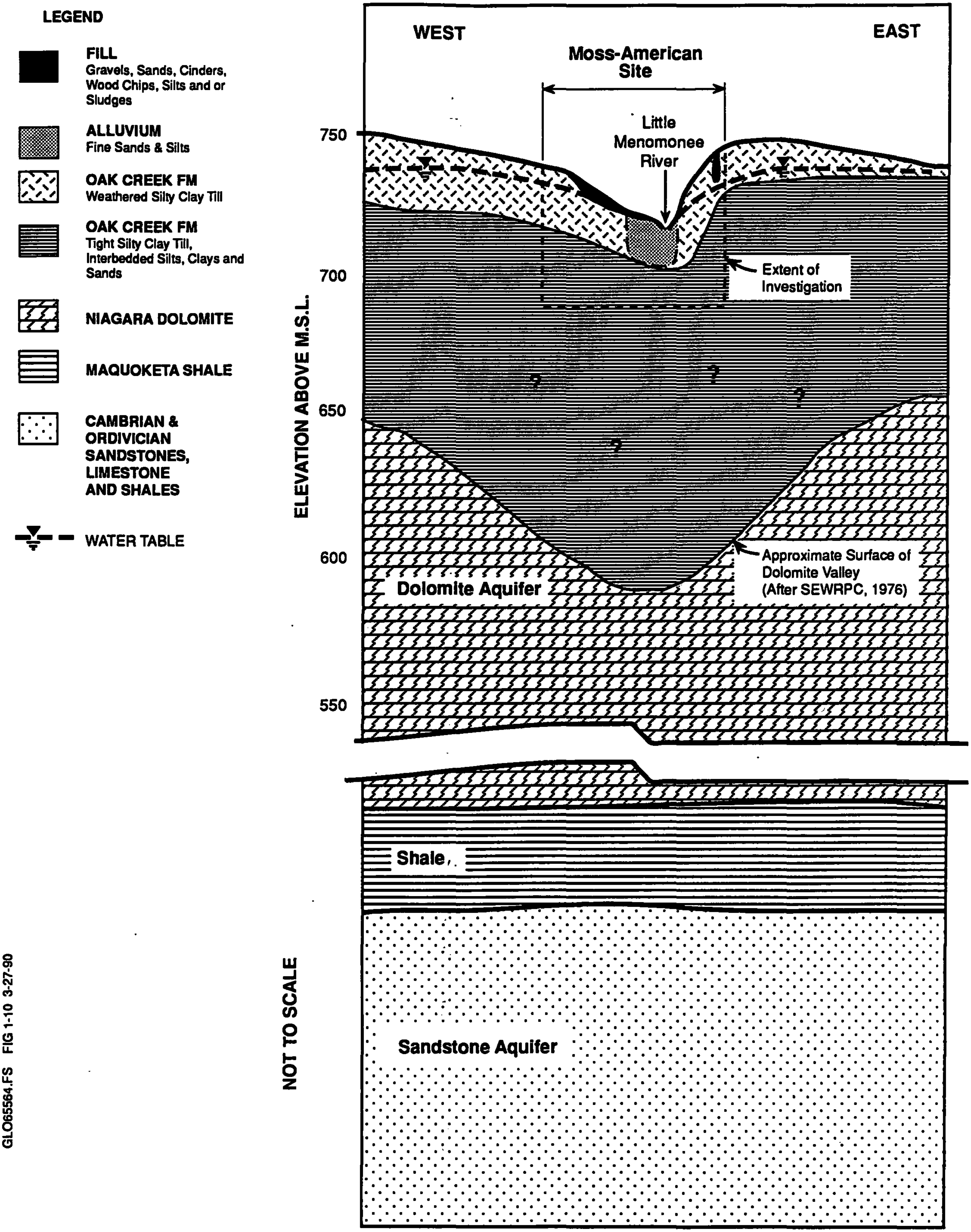
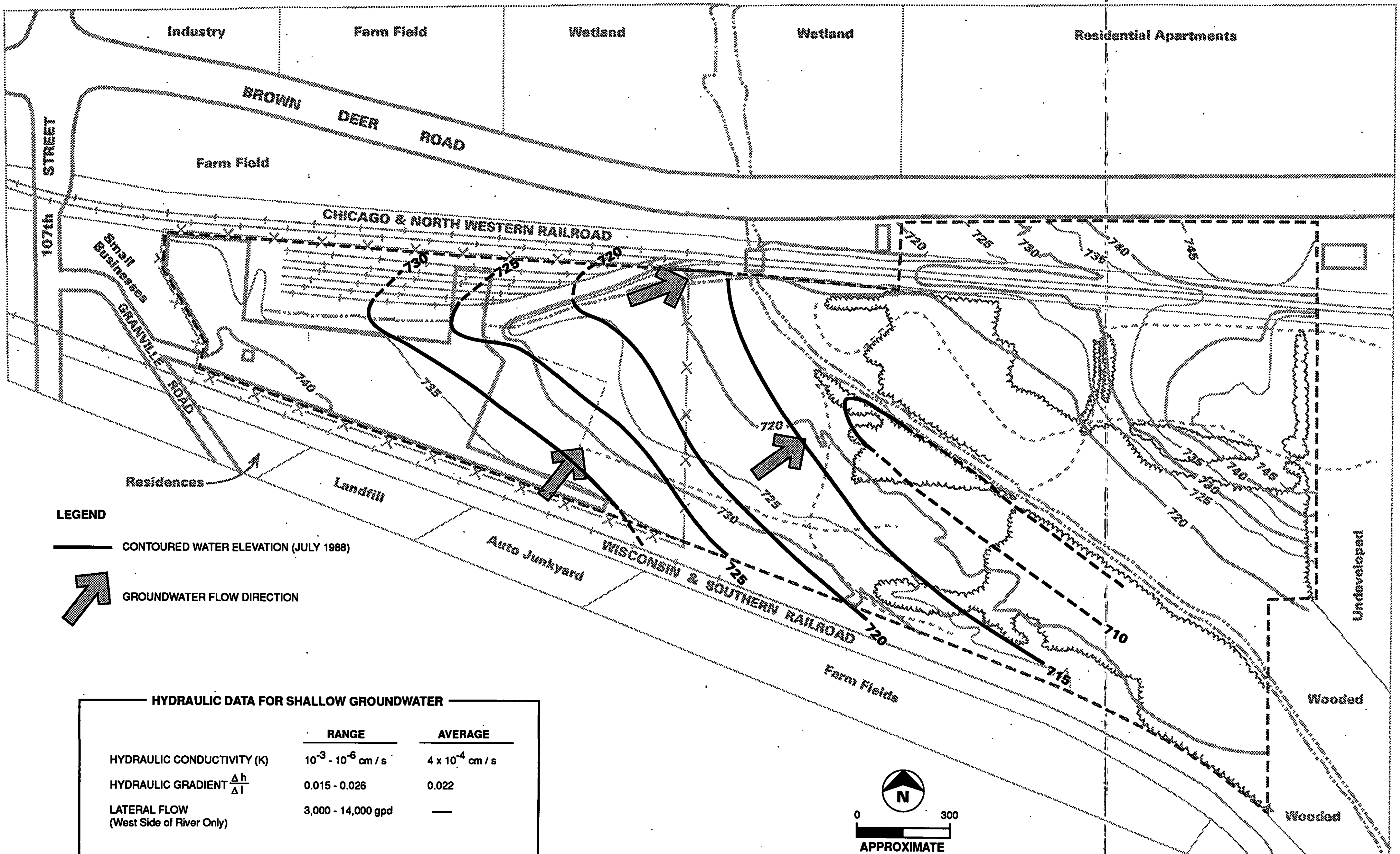


FIGURE 1-10
CONCEPTUAL REGIONAL GEOLOGIC CROSS SECTION
MOSS-AMERICAN FS



LEGEND

CONTOURED WATER ELEVATION (JULY 1988)

GROUNDWATER FLOW DIRECTION

HYDRAULIC DATA FOR SHALLOW GROUNDWATER

	RANGE	AVERAGE
HYDRAULIC CONDUCTIVITY (K)	10^{-3} - 10^{-6} cm / s	4 x 10^{-4} cm / s
HYDRAULIC GRADIENT $\frac{\Delta h}{\Delta l}$	0.015 - 0.026	0.022
LATERAL FLOW (West Side of River Only)	3,000 - 14,000 gpd	—

FIGURE 1-11
HYDRAULIC CHARACTERISTICS OF THE SHALLOW GROUNDWATER
MOSS-AMERICAN FS

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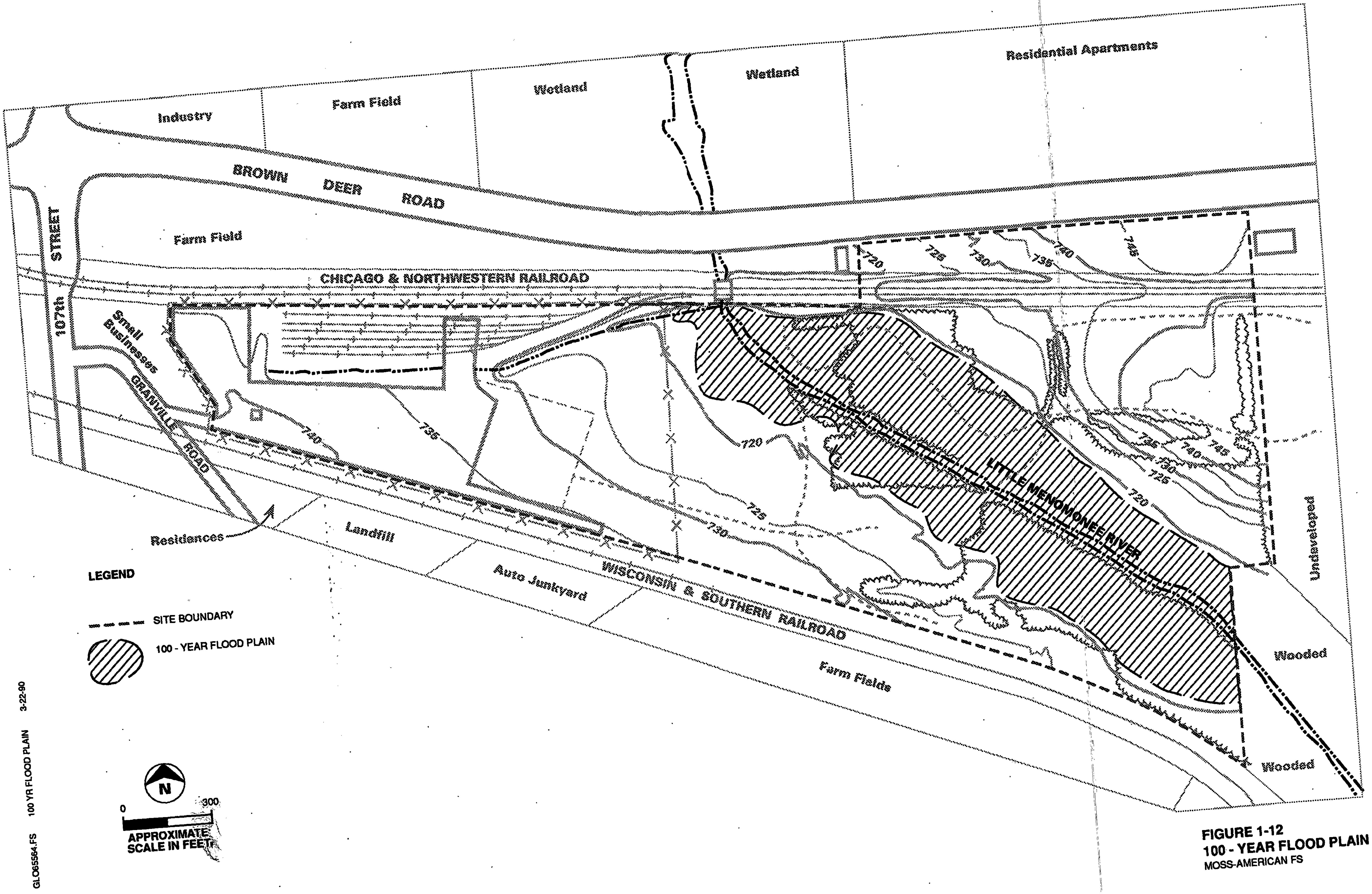
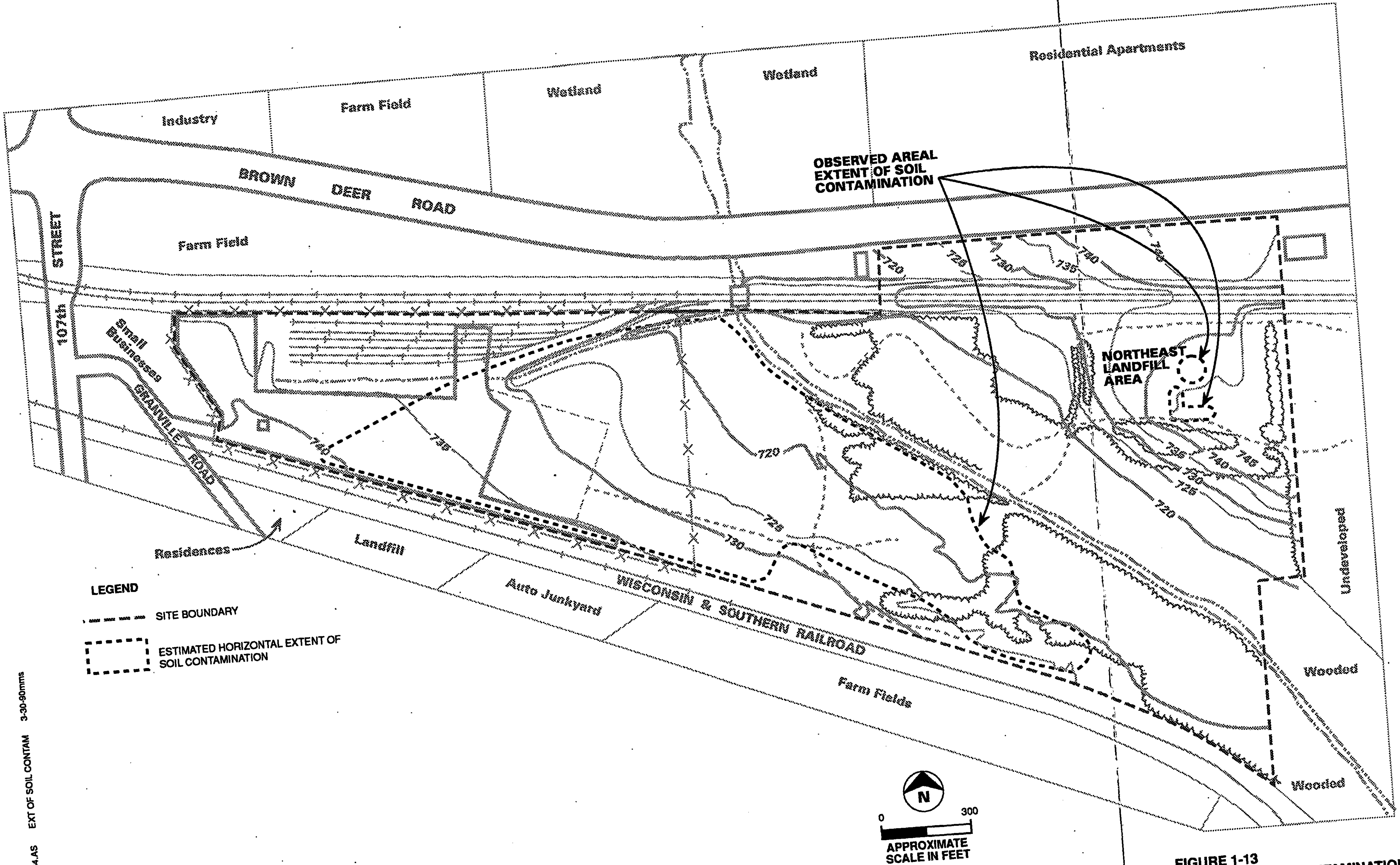


FIGURE 1-12
100 - YEAR FLOOD PLAIN
MOSS-AMERICAN FS



GLO65564.AS EXT OF SOIL CONTAM 3-30-90mms

FIGURE 1-13
EXTENT OF SOIL CONTAMINATION
MOSS-AMERICAN FS

The following text often refers to areas of the site based upon historical usage patterns. These areas are described in the following paragraphs. Figure 1-3 delineates the approximate boundaries of these areas.

Processing Area and Vicinity. The processing area and vicinity includes the processing area and portions of the drip tracks and untreated storage area. The area is covered with a layer of fill that was added after the demolition and removal of the Moss-American facilities. The fill over the processing area varies up to a thickness of at least 3 feet.

Treated Storage Area. The treated storage area includes contaminated parts of the treated storage area and a band of highly-contaminated fill between the storage area and river. Fill in this band consists of glass, cable and other construction debris in a tarry sand and gravel matrix. The treated storage area also includes the lower section of the series of settling ponds that previously drained the area.

Settling Pond Area. The settling pond area is the portion of the settling ponds not already included as part of the process area and vicinity or the treated storage area. The distinction is made because analytical results indicate that the surface soil above the settling pond area has near-background levels of PAHs.

Southeast Landfill. Fill has been added to the area between the railroad tracks and the low, wet area on the north. Wood, cinder blocks, cable, plastic, and metal were observed in test pits in this area. Portions of the area were used for the disposal of rubble and construction debris. Fill thicknesses can vary up to 5 feet.

Northeast Landfill. The northeast landfill consists of trenched disposal areas containing sediment dredged from the settling ponds. The lateral extent of the southern unit of this landfill was defined by barren areas with tarry surface deposits. The extent of the northern unit was not as well defined; it appears that the northern unit was removed.

Groundwater

Groundwater contamination was observed in the monitoring wells adjacent to the settling ponds and downgradient from the process area. PAHs were also the principal contaminant in the groundwater with total dissolved PAH concentrations as high as 11,000 µg/l (excluding three soil borings where pure phase was encountered). Groundwater samples collected from depths greater than 20 feet below ground contained no detectable contamination. Because of the nature of activities conducted at the site, additional wells should be installed before the design phase, particularly in the process and drip track areas. Uncertainties regarding depth of contamination are not expected to have an impact on the selection of a remedial action alternative. The observed horizontal and vertical extent of contaminated groundwater is illustrated in Figures 1-14 and 1-15, respectively.

Oil was observed in three boreholes, essentially in a line between the source area and the river, and along the old settling ponds. Oil was observed at a depth of 8 feet in a thin (2-inch) sand seam beneath the area of the settling ponds. In the source area, oil was observed on soil surfaces from the water table to approximately 18 feet below ground.

Sediments

The compounds detected in the river sediment are consistent with those found onsite. The primary contaminant group is the PAH group, with dibenzofuran following a similar distribution pattern. BTX compounds were not commonly found in the sediment samples. Total PAH concentrations in sediment were as high as 5,900,000 μg/kg. Individual PAH concentrations were as high as 4,600,000 μg/kg (for phenanthrene). Other compounds that were detected were not widespread and were at generally low concentrations.

Sediment contamination was measured along the entire length of the Little Menomonee River included in the investigation. Additional sediment sampling was performed upriver from the site and in tributaries to determine background PAH concentrations. The maximum probable background concentration of carcinogenic PAHs is estimated to be about 18,000 μg/kg. The details of the background sediment sampling effort are presented in Appendix J.

Surface Water

Surface water contamination was measured only in the ditch draining the north side of the site. Total PAH concentration in this sample was 31 μg/l. Other compounds were also encountered at the site and in the river sediments. The most predominant of these are toluene, which was found in concentrations as high as 1,300 μg/kg, and dibenzofuran (often a component of creosote), which was detected at concentrations up to 1,300,000 μg/kg. Other compounds were found in a few samples or in low concentrations.

RISK ASSESSMENT SUMMARY

A baseline risk assessment was performed as part of the RI, in accordance with the Superfund *Public Health Evaluation Manual* (1986), to evaluate the potential threats to public health and the environment from the Moss-American site contamination in the absence of remedial action. The estimate of risk to human health requires making certain assumptions about exposure conditions, called "exposure settings," that relate the frequency, duration, and means through which a person could be exposed to contaminated soil, sediment, or groundwater. The exposure settings describe potential human exposures under current site conditions and potential future site uses. Potential effects on the environment were also evaluated.

To evaluate human health risks from onsite soil, exposure under current and potential future use conditions was evaluated. The "trespass setting" exposure condition was used to estimate human health risk under current conditions. Under this condition contact with the surface soil is considered to be possible. The individual excess lifetime cancer risks for these conditions were estimated to range from 2×10^{-4} (based on the highest detected concentrations) to 4×10^{-6} (based on mean concentrations). The group of chemicals contributing most to the risk are the PAHs.

A "residential use" setting was used to evaluate a maximum human exposure resulting from potential future development of the site for residential use. For the exposure conditions assumed (that is, that residents may come into contact with contaminants exposed during site development and those that remain on the site surface), the

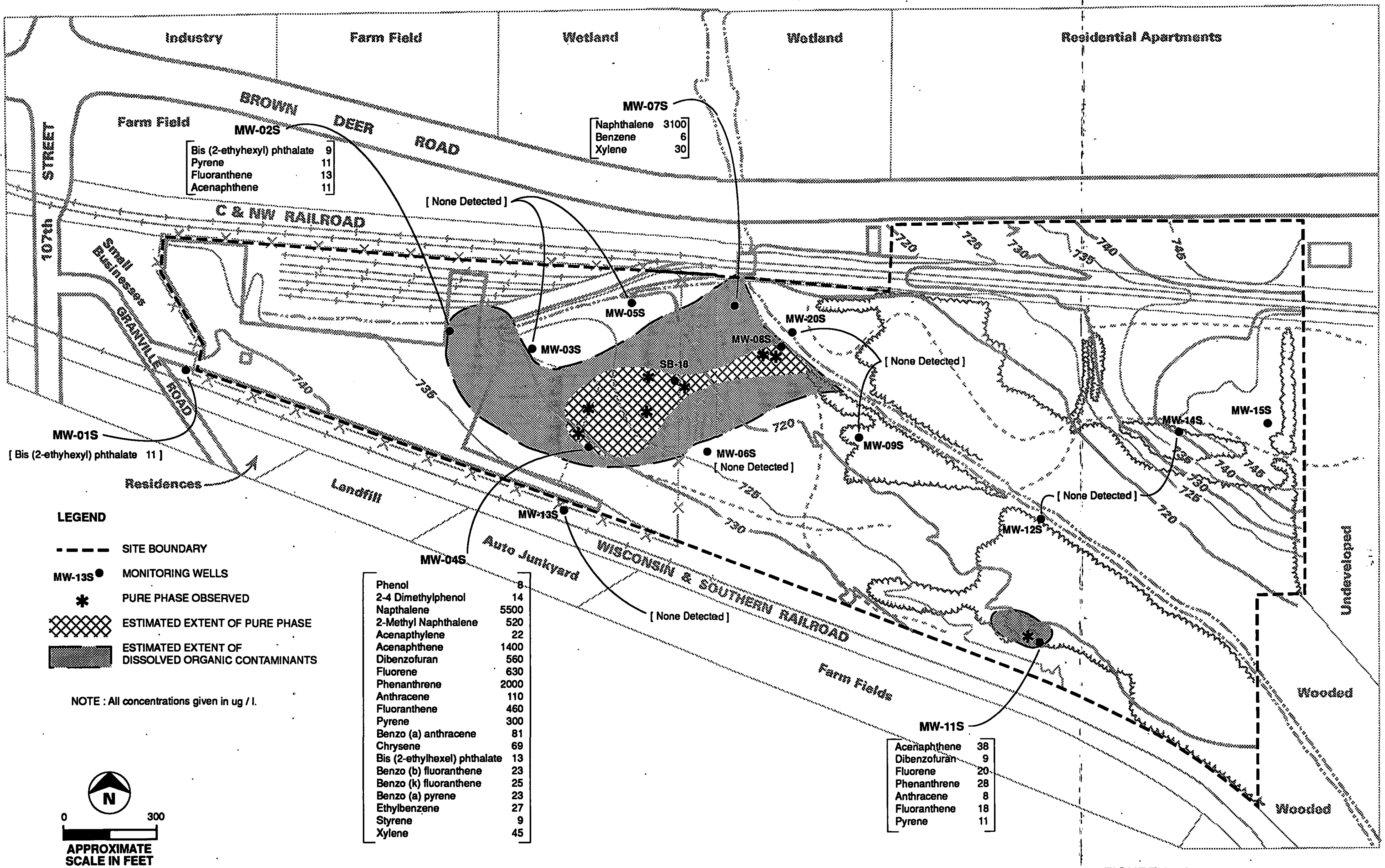


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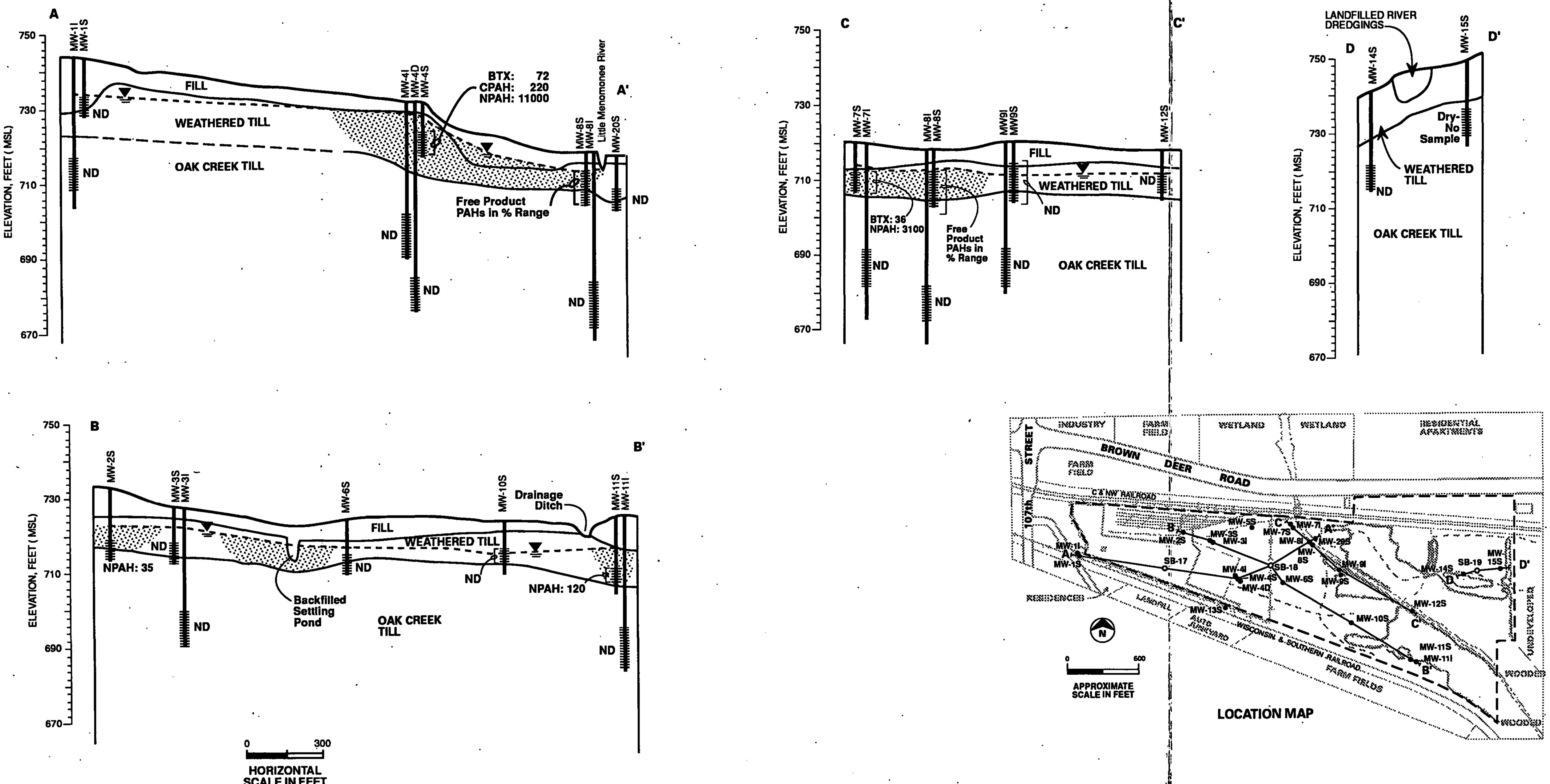
FIGURE 1-14
ESTIMATED EXTENT OF CONTAMINATION IN SHALLOW GROUNDWATER
MOSS-AMERICAN FS



LEGEND

PROBABLE LIMIT OF DETECTABLE ORGANIC CONTAMINATION IN GROUNDWATER

MW-1I MONITORING WELL LOCATION

SCREENED INTERVAL

WATER LEVEL

CPAH TOTAL CARCINOGENIC PAH

NPAH TOTAL NONCARCINOGENIC PAH

BTX BENZENE, ETHYLBENZENE, TOULENE, XYLENES

ND NOT DETECTED
Above detection limit of 5 ug / l for BTX
and 10 ug / l carcinogenic and noncarcinogenic PAHs

All concentrations in ug / l.

FIGURE 1-15
ORGANIC COMPOUNDS IN GROUNDWATER
MOSS-AMERICAN FS

GLO65564.FS 1-13 X-SECT Org Grdwtr 3-30-90 individual excess lifetime cancer risks were estimated to range from 3 x 10^{-2} (highest concentrations) to 1 x 10^{-4} (mean concentrations). The group of chemicals that contributes most to this risk is the PAHs. These calculations do not include estimates of natural degradation of PAHs over time.

To evaluate the health risks to people engaged in activities along the Little Menomonee River, a recreational use setting was described. For the exposure conditions that were assumed (individuals may come into contact with sediments in the river) the individual excess lifetime cancer risks were estimated to range from 1 x 10^{-4} (highest concentrations) to 6 x 10^{-6}. The major group of chemicals contributing to the risks are the PAHs. There is also the potential for acute effects such as skin irritation from contact with creosote in the river sediments. While skin irritation effects from dermal exposure to creosote have been documented, there are no adequate quantitative data to establish limits for dermal exposure for the general population or those occupationally exposed to creosote (U.S. EPA 1987).

Biological investigations on the Little Menomonee River performed prior to the RI have led to the conclusion that the river downstream from the site is ecologically impaired. Some effect is probably a result of the creosote contamination from the Moss-American site. However, those same studies have generally noted that the various effects on the river of habitat loss, soil erosion, channelization, and nonpoint pollution may also severely restrict the quality of the ecological community of the river. Consequently, while it may be inferred that the discharge of creosote from the site to the river has had adverse impacts on the biota of the river, other human activities may have also led to the degradation of the river.

The RI concluded that unacceptable exposures could occur under the no action alternative, and that an FS was warranted to assess remedial alternatives for the site and the river to mitigate potential exposure.

REFERENCES

United States Environmental Protection Agency. *Remedial Investigation Report, Moss-American Site*. January 1990.

United States Environmental Protection Agency, Office of Emergency and Remedial Response. *Superfund Public Health Evaluation Manual.* EPA 540/1-86/060. Washington, D.C. 1986.

United States Environmental Protection Agency. *Interim Final Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA*. OSWER Directive 9355.3-01. Washington, D.C. 1988.

United States Environmental Protection Agency, Environmental Criteria and Assessment Office. Health Effects Assessment for Creosote. Cincinnati, Ohio. EPA/600/8-88/025. 1987.

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Chapter 2
REMEDIAL ACTION GOALS

Chapter 2
REMEDIAL ACTION GOALS

Remedial action goals are requirements that remedial action plans should achieve to provide adequate protection of human health and the environment. This chapter presents general and site-specific remedial action goals for the Moss-American site.

General remedial action goals are defined by the NCP and CERCLA (as amended by SARA) and are applicable to all Superfund sites. Whereas CERCLA goals relate to statutory requirements for development of the remedy, site-specific goals relate to specific contaminated media, such as groundwater or soil, and potential exposure routes and identification of target remediation levels. Site-specific goals are based on understanding the contaminants in their respective media, an evaluation of risk to public health and the environment, and applicable or relevant and appropriate requirements (ARARs) of other environmental laws. These goals are intended to be as specific as possible without limiting the range of alternatives that could be developed.

NCP AND CERCLA GOALS

The NCP states: "The appropriate extent of remedy shall be determined by the lead agency's selection of a cost-effective remedial alternative that effectively mitigates and minimizes threats to and provides adequate protection of public health and welfare and the environment." [40 CFR 300.69(i)]. For the Moss-American site, the lead agency is the U.S. EPA.

The statutory scope of CERCLA was amended by SARA to include the following:

- Refinement of the objectives for the degree of remedial action cleanup in that remedial actions "shall attain a degree of cleanup of hazardous substances, pollutants, and contaminants released into the environment and of control of further releases at a minimum which assures protection of human health and the environment" (Section 121(d)).

- Preference for the selection of remedial actions "in which treatment that permanently and significantly reduces the volume, toxicity, or mobility of the hazardous substances, pollutants, and contaminants is a principal element" (Section 121(b)). An explanation must be published if a permanent solution using treatment or recovery technologies is not selected.

- Requirements that the selected remedy comply with or attain the level of any "standard, requirement, criteria, or limitation under any Federal environmental law . . . or any promulgated standard, requirement, criteria, or limitation under a State environmental or facility siting law that is more stringent than any Federal standard, requirement, criteria, or limitation" (Section 121(d) (2) (A)).

These constitute general goals for remedial action at all CERCLA sites.

DEVELOPMENT OF SITE-SPECIFIC GOALS

Site-specific goals are established for individual media groups, referred to as "operable units." Operable units are media groups expected to require similar or special remedial actions, based on similarities in physical characteristics of media, the relative risk posed by the material (e.g., if it is a source material), or by distinctions drawn by ARARs. The Moss-American site was divided into three operable units: a soil operable unit, a sediment operable unit, and a groundwater operable unit.

Site-specific goals include contaminant-specific goals that define the concentrations of various contaminants considered to pose an unacceptable endangerment to human health or the environment. Contaminant-specific goals are used in conjunction with quantitative information obtained during the RI to identify areas and volumes of media that require remediation. The concentrations for contaminant-specific goals are arrived at by comparison to background concentration levels, through evaluation and comparison of concentrations that could pose a risk to human health (e.g., drinking water standards for groundwater or the concentration in soil that could result in one excess cancer occurrence in an exposed population of 1 million), and through evaluation of concentrations that could pose a risk to aquatic life (as defined by regulatory criteria).

For the Moss-American site, protection of human health and aquatic life are primary concerns. The human exposure to contaminants and exposure pathways that could pose acute or chronic toxicity concerns was assessed. The RI concluded that the principal contributors to risk to human health are carcinogenic PAHs. Chronic toxicity risk posed by noncarcinogens was not considered a significant risk.

The site-specific goals for each operable unit are described below.

SOIL OPERABLE UNIT

The RI determined that both surface and subsurface soils are contaminated. Because of the similarities in physical characteristics and contaminants, surface and subsurface soils are grouped into a single operable unit in this FS. Although the RI did not investigate flood plain soil in detail, goals for flood plain soil were assumed to be the same as for onsite soil. Because the nature and extent of contamination in flood plain soil is unknown and because the factors affecting selection of a remedy for flood plain soil could be significantly different than for onsite soil, management of flood plain soil is not addressed in the detailed alternatives in this FS. The flood plain soil issue will be addressed separately as part of the preliminary design and, if necessary, a separate operable unit FS may be performed.

The remedial action objectives for the soil operable unit are to:

- Minimize direct contact, inhalation, or ingestion of soil contaminants that present unacceptable risks to public health
- Minimize the threat to public health and the environment from migration of contaminants from the soil into the groundwater and subsequently into the river

The major contaminants found in the soil were PAHs. Although a variety of other contaminants were also found in soil, the risk to human health from contaminated soils is predominately derived from compounds in the carcinogenic PAH group. Because no chemical-specific ARARs have been defined for carcinogenic PAHs, and because the background level for carcinogenic PAHs was determined to be below the detection limit, the risk-based concentration is used as the contaminant-specific goal for soil. For this FS, the concentration of contaminants in the soil that could result in a 1×10^{-6} excess lifetime cancer risk under a residential exposure setting was considered the benchmark of unacceptable risk to human health. The concentrations of carcinogens in soil that equate to a specific excess lifetime cancer risk are referred to as "target concentrations." Risk-based concentrations for noncarcinogenic PAHs (reference concentrations) have not been developed yet, and therefore contaminant-specific goals for noncarcinogens were not considered in this FS. The 1×10^{-6} and 1×10^{-4} target concentrations for carcinogenic PAHs in soil are listed in Table 2-1. Table 2-1 also provides a comparison of these targets to concentrations observed in soil as well as concentrations that would have to be achieved to meet treatability variance limits.

Figure 2-1 outlines the estimated horizontal extent of soil contaminated above the 10^{-6} target concentrations. Because the 10^{-6} target concentrations are below detection limits, the presence of any carcinogenic PAH in soil indicates that soil exceeds the 10^{-6} target, probably the 10^{-5} target, and possibly the 10^{-4} target. Thus, the area outlined in Figure 2-1 is the same as that identified in Figure 1-13 (extent of soil contamination). The areas were based on RI results and historical uses of the site. These areas and depths of contamination are presented for use in developing and comparing alternatives in the FS. Actual areas and volumes of contamination would be refined or determined in the predesign investigation or during construction of the remedial action. The area of greatest uncertainty is the process area where depths of contamination may be much greater in localized areas and in the area of the pit and ditch (untreated storage) in the northwest portion of the site.

The estimated volume of contaminated soil having concentrations exceeding the 1×10^{-6} targets is presented in Table 2-2. Since the 1×10^{-4} target concentration approximates the detection limit, this volume could not be easily differentiated from the 10^{-6} volume. Table 2-2 provides a breakdown of the volume estimate based on

Table 2-1

EVALUATION OF REMEDIAL ACTION OBJECTIVES FOR SOIL

Contaminant	Detection (a) Limit (mg/kg)	Background (d) Concentration (mg/kg)	Sampling Data: Surface Soil: Highest (e) Observed Concentration (mg/kg)	Sampling Data: Surface Soil: Geometric (f) Mean (mg/kg)	Sampling Data: Subsurface Soil: Highest (g) Observed Concentration (mg/kg)	Sampling Data: Subsurface Soil: Geometric (h) Mean (mg/kg)	Non Carcinogenic Risk Based Target Concentrations (mg/kg)	Carcinogenic Risk Based Target Concentrations (mg/kg) 10-4	Carcinogenic Risk Based Target Concentrations (mg/kg) 10-6	Treatability Variance Range (i) (mg/kg)
CARCINOGENS										
Asenic	0.010	3.700	110	7.8	7.8	4.5	NA	2400		
Benzene	0.005		0.1	0.004	-	0.004	"	6087	24	
Chrysene	0.330	0.330	510	16	120	4	"	6087	0.061	
Benzo(a)anthracene	0.330	0.330	420	13	190	3.9	"			
Benzo(a)pyrene			230	8.2	34	2.6		6087	0.061	
Benzo(b)fluoranthene	0.330	0.330	270	11	87	2.8	"	6087	0.061	
Benzo(k)fluoranthene	0.330	0.330	250	10	20	2.2	"	6087	0.061	
Benzo(ghi)perlyene	0.330	0.330	77	6.8	10	2.1	"	6087	0.061	
Dibenz(ah)anthracene	0.330	0.330	24	--	1.8	0.4	"	6087	0.061	
Ideno(123cd)pyrene	0.330	0.330	78	6.8	9.9	2	"	6.1	0.061	
Sum of Carcinogenic PAHs (b)	0.330		420	13	190	3.9				
NONCARCINOGENS (c)										
Cadmium	0.005		75.9	13	6.9	5	37.5	NA	NA	
2,4-Dinitrophenol	1.600		620	x	-	x	150	"	"	
Lead	0.005		519	60	31	22	105	"	"	3.0 mg/kg (TCLP)
Pentachlorophenol	1.600		-	-	-	-		"	"	95% Reduction
Naphthalene	0.330		1800	13	2600	4.3		"	"	or 20 mg/kg (TWA)
Phenanthrene	0.330		2700	--	4600	--		"	"	"
Pyrene	0.330		2000	--	1600	--		"	"	"
Toluene	0.005		1.3	170	2	0.04		"	"	90% Reduction
Xylene	0.005		14	0.008	17	0.005		"	"	or 10 mg/kg (TWA)
2,3,7,8 - TCDD (Dioxin)	2.0E-06		0.0001		0.007	7.9E-07		"	"	

NOTES:

(a) Reference: Table N-2 of RI report, Volume 2 (dated January 9, 1990).
(b) Carcinogenic PAHs include benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, benzo(g,h,i)perlyene, chrysene, dibenz(a,h)anthracene, and indeno(123cd)pyrene
(c) Only the noncarcinogenic contaminants that exceeded reference concentrations are listed. Exceedences were based on reseidential development, child exposure.
(d) Background limits for carcinogens taken to equal detection limit
(e) Reference: Tables O-1 and O-4 of RI report
(f) Reference: Tables M-5 and M-6 of RI report.
(g) Reference: Tables O-5 and O-7 of RI report.
(h) Reference: Tables M-17 and M-18 of RI report.
(i) TWA = Total Waste Analysis; TCLP = concentration in waste extract per Toxicity Characteristic Leaching Procedure.

'--' = No geometric mean calculated for this chemical.
'-' = Not detected.
'x' = Insufficient sample size-to estimate mean.

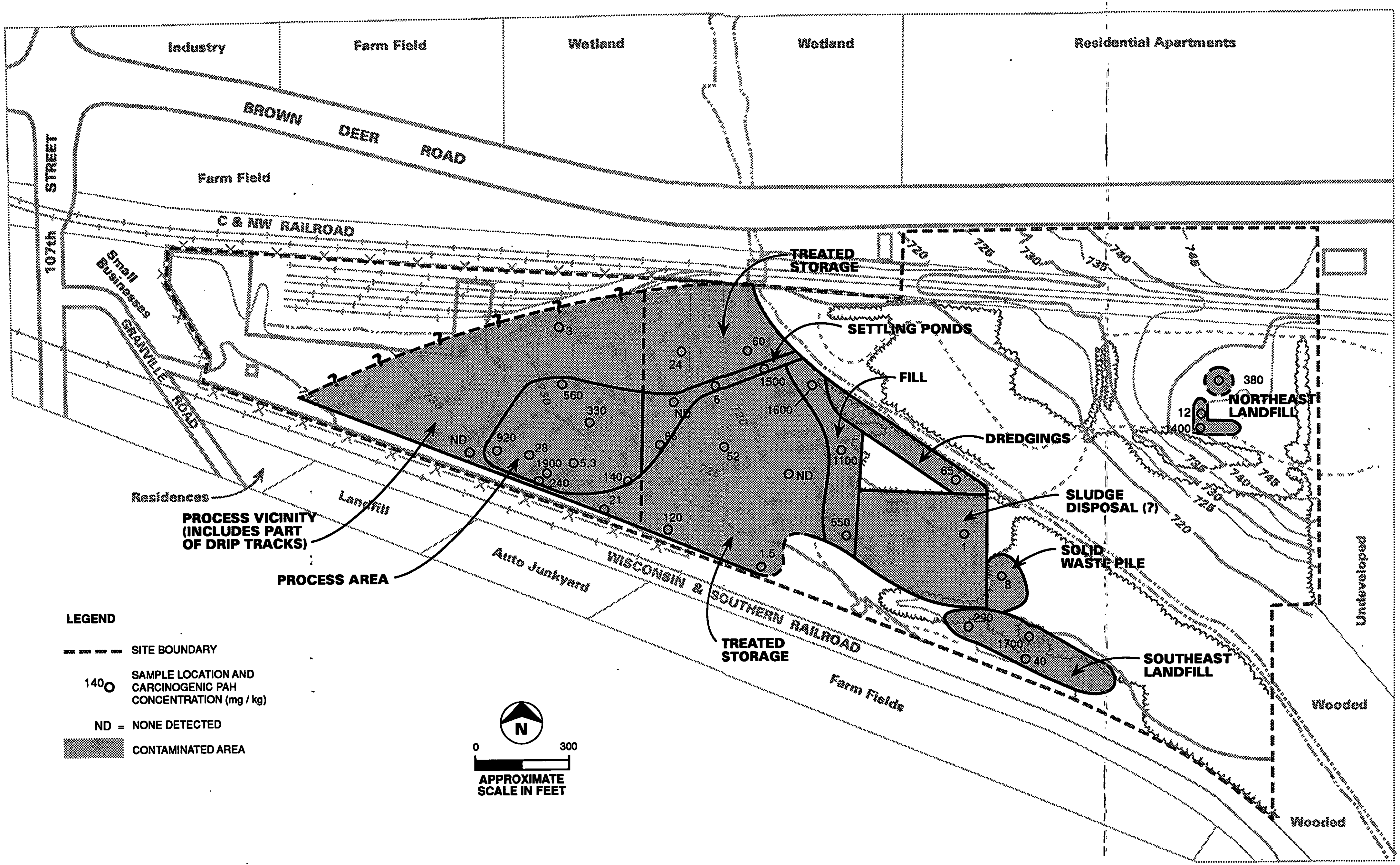

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FIGURE 2-1
SOIL EXCEEDING REMEDIAL ACTION GOALS
MOSS-AMERICAN FS

Table 2-2
ESTIMATED VOLUME OF CONTAMINATED SOIL

Location/Area	Approximate Surface Area (ft^2)	Average Thickness (ft)[a]	Carcinogenic PAH Conc[b] (mg/kg)	Soil Exceeding 10^{-6} Risk-Based Target Concentrations (yd^3)[c]	Soils Exceeding 10^{-6} Risk Above The Low Water Table (yd^3)[c]	Visibly Contaminated Soils (yd^3)[c]
Processing Area	120,000	10	400	45,000	45,000	55,000
Processing Vicinity	280,000	2	40	20,000	20,000	included above
Settling Ponds[d]	40,000	10	500	15,000	15,000	included above
Treated Storage	400,000	2	40	30,000	30,000	included above
Fill	60,000	3	1,000	7,000	7,000	9,000
Dredgings	30,000	0.5	60[e]	600	600	0
Sludge Disposal	140,000	0.5	1[e]	3,000	3,000	0
Solid Waste Pile	20,000	3	8	2,000	2,000	2,000
Southeast Landfill	60,000	4	700	9,000	9,000	11,000
Northeast Landfill	10,000	4	600	1,500	1,500	1,000
Deep Soils				75,000	0	0
TOTAL				210,000[e]	130,000	80,000

[a]Based on data from test pit logs and soil borings.
[b]Arithmetic average of measurements from within the area.
[c]Volume of contaminated soil in bank cubic yards (i.e., in place). Add 10 to 20 percent for loose cubic yards.
[d]Data is questionable due to variability within the area.
[e]Rounded to two significant figures.

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issue will be addressed separately as part of the preliminary design and, if necessary, a separate operable unit FS may be performed.

The remedial action objectives for the soil operable unit are to:

- Minimize direct contact, inhalation, or ingestion of soil contaminants that present unacceptable risks to public health

- Minimize the threat to public health and the environment from migration of contaminants from the soil into the groundwater and subsequently into the river

The major contaminants found in the soil were PAHs. Although a variety of other contaminants were also found in soil, the risk to human health from contaminated soils is predominately derived from compounds in the carcinogenic PAH group. Because no chemical-specific ARARs have been defined for carcinogenic PAHs, and because the background level for carcinogenic PAHs was determined to be below the detection limit, the risk-based concentration is used as the contaminant-specific goal for soil. For this FS, the concentration of contaminants in the soil that could result in a 1×10^{-6} excess lifetime cancer risk under a residential exposure setting was considered the benchmark of unacceptable risk to human health. The concentrations of carcinogens in soil that equate to a specific excess lifetime cancer risk are referred to as "target concentrations." Risk-based concentrations for noncarcinogenic PAHs (reference concentrations) have not been developed yet, and therefore contaminant-specific goals for noncarcinogens were not considered in this FS. The 1×10^{-6} and 1×10^{-4} target concentrations for carcinogenic PAHs in soil are listed in Table 2-1. Table 2-1 also provides a comparison of these targets to concentrations observed in soil as well as concentrations that would have to be achieved to meet treatability variance limits.

Figure 2-1 outlines the estimated horizontal extent of soil contaminated above the 10^{-6} target concentrations. Because the 10^{-6} target concentrations are below detection limits, the presence of any carcinogenic PAH in soil indicates that soil exceeds the 10^{-6} target, probably the 10^{-5} target, and possibly the 10^{-4} target. Thus, the area outlined in Figure 2-1 is the same as that identified in Figure 1-13 (extent of soil contamination). The areas were based on RI results and historical uses of the site. These areas and depths of contamination are presented for use in developing and comparing alternatives in the FS. Actual areas and volumes of contamination would be refined or determined in the predesign investigation or during construction of the remedial action. The area of greatest uncertainty is the process area where depths of contamination may be much greater in localized areas and in the area of the pit and ditch (untreated storage) in the northwest portion of the site.

The estimated volume of contaminated soil having concentrations exceeding the 1×10^{-6} targets is presented in Table 2-2. Since the 1×10^{-4} target concentration approximates the detection limit, this volume could not be easily differentiated from the 10^{-6} volume. Table 2-2 provides a breakdown of the volume estimate based on areas outlined by historical use patterns. The details of the approach used to estimate these volumes is presented in Appendix C.

SEDIMENT OPERABLE UNIT

The remedial action objectives for the sediment operable unit are to:

- Minimize direct contact, or ingestion of contaminants in sediment that present unacceptable risks to public health

- Minimize the acute exposure risk to occasional recreational users of the river

- Minimize the acute and chronic effects on aquatic life posed by contaminants in the sediment

- Minimize migration of contaminants in sediment downstream into the Menomonee River

A recreational exposure setting was applied to determine target concentrations in sediment that would be protective of human health. The Wisconsin DNR has recently developed sediment quality criteria for the river that would be protective of human health and aquatic life. These "to-be-considered" criteria are based on an equilibrium partitioning approach and the methodology used to derive them is to be applied consistently throughout the state. These target concentrations are presented in Table 2-3. The areas and volume of sediment requiring remediation based on human health risk were evaluated and estimated (see Appendix C for details). Although acute exposure risk for humans who come into direct contact with the sediment has been a concern, no dermal exposure limit has been determined.

The estimated volume of sediment requiring remediation is presented in Table 2-4. Volumes of contaminated sediment were estimated using sediment thickness measurements taken in the RI and the percentage of CLP samples that exceeded target concentrations. Because of the poor correlation between concentrations of extractable organics and carcinogenic PAHs, the extractable organic data could not be used to estimate volumes of contaminated sediment. The volume estimates are used to develop and compare alternatives in the FS. Actual areas and volumes would need to be determined during construction of the remedial action.

A review of the data and field observations suggests that removal of visibly contaminated sediment (i.e., oil in sediment) would probably result in removal of less than one-third of the sediment exceeding background levels, and that removal of sediments exceeding background levels would nearly achieve the proposed sediment quality criteria. While it is uncertain whether an acute exposure risk to humans is present, removal of the sediment exceeding the 10^{-6} target concentrations or background levels would probably eliminate acute risk concerns.

Table 2-3
TARGET CONCENTRATIONS FOR CARCINOGENS IN SEDIMENTS

Chemical	Maximum Concentration Observed (mg/kg)	Risk-Based Targets 1E-04 (mg/kg)	Risk-Based Targets 1E-05 (mg/kg)	Risk-Based Targets 1E-06 (mg/kg)	Wisconsin DNR SQC (mg/kg)	Max. Probable Background (mg/kg)
Arsenic		2230	223	22		
Benzo[a]anthracene	140	388	39	4		3
Benzo[b]fluoranthene	64	388	39	4		3
Benzo[k]fluoranthene	35		39	4		3.2
Benzo[a]pyrene	54	388	39	4	3	3
Benzo[g,h,i]perlyene	13	388	39	4		0.9
Chloroform		730984	73098	7310	87	
Chyrsene	150	388	39	4		3.2
Dibenzo[a,h]anthracene	2.4	388	39	4		0.9
Indeno[1,2,3-cd]pyrene	15	388	39	4		1
Methylene chloride		594533	59453	5945	4	
Total PAHs (carcinogenic)	500	388	39	4	3	18
2,3,7,8-TCDD (Dioxin)		0	0	0	0	

EXPOSURE ASSUMPTIONS:

Exposure setting:	Recreational Based on Sediment Ingestion
Soil intake (g/day)	0.1
Body weight (kg)	70
Number of days/week exposed	2
Number of weeks/year exposed	20
Number of years exposed	10
Years in lifetime	70
Lifetime average soil intake (g/kg body weight per day)	0.0000

NOTES:

1. Carcinogenic PAHs based on benzo[a]pyrene potency from Ambient Water Quality Criteria Document. U.S.EPA 1980.
2. WDNR SQC (average percent organic carbon in sediment) derived from NR 105.09 WAC: Human Cancer Criterion.
3. The risk-specific concentrations presented in this table do NOT represent a determination of "safe" soil concentrations. They are estimated using procedures established by U.S. EPA. They are based on specific exposure assumptions and cancer potency factors and are calculated for specific cancer risk levels. Because cancer potency factors are subject to change, the reference concentrations are also subject to change. The risk-specific concentrations are provided for information purposes only. They can serve as only the first cut at developing clean up goals based on public health protection. The risk-specific concentrations are for individual chemicals. They do not account for exposure to multiple chemicals and by other routes of exposure.
4. Maximum concentrations observed were taken from Table O-14 of the RI report.
5. See Appendix J for a discussion of background concentrations.
6. See Appendix A for concentration ranges to be achieved for Treatability Variance.

Table 2-4
VOLUME OF SEDIMENT
EXCEEDING TARGET LEVELS

Stream Reach	Estimated Volume of Sediment (yd^3)	Range of Carcinogenic PAH Concentrations	Estimated Volume of Contaminated Sediment (yd^3) >10^{-4}	>10^{-6}	Volume Exceeding Background Levels for Carcinogenic PAHs	Volume with Visible Traces of Oil
Brown Deer Rd. to Bradley Rd.	8,500	DL-452	1,000	7,500	7,500	2,200
Bradley Rd. to Good Hope Rd.	5,900	DL-570	500	5,400	4,900	1,200
Good Hope Rd. to Mill Rd.	11,700	7-504	1,100	10,700	8,500	1,800
Mill Rd. to Silver Spring Dr.	9,800	DL-313	900	6,200	4,500	0
Silver Spring Dr. to Hampton Rd.	7,900	4-103	0	6,500	700	0
	43,800		3,500	36,300	26,100	5,200

Notes: 1. See Table C-4 for samples and corresponding concentrations for each reach.
2. Background level of total carcinogenic PAHs based on maximum probable concentration. See Appendix J.
3. DL = detection limit.

GROUNDWATER OPERABLE UNIT

The site is underlain by a shallow, water-bearing zone. Although it is unlikely that the saturated zone would ever be developed as a water source (because of its small capacity and the availability of the municipal supply), the contaminated groundwater could migrate and discharge into the Little Menomonee River. Therefore, alternatives developed for remediating the groundwater operable unit will include the shallow, water-bearing zone within the onsite boundaries.

The remedial action objectives for the groundwater operable unit are to:

- Prevent ingestion of or direct contact with water having carcinogens exceeding MCLs, or having a total excess lifetime cancer risks of 1×10^{-6}, or having a total hazard index exceeding 1 for inorganics

- Prevent release of contaminants through the surficial groundwater aquifer to the Little Menomonee River so that surface water quality standards are not exceeded or sediments do not become contaminated to levels exceeding the 1×10^{-6} excess lifetime cancer risk

- Remove contaminants from groundwater such that concentrations are less than those established in NR 140 (Enforcement Standard)

For groundwater, the identification of areas requiring remediation was based on applicable or relevant and appropriate requirements (ARARs) and "to-be-considereds" for groundwater at the site (see Appendix A for details). Field observation of pure phase was also used to define areas of groundwater requiring remediation. The horizontal extent of these areas and estimated depth is shown in Figure 2-2. The observed vertical extent of contamination is illustrated in Figure 2-3.

POTENTIAL ARARs

Section 121(d)(2)(A) of CERCLA specifies that Superfund remedial actions must meet any federal standards, requirements, criteria, or limitations that are determined to be legally applicable or relevant and appropriate requirements (ARARs). CERCLA also provides that state ARARs must be met if they are more stringent than federal requirements. Remedial actions must also take into account the "to be considered" criteria or guidelines if the ARARs do not address a particular situation. Potential ARARs for the site and for actions proposed for each of the remedial alternatives are discussed in Appendix A.

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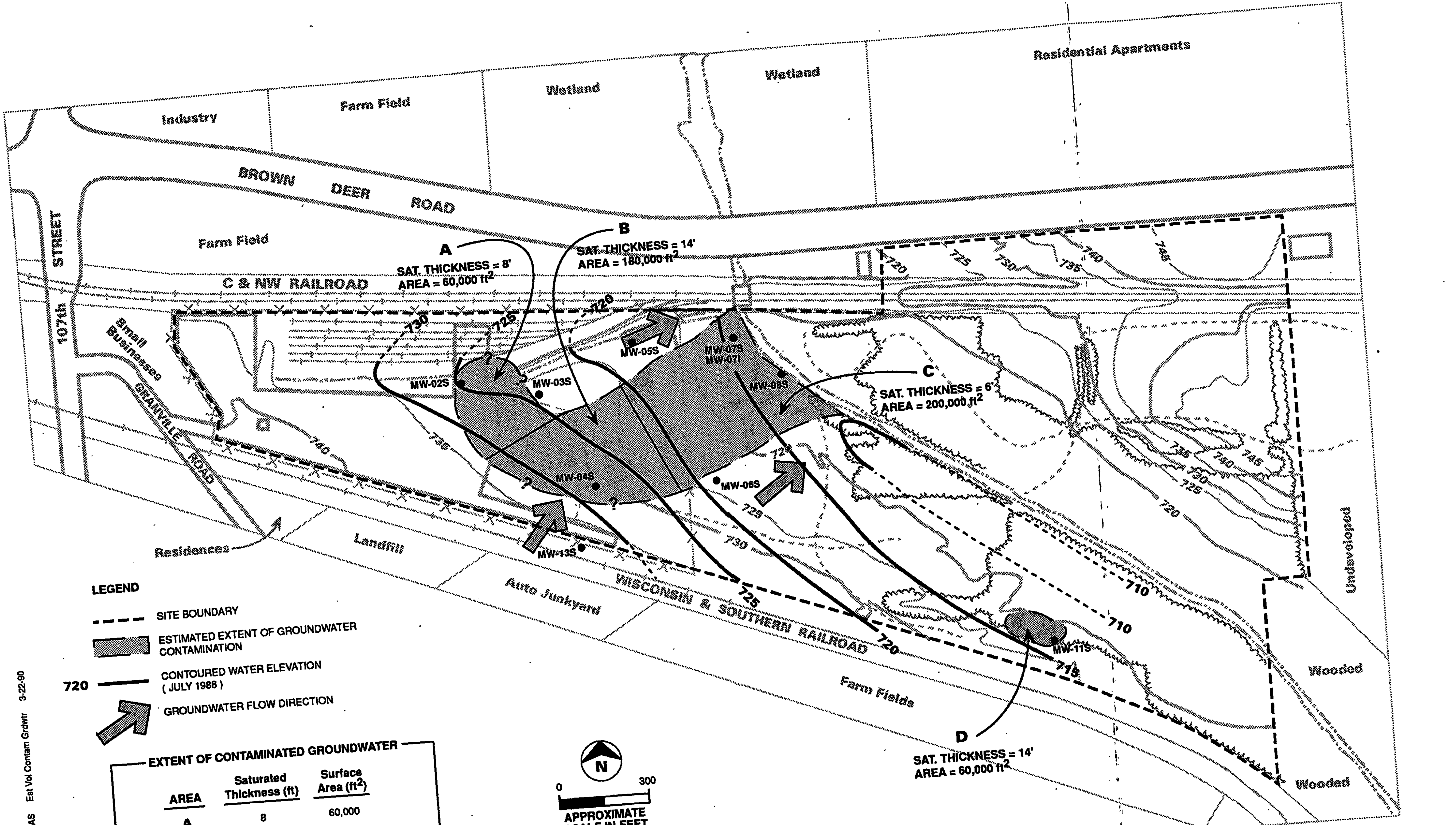

EXTENT OF CONTAMINATED GROUNDWATER

AREA	Saturated Thickness (ft)	Surface Area (ft²)
A	8	60,000
B	14	180,000
C	8	200,000
D	14	60,000

GLO65564.AS Est Vol Contam Grdwtr 3-22-90

FIGURE 2-2
ESTIMATED EXTENT OF CONTAMINATED GROUNDWATER
MOSS-AMERICAN FS

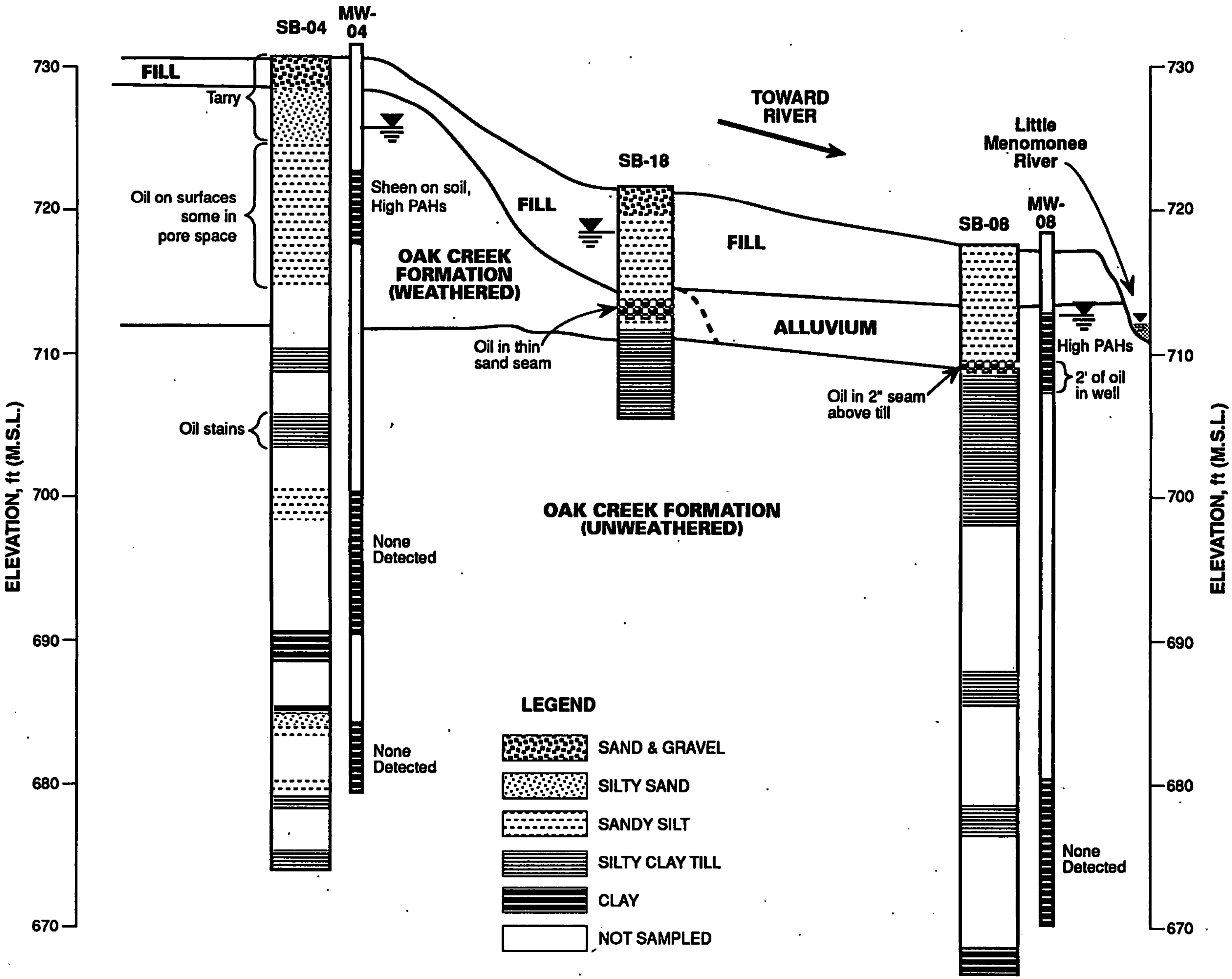

FIGURE 2-3
VERTICAL DISTRIBUTION OF CONTAMINANTS IN SOIL BORINGS AND WELLS
MOSS-AMERICAN FS

Chapter 3
TECHNOLOGIES SCREENING AND DEVELOPMENT

Chapter 3
TECHNOLOGIES SCREENING AND ALTERNATIVES DEVELOPMENT

This chapter describes a range of remedial action alternatives developed from selected remedial action technologies to achieve the remedial action goals. The alternatives development process (see Figure 3-1) consists of the following steps:

- Identify general response actions that can achieve the remedial action goals for each of the contaminated media groups. General response actions are broad classes of responses or remedies (e.g., "containment" or "treatment") intended to meet the remedial action objectives. General response actions outline a general approach to remediate each operable unit, and can be grouped together to outline a general approach to remediate the site. The remedial action goals and general response actions for the site are presented in Table 3-1.

- Identify specific technologies and process options that may feasibly achieve the goal of each response action (e.g., incineration might achieve adequate "treatment" of soil). This process, referred to as "initial screening," serves to identify potentially applicable technologies and to eliminate technologies and process options that are clearly not implementable.

- Screen the potentially applicable technologies and process options (that were retained from initial screening) on the bases of effectiveness, implementability, and relative cost to reduce the number of technologies and process options considered for incorporation into detailed alternatives. This process constitutes the "secondary screening" of technologies.

- Assemble the remaining technologies into a small number of remedial action alternatives that provide a range of levels of remediation and achieve the remedial action goals.

Screening of alternatives was not performed since it was not necessary to develop a large number of alternatives.

INITIAL SCREENING OF TECHNOLOGIES

The evaluation of remedial technologies and process options (subcategories within technologies) was conducted in two phases. In the first phase (initial screening), process options were screened on the basis of technical implementability. This criterion considers the compatibility of the process with the site characteristics (e.g., physical and chemical characteristics of contaminated media, depth to bedrock) and the contaminants present to eliminate processes that are clearly unworkable or inappropriate for the contaminated media. During the initial screening, technologies and process options were assessed independently and without consideration of the

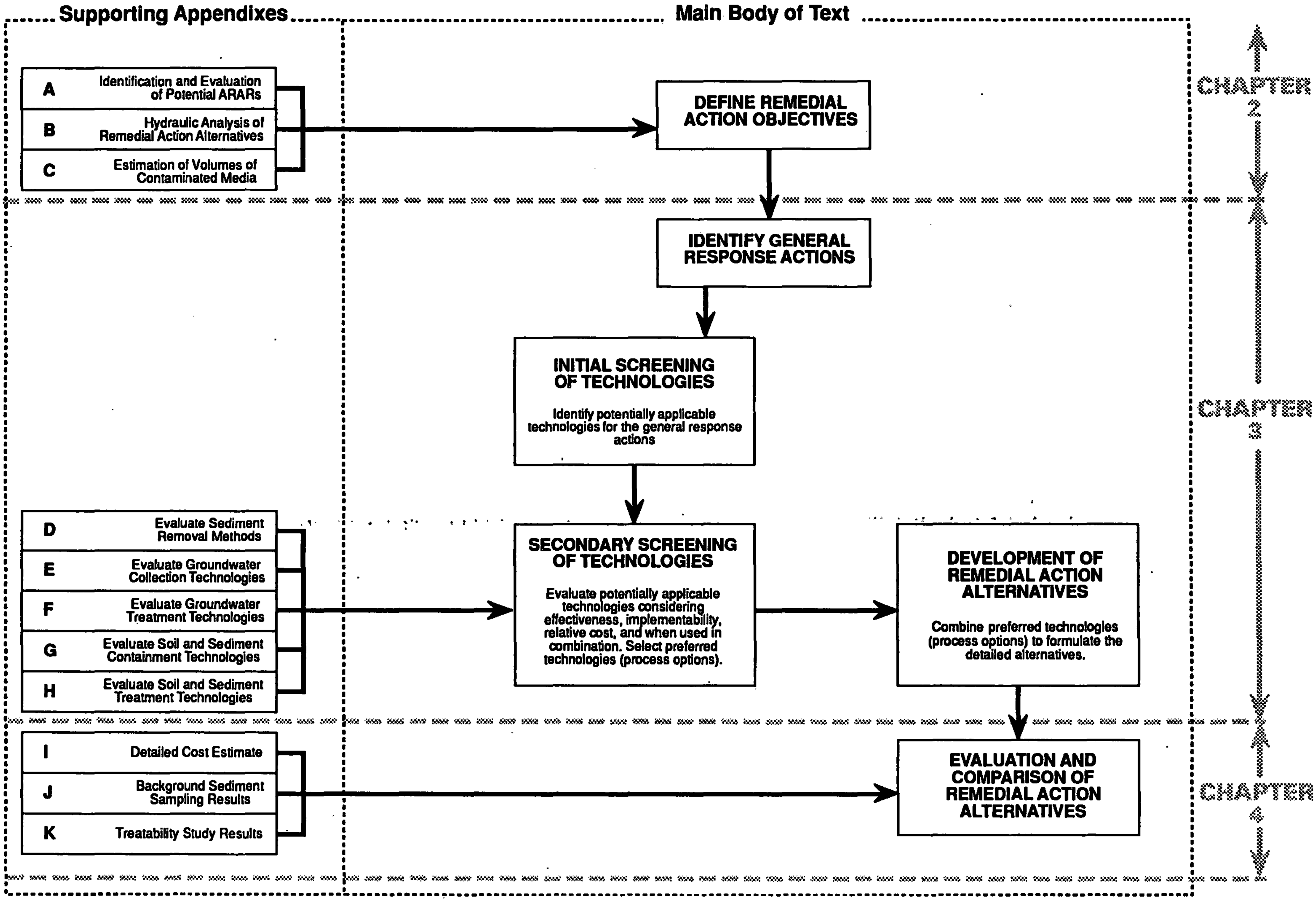

FIGURE 3-1
DEVELOPMENT OF DETAILED ALTERNATIVES
MOSS-AMERICAN FS

Table 3-1 (Page 1 of 2)
REMEDIAL ACTION GOALS AND ASSOCIATED
GENERAL RESPONSE ACTIONS

Operable Unit	Goal	Possible General Response Actions to Meet These Goals
Soil	Minimize direct contact, inhalation, or ingestion of contaminated soil. Minimize threat to public health and the environment from migration of contaminants in soil to groundwater and river.	Institutional controls Containment of soil Removal of soil Treatment of soil Disposal of soil
Sediment	Minimize direct contact, inhalation, ingestion of contaminants in sediment. Minimize migration of contaminants in sediment downstream to Menomonee River. Minimize risk of skin irritation from direct contact for occasional recreational users of the river. Minimize acute and chronic effects on aquatic life, posed by contaminants in sediment.	Institutional controls Containment of sediment Removal of sediment Treatment of sediment Disposal of sediment

Table 3-1 (Page 2 of 2)

Operable Unit	Goal	Possible General Response Actions to Meet These Goals
Groundwater	Prevent ingestion of or direct contact with water having carcinogens exceeding MCLs, or having a total excess lifetime cancer risks of 1 x 10^{-6} or having a total hazard index exceeding 1 for inorganics.	Institutional controls Containment of groundwater Collection of groundwater Treatment of groundwater Disposal of groundwater
	Prevent release of contaminants through the surficial groundwater aquifer to the Little Menomonee River such that remediated sediments would not become contaminated to levels exceeding the 1 x 10^{-6} excess lifetime cancer risk.	
	Remove contaminants from groundwater such that concentrations are less than those established in NR 140 (Enforcement Standard).	

screening of technologies is summarized in Figures 3-2 through 3-4. Technologies and process options that survived initial screening were considered potentially applicable.

SECONDARY SCREENING OF TECHNOLOGIES

Remedial alternatives were developed by combining specific technologies and process options to achieve the remedial action goals. Many remedial technologies and process options were retained after initial screening, and so combining all of them into detailed alternatives would have resulted in a cumbersome number of alternatives. To reduce the number of possible alternatives, technologies and process options retained after initial screening were reevaluated using screening criteria more stringent than used in the initial screening. Preferably, a single process option is retained as representative for a given technology. Whether this could be done depends on the feasibility of implementing any of the technologies and process options based on the broader screening criteria and whether the retained technologies are significantly different from each other. In some cases more than one process option was retained for a technology if one option was not clearly preferable in terms of effectiveness, implementability, or relative cost. The identification of a representative process option was not intended to limit the technologies that could be used in design, but to provide a manageable number of alternatives for the FS.

SCREENING CRITERIA

During secondary screening, process options were evaluated on the bases of effectiveness, implementability, and relative cost. Emphasis was placed on effectiveness and implementability.

Effectiveness

Technologies and process options were evaluated on the bases of their effectiveness in protecting human health and the environment and in satisfying one or more of the remedial objectives. Effectiveness pertains to:

- The ability of a process option to handle the estimated areas or volume of media
- Meeting the remediation goals identified in the remedial action objectives
- The degree of protection of human health and the environment during construction and operation
- The expected reliability and performance with respect to contaminants at the site and physical conditions of the site

Implementability

Evaluation of implementability addresses both technical and administrative feasibility of implementing a technology or process option. Because technical implementability served as the criterion for the initial screening, implementability considerations at the secondary level of screening placed greater emphasis on institutional aspects of implementability. Implementability pertains to:

- Ability to obtain necessary permits for offsite actions
- Availability and capacity of offsite treatment, storage, and disposal services
- Availability of the necessary equipment and skilled workers to implement the technology
- Constructibility under site conditions
- Time to implement the technology or process option and time required to achieve beneficial results such as elimination or minimization of exposure to hazardous substances

Relative Cost

The assessment of relative cost considered general capital costs and operation and maintenance costs for technologies. It does not involve site-specific, detailed cost estimates. Relative cost was used to screen out process options only if the relative cost was believed to be significantly higher while relative effectiveness or implementability were not significantly different.

RESULTS OF SECONDARY SCREENING

Technologies and process options were screened with respect to the operable units and general response actions. Results of the secondary screening of technologies are discussed below and summarized in Figures 3-5, 3-6, and 3-7.

Some of the details of the secondary screening can be found in the following appendixes:

- Sediment removal options (Appendix D)
- Groundwater collection options (Appendix E)
- Groundwater treatment and disposal technologies (Appendix F)
- Soil and sediment containment options (Appendix G)
- Soil and sediment treatment technologies (Appendix H)

SOIL OPERABLE UNIT

Institutional Controls

Institutional control options that remained after initial screening included use (deed) restrictions and access restrictions. Both use restrictions and access restrictions are implementable, low-cost options that would reduce the likelihood of exposure to contaminated soil. The long-term effectiveness of using these controls alone as a measure to mitigate exposure is questionable. Access restrictions could be difficult to enforce over the long term. Therefore, only use restrictions, when used in

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENTS
NO ACTION	None		No remedial actions taken at site.	Retained (NCP requires consideration of no action)
INSTITUTIONAL CONTROLS	Access and Use Restrictions		Use of deed restrictions to restrict property use and fencing to limit access to surficial comtamination.	Potentially applicable
CONTAINMENT	Soil Cover	Native Soil	Placement of uncontaminated locally available soil over contaminated areas to prevent erosion and direct contact exposure.	Potentially applicable
	Caps	Single Barrier Cap	Use of asphalt, sprayed asphalt, concrete, synthetic membrane or compacted clay in a single layer to prevent erosion and direct contact and to minimize infiltration.	Potentially applicable
		Double Barrier Cap	Use of two impermeable layers such as compacted clay and synthetic liners to prevent erosion and direct contact and to minimize infiltration.	Potentially applicable
REMOVAL	Excavation		Excavation of contaminated soils with backhoes, bulldozers, and front end loaders.	Potentially applicable
DISPOSAL	Onsite RCRA Landfill		Construction of a RCRA compliant landfill onsite for disposal of contaminated soils.	Potentially applicable
	Offsite RCRA Landfill		Disposal at a RCRA permitted landfill.	Potentially applicable
	Sanitary Landfill		Disposal in a non-RCRA landfill (such as a local municipal landfill) of contaminated soils or treated soil residual.	Potentially applicable.
	Onsite Placement		Placement of treated or untreated soil back on site after its removal.	Potentially applicable

GLO65564.FS SOIL OPERABLE 1 of 3 3-21-90

TECHNOLOGY NOT CARRIED FORWARD

FIGURE 3-2 (Sheet 1 of 3)
TECHNOLOGY SCREENING
SOIL OPERABLE UNIT
MOSS-AMERICAN FS

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENTS
TREATMENT	Solidification/Fixation Stabilization	Pozzolonic Agents	Addition of lime and fine-grained oiliceous material aqueous or semisolid waste to produce a concrete like solid.	Not appriopriate to organic contaminants since contaminants are not chemically bound.
		Sorption	Addition of an inert, nondegradeable sorbent to sorb moisture and reduce permeability of soil with high moisture content.	Not effective as a treatment or pretreatment mechanism.
	Physical/Chemical Treatment	Soil Washing	Addition of polymers, surfactants, and / or alkaline chemicals to reduce surface tension or solubilize contaminants and physical agitation to transfer contaminants to water stream for treatment.	Potentially applicable
		Solvent Extraction	Addition of solvents such as alcohol or triethylamine to remove and concentrate contaminants in the solvent. Separation of contaminants from solvent by distillation or disposal of solvent.	Potentially applicable to highly contaminated soil.
		Supercritical Fluid Extraction	Addition of a gas (typically CO_2) at its critical point countercurrent to a contaminated waste, extract organics, which then separate from the gas at atmospheric conditions.	Requires soil to be finely ground and treated as an aqueous solution. The heterogenous character of the soil (gravel, clay, sand, debris) would make this very difficult to implement and control.
		Oxidation	Addition of oxidizing agents to waste for oxidation of organic contaminants to less toxic oxidation states.	Chemical oxidation of creosote contaminated soils has not been demonstrated in field applications.
		Chemical Reduction	Addition of reduction agents to wastes to stabilize metals by converting them to a less soluble, more stable form.	Not applicable to organic substances.
		Steam Stripping	Removal of VOCs from soil by application of steam. Injection wells force steam through contaminated subsurface. Steam carrying stripped volatiles are collected at surface through extraction wells.	Applicable to volatile organic contaminants. Not as effective for PAHs. Not applicable to metals onsite.
		Vitrification	Placement of graphite electrodes in a square array, and passing electric current through them to create high temperatures that melt the soil or waste solids into a block of glasslike material. Experimental process option.	Potentially applicable to contaminated soil above the water table.
		Soil Vapor Extraction	Movement of large volumes of air through the soil to strip volatile contaminants from the soil in a manner similar to air stripping.	Not effective for removal of PAHs. Not applicable to metals onsite.
		Soil Flushing	Flushing of contaminated soil with an appropriate solution and the collection of the elutriate in a series of shallow well points or subsurface drains.	Potentially applicable.

Continued on Sheet 3 of 3

TECHNOLOGY NOT CARRIED FORWARD (shaded): Pozzolonic Agents, Sorption, Solidification/Fixation Stabilization, Supercritical Fluid Extraction, Oxidation, Chemical Reduction, Steam Stripping, Soil Vapor Extraction

GLO65564.FS SOIL OPERABLE 2 of 3 3-26-90mms

FIGURE 3-2 (Sheet 2 of 3)
TECHNOLOGY SCREENING
SOIL OPERABLE UNIT
MOSS-AMERICAN FS

Continued From Sheet 2 of 2

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENTS
TREATMENT	Biological Treatment	Slurry Bioreactor	Degradation and mineralization of organic wastes using a mixed culture of organisms under aerobic conditions in a batch reactor vessel.	Potentially applicable.
		Anaerobic Processes (shaded)	Oxidation of compounds using a mixed culture of organisms in anaerobic conditions.	Aerobic biodegradation of PAHs is more effective than anaerobic processes.
		Facultative Processes (shaded)	Removal of organic compounds from wastewaters using of a mixed culture of organisms in both aerobic and anaerobic conditions.	Aerobic biodegradation is more effective.
		New Biotechnologies	Application of genetically modified microorganisms to waste to oxidize specific organic compounds. Purified enzyme systems detoxify organic contaminants.	Still largely experimental. Genetically modified organisms could be used in aerobic soil treatment process.
		Land Treatment	Enhancement of microbiological degradation, detoxification, and mineralization of hazardous substances by adjusting biodegradation of contaminated soil, nutrient levels, moisture content, pH, and temperature. Performed onsite in a lined cell.	Potentially applicable.
		Surface Bioreclamation	Degradation of organic compounds in place by microorganisms through the addition of nutrients and oxygen using tilling.	Potentially applicable.
		Subsurface Bioreclamation	Degradation of organic compounds by microorganisms by the addition of nutrients and oxygen into the subsurface using injection wells, recharge ponds, or infiltration galleries.	Potentially applicable.
	Thermal Treatment	Incineration	Thermal destruction of hazardous materials in a controlled, oxygen-sufficient environment. Generally, products include carbon dioxide, water, and ash. Many types of incinerators with varying capabilities exist.	Potentially applicable.

(shaded) TECHNOLOGY NOT CARRIED FORWARD

GLO65564.FS SOIL OPERABLE 3 of 3 3-21-90 mms

FIGURE 3-2 (Sheet 3 of 3)
TECHNOLOGY SCREENING
SOIL OPERABLE UNIT
MOSS-AMERICAN FS

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENTS
NO ACTION	None		No remedial actions taken at site.	Retained per the NCP.
INSTITUTIONAL CONTROLS	Access and Use Restrictions		Use of deed restrictions to restrict property use and fencing to limit access to the river.	Potentially applicable. Fencing of river in the county park to prevent access to the sediment is technically feasible.
CONTAINMENT	In-Place Horizontal Barriers	Armoring	Placement of synthetic liner over sediments and anchor to river bottom and banks.	Potentially applicable, although not demonstrated for streams or rivers.
		Cover and Reroute River	Covering of sediments in place and digging a new stream channel adjacent to existing river. Cover could be soil or an engineered cap.	Potentially applicable.
	Sediment Control Barriers		Use of sediment traps, curtain barriers or cofferdams to reduce sediment transport to the Menomonee River.	Sediment barriers alone do not prevent direct contact with creosote. May be used during or after construction to control sediment transport.
REMOVAL	Hydraulic Dredging		Use of hydraulic dredging to excavate contaminated sediment.	Potentially applicable.
	Dry Excavation		Use of clamshell, dragline, front end loader or backhoes to excavate sediments with river diverted.	Potentially applicable.
DISPOSAL	Sanitary Landfill		Disposal of sediment, or treatment of residue in local sanitary landfill.	Potentially applicable.
	Onsite RCRA Landfill		Construction of a RCRA - compliant landfill onsite.	Potentially applicable.
	Offsite RCRA Landfill		Disposal of untreated sediment or treatment residues in an offsite RCRA landfill. Assumes residual is not delistable after treatment.	Potentially applicable.
	Onsite Placement		Disposal of treated sediment onsite assumes residual is delistable. May consolidate with treated soil residuals.	Potentially applicable.

TECHNOLOGY NOT CARRIED FORWARD

GLO65564.FS SEDIMENT 1 3-27-90 mms

FIGURE 3-3 (Sheet 1 of 3)
TECHNOLOGY SCREENING
SEDIMENT OPERABLE UNIT
MOSS-AMERICAN FS

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENTS
TREATMENT	Solidification, Fixation, Stabilization	Pozzolanic Agents	Addition of lime and fine-grained siliceous material added to waste to produce a concrete-like solid.	Not appropriate to organics.
		In situ Stabilization	Addition of an inert, nondegradeable stabilization agent to reduce permeability of sediment contained in-place.	Potentially applicable.
	Physical/Chemical Treatment	Solids Dewatering	Use of sedimentation, centrifuges, filter presses, etc. for dewatering of sediments prior to treatment.	Potentially applicable in conjunction with other treatment process.
		Soil Washing	Addition of polymers, surfactants and/or alkaline chemicals to reduce surface tension or solubilize contaminants and physical agitation to transfer contaminants to water stream for treatment.	Potentially applicable
		Solvent Extraction	Addition of solvents such as alcohol or triethylamine to remove and concentrate contaminants in the solvent. Separation of contaminants from solvent by distillation or disposal of solvent.	Potentially applicable to highly contaminated sediment.
		Flotation	Release of gas bubbles into wastewater to attract suspended solids, free and emulsified oils, and grease. Bubbles float to the top and are skimmed off.	Potentially applicable in conjunction with wet dredging or slurry biotreatment.
		Media Filtration	Removal of fine solid particles from liquid stream by a filter medium. Common media are sand, diatomite, coal, natural or synthetic fabric, and wire cloth.	Potentially applicable in conjunction with wet dredging or slurry biotreatment.
		Vitrification	Placement of graphite electrodes in a square array and passing electric current through them to create high temperatures that melt the sediment into a block of glasslike material. Experimental process option.	Sediment not well suited for vitrification because it is below the water table, has low permeability, has significant organic content, and contaminants are dispersed over a long, narrow, shallow area.
		Soil Vapor Extraction	Movement of large volumes of air through the sediment to strip volatile contaminants from sediment in a manner similar to air stripping.	PAHs would not be effectively removed from sediment using air stripping due to low volatility.
		Sediment Flushing	Flushing of contaminated sediment with an appropriate solution and collection of the elutriate in drains parallel to the river bed.	Potentially applicable under controlled conditions. Rerouting of river could be necessary.

Continued on Sheet 2 of 3

[shaded box] TECHNOLOGY NOT CARRIED FORWARD

GLO65564.FS SEDIMENT 2 01-08-90

FIGURE 3-3 (Sheet 2 of 3)
TECHNOLOGY SCREENING
SEDIMENT OPERABLE UNIT
MOSS-AMERICAN FS

Continued From Sheet 2 of 2

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENTS
TREATMENT	Biological Treatment	In Situ Bioreclamation	Enhancement of microbiological degradation, detoxification, and mineralization of hazardous substances with respect to electron acceptors, nutrient levels, moisture content, pH, and temperature.	Potentially applicable under controlled conditions. It would be necessary to permanently reroute river due to long time period required for biodegradation.
		Slurry Bioreactor	Oxidation of organic wastes using a mixed culture of organisms in aerobic conditions in a batch reactor vessel.	Potentially applicable. See soils.
		Anaerobic Processes	Oxidation of organic compounds using a mixed culture of organisms in anaerobic conditions.	Aerobic biodegradation of creosote has been shown to be more effective than anaerobic degradation.
		Facultative Processes	Removal of organic compounds from wastewaters using a mixed culture of organisms in both aerobic and anaerobic conditions.	Aerobic biodegradation is more effective.
		New Biotechnologies	Application of genetically modified microorganisms to wastewater to oxidize specific organic compounds. Purified enzyme systems detoxify organic contaminants. Experimental process option.	Still largely experimental. Genetically modified microorganisms could be added to the aerobic treatment process.
		Land Treatment	Enhancement of microbiological degradation, detoxification, and mineralization of hazardous substances by adjusting biodegradation of contaminated soil, nutrient levels, moisture content, pH, and temperature. Performed onsite in a lined cell.	Potentially applicable.
	Thermal Treatment	Incineration	Incineration of organic components of sediment.	Potentially applicable.

TECHNOLOGY NOT CARRIED FORWARD

GLO65564.FS SEDIMENT 3 3-22-90mms

FIGURE 3-3 (Sheet 3 of 3)
TECHNOLOGY SCREENING
SEDIMENT OPERABLE UNIT
MOSS-AMERICAN FS

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENTS
NO ACTION	None		No action.	Retained per the NCP.
INSTITUTIONAL CONTROLS	Access and Use Restrictions		Use of deed restrictions to restrict installation of wells in surficial aquifer onsite.	Potentially applicable.
CONTAINMENT	Vertical Barriers	Geomembrane	Placement of synthetic membrane vertically in trench to prevent groundwater movement through trench.	Potentially applicable to mitigate migration, when used in conjunction with extraction.
		Slurry Wall	Construction of a 20-foot-deep trench along the river onsite surrounding the contaminated groundwater onsite using a bentonite slurry. Trench backfilled with a soil-bentonite or cement-bentonite mix.	Potentially applicable to mitigate migration, when used in conjunction with extraction.
		Grout Curtains	Pressure injection of grout along contamination boundaries in a regular overlapping pattern of drilled holes.	Difficult to ensure proper overlap of injected grout and continuity of low permeability wall.
		Sheet Piling	Driving of steel sheet piling driven along contamination boundaries.	Useful life of steel is limited due to corrosion. Leakage at interlocks of piles is difficult to prevent.
	Horizontal Barriers		Injection of grout below zone of contamination to establish horizontal zone of low permeability.	Oak Creek Formation glacial till beneath contaminated alluvial deposit is of sufficiently low permeability to minimize potential for downward contaminant migration.
COLLECTION	Wells		Installation of groundwater extraction wells to collect contaminated groundwater in alluvial deposit.	May not be as effective in removing groundwater in the alluvial deposit as are drains but potentially applicable.
	Drains		Installation of subsurface gravel filled trench paralleling river onsite. Perforated pipe in bottom of trench collects contaminated groundwater.	Potentially applicable.
TREATMENT	Physical Treatment	Coagulation / Flocculation	Suspension of particle aggregation that results from chemical additions to the wastewater. Once particles have aggregated into larger particles, they can be removed by sedimentation, flotation, or filtration.	Potentially applicable to solids treatment waste streams.
		Oil-Water Separation	Gravity separation of oil from water. Treatment may be required for dissolved and emulsified oil prior to simple physical separation.	Potentially applicable.
		Flotation	Release of gas bubbles into wastewater to attract suspended solids, free and emulsified oils, and grease. Bubbles float to the top and are skimmed off.	Potentially applicable.
		Media Filtration	Removal of fine solid particles from liquid stream by a filter medium. Common media are sand, diatomite, coal, natural or synthetic fabric, and wire cloth.	Filtration not appropriate for removal of contaminants unless the groundwater contains high suspended solids, which is not anticipated for this site.
		Granular Activated Carbon Adsorption	Removal of contaminant by passing contaminated liquid or gas stream over adsorbant material.	Potentially applicable.

Continued on Sheet 2 of 3

Continued on Sheet 2 of 3

TECHNOLOGY NOT CARRIED FORWARD

GLO65564.FS GROUNDWATER 1 3-27-90mms

FIGURE 3-4 (Sheet 1 of 3)
TECHNOLOGY SCREENING
GROUNDWATER OPERABLE UNIT
MOSS-AMERICAN FS

Continued from Sheet 1 of 3

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENTS
TREATMENT	Physical Treatment	Membrane Processes	Preferential passage of some components of a fluid mixture or solution through a barrier membrane.	Not appropriate for low concentrations of contaminants in presence of high concentrations of inorganic chemicals.
		Air Stripping	Passage of large volumes of air through liquid in a packed column or by diffused aeration to promote transfer of volatile contaminants to air.	PAHs are not sufficiently volatile for air stripping removal.
		Stream Stripping	Similar to air stripping. Steam is pumped into stripping column. Heat promotes transfer of volatile contaminants from liquid to air.	PAHs are not sufficiently volatile for air stripping removal.
		Evaporation	Heating of wastewater to its boiling point followed by condensation. The remaining brine stream contains virtually all the dissolved solids.	High energy requirements make evaporation not cost -effective relative to GAC treatment.
		Distillation	Release of volatile compounds into a vapor phase by boiling organic liquid waste. The vapor phase is condensed, treated, or disposed.	High energy requirement makes distillation cost-effective only for high strength waste streams.
		Liquid-Liquid Extraction	Bringing together of two immiscible liquids by forced mixing or countercurrent flow to promote the transfer of a solute from one liquid to the other. Applicable for removal of organics from aqueous solutions or water soluble compounds from organic sources.	Not appropriate for low levels of contaminants. Insufficient volume of nonaqueous phase liquids for application.
		Critical Fluid Extraction	Addition of a gas (typically CO_2) at its critical point countercurrent to a contaminanted waste, to extract organics, which then separate from the gas at atmospheric conditions.	Relatively complex operation and high cost make this technology more suitable to high strength waste streams.
		Permeable Treatment Beds	Trench excavated, filled with activated carbon, and capped to intercept contaminated groundwater plume. Organics can be removed, and nutrients can be added. Conceptual process option.	High cost of activated carbon used in trenches. Not cost-effective relative to GAC treatment of collected groundwater.
	Chemical Treatment	Oxidation	Additon of oxidizing agents to wastes for oxidation of cyanide, heavy metals, unsaturated organics, sulfides, phenolics, pesticides, aldehydes, and aromatic hydrocarbons to less toxic oxidation states.	Potentially applicable.
		Organic Chemical Dechlorination	Addition of chemical reagents or catalysts to wastes to remove chlorine atoms from chlorinated hydrocarbons.	Not applicable to aqueous wastes. Experimental process option.
		Photolysis	Application of sunlight, fluorescent lamps, or mercury arcs to liquid waste stream to promote the photodegradation of the contaminant. Experimental process option.	Potentially applicable.

Continued on Sheet 3 of 3

(Shaded box) TECHNOLOGY NOT CARRIED FORWARD

Shaded (not carried forward): Membrane Processes, Air Stripping, Stream Stripping, Evaporation, Distillation, Liquid-Liquid Extraction, Critical Fluid Extraction, Permeable Treatment Beds, Organic Chemical Dechlorination.

FIGURE 3-4 (Sheet 2 of 3)
TECHNOLOGY SCREENING
GROUNDWATER OPERABLE UNIT
MOSS-AMERICAN FS

GLO65564.FS GROUNDWATER 2 3-27-90mms

Continued from Sheet 2 of 3

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENTS
TREATMENT	Biological Treatment	Aerobic Processes	Oxidation of organic wastes using a mixed culture of organisms in aerobic conditions.	Groundwater does not have sufficient organic strength to allow biodegradation. Potentially applicable to solids treatment waste streams.
		Anaerobic Processes	Oxidation of organic compounds using a mixed culture of organisms in anaerobic conditions.	Aerobic treatment of creosote components is more effective than anaerobic treatment.
		Faculative Processes	Removal of organic compounds from wastewaters using a mixed culture of organisms in both aerobic and anerobic conditions.	Aerobic biodegradation is more effective.
		New Biotechnologies	Application of genetically modified microorganisms to wastewater to oxidize specific organic compounds. Purified enzyme systems detoxify organic contaminants. Experimental process options.	Still largely experimental. Genetically modified microorganisms could be added to the aerobic treatment process. New biotechnologies for groundwater treatment addressed under in situ and aerobic processes.
		Land Treatment	Microbiological degradation of organic contaminants by spraying or irrigating over lined treatment soil beds.	Potentially applicable for underdrain water from land treatment.
	In Situ Treatment	Bioreclamation	Enhancement of microbiological degradation, detoxification, and mineralization of hazardous substances with respect to electron acceptors, nutrient levels, moisture content, pH, and temperature.	Potentially applicable.
DISPOSAL (DISCHARGE)	Reinjection / Recycle		Reinjection of treated groundwater to the contaminated aquifer.	Not permissible unless used in conjunction with treatment (see In Situ Treatment).
	POTW		Discharge of treated water to the sanitary sewer interceptor paralleling the river. Further treatment of water at the MMSD POTW.	Potentially applicable.
	River		Discharge of treated water to the Little Menomonee River.	Potentially applicable.

[shaded box] TECHNOLOGY NOT CARRIED FORWARD

GLO65564.FS GROUNDWATER 3 3-22-90mms

FIGURE 3-4 (Sheet 3 of 3)
TECHNOLOGY SCREENING
GROUNDWATER OPERABLE UNIT
MOSS-AMERICAN FS

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGIES RETAINED FROM PRELIMINARY SCREENING	REMEDIAL TECHNOLOGIES RETAINED FOLLOWING SECONDARY SCREENING
INSTITUTIONAL CONTROLS	Access Restrictions Use Restrictions	Use Restrictions
CONTAINMENT	Soil Cover Single Barrier Cap Double Barrier Cap	Soil Cover
REMOVAL	Excavation	Excavation
DISPOSAL	Sanitary Landfill Onsite RCRA Landfill Offsite RCRA Landfill Onsite Placement	Onsite Placement Offsite RCRA Landfill (for treated soil only)
TREATMENT	Stabilization Physical / Chemical Biological Thermal	None Soil Washing Slurry Bioreactor Land Treatment Onsite Incineration Offsite Incineration

GLO65564.FS FIG 3-5 5-17-90

FIGURE 3-5
SECONDARY SCREENING
SOIL OPERABLE UNIT
MOSS-AMERICAN FS

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGIES RETAINED FROM PRELIMINARY SCREENING	REMEDIAL TECHNOLOGIES RETAINED FOLLOWING SECONDARY SCREENING
INSTITUTIONAL CONTROLS	Access Restrictions Use Restrictions	Use Restrictions
CONTAINMENT	Horizontal Barriers Sediment Control Barriers Soil Cover Caps	Cover and Reroute River Soil Cover
REMOVAL	Dry Excavation Hydraulic Dredging	Dry Excavation
DISPOSAL	Sanitary Landfill Onsite RCRA Landfill Offsite RCRA Landfill Onsite Placement	Onsite Placement (for treated sediment only)
TREATMENT	Stabilization Physical / Chemical Biological Thermal	None Soil Washing Solids Dewatering Flotation Slurry Bioreactor Land Treatment Onsite Incineration

GLO65564.FS FIG 3-6 5-17-90

FIGURE 3-6
SECONDARY SCREENING
SEDIMENT OPERABLE UNIT
MOSS-AMERICAN FS

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGIES RETAINED FROM PRELIMINARY SCREENING	REMEDIAL TECHNOLOGIES RETAINED FOLLOWING SECONDARY SCREENING
INSTITUTIONAL CONTROLS	Use Restrictions	Use Restrictions
CONTAINMENT	Vertical Barriers	Geomembrane
COLLECTION	Drains Wells	Drains
TREATMENT	Physical	Oil - Water Separation Granular Activated Carbon
	Chemical Biological In Situ	None None None
DISPOSAL	POTW River	POTW River

GLO65564.FS FIG 3-7 3-26-90

FIGURE 3-7
SECONDARY SCREENING
GROUNDWATER OPERABLE UNIT
MOSS-AMERICAN FS

conjunction with other actions such as containment, were retained for further evaluation in the analysis of detailed alternatives.

Containment Options

Containment options that survived the initial screening included native soil cover, single barrier cap, and double barrier cap. The use of a cap to reduce infiltration would provide only marginal benefits in terms of achieving the goals for soil and groundwater. Therefore, the soil cover technology was retained for use in detailed alternatives where untreated soil or sediment is contained in place, or where treated soil is replaced and covered onsite. A more detailed discussion of containment options is presented in Appendix G.

Removal Options

The only removal process option considered for soil was excavation, and so excavation was retained as the process option representative of the removal general response action.

Disposal Options

Disposal process options that survived the initial screening included sanitary landfilling, onsite and offsite disposal in a RCRA landfill, and onsite placement of soil. These options survived initial screening because they are technically feasible and would be effective in reducing potential exposure. The LDRs will disallow disposal of contaminated soil or sediment without treatment after 1990, because the U.S. EPA has determined that, on the basis of the mixture rule, these materials must be managed as RCRA K001 and U051 wastes. According to the LDRs, untreated soil subject to these restrictions could be landfilled if it could be demonstrated to the satisfaction of the EPA that there will be no migration from the disposal unit of hazardous chemicals above health-based levels for as long as the wastes remain hazardous. Because of the significant uncertainties as to whether the soil would meet these requirements and because of the SARA preference for treatment, landfilling of untreated soil was excluded from further consideration. If cost-effective treatment technologies are not found or certain soil can be managed as a nonhazardous waste, the feasibility of landfilling this material should be reconsidered. This analysis may require the preparation of a "no-migration petition."

A key issue regarding disposal and the LDRs is the definition of "disposal." For LDRs to be applicable to a CERCLA response, the action must constitute "placement" of a restricted waste. Under RCRA, the terms "placement" and "disposal" are synonymous. In the screening of remedial technologies, the technology "onsite placement" is presented as a potentially applicable disposal response action. Under current interpretation of RCRA, "placement" (or disposal) occurs when wastes are excavated from an area of contamination, treated in a separate unit (such as an incinerator), and then redeposited onto the same area of contamination. This interpretation could severely hinder the implementability of using onsite placement as a remedial technology for contaminated soil. However, because onsite placement of treated sediment and soil is considered more practical and nearly as protective of human health as offsite disposal in a RCRA landfill, "onsite placement" was retained as a disposal option in the detailed alternatives. Delisting of residues or obtaining an ARARs waiver may be necessary to implement this action.

Sanitary landfilling of treatment residues from incineration or other treatment methods that reduce contaminant levels to cleanup criteria was not retained for further consideration because obtaining a permit for this action would be impeded by the LDRs. Offsite disposal of treated residuals in a RCRA landfill is technically implementable and in accordance with LDRs. Therefore, this option was retained for disposal of residuals generated from materials outside the area of contamination.

Treatment Options

Treatment process options that remained after initial screening included soil washing, solvent extraction, slurry bioreactor treatment, land treatment, incineration, surface bioreclamation, vitrification, subsurface bioreclamation, and soil flushing. Following secondary screening on the bases of effectiveness, implementability, and relative cost, only soil washing, slurry bioreactor, land treatment, and incineration were retained for further consideration. Appendix H presents the details of this analysis.

SEDIMENT OPERABLE UNIT

Institutional Controls

Use of access restrictions to control access and limit contact with river sediments was considered technically feasible in the initial screening, but was not considered implementable or effective for the entire river. Most of the 5-mile stretch of river is within county parkland and fencing would seriously limit the aesthetic appeal. As a result, fencing was not retained. No options were retained for institutional controls on sediment. (Use restrictions were not considered an institutional control for sediment since development of the river, unlike development of the original property, is not feasible.)

Containment Options

Containment options that survived the initial screening included use of a single barrier cap over existing sediments ("armoring" without river rerouting), containing sediment in-place using a soil cover or a single or multibarrier cap in combination with river rerouting, and sediment control barriers. Use of a soil cover in conjunction with river rerouting was retained for further consideration as a sediment containment option. Use of synthetic liners to cover sediments in-place ("armoring") was eliminated from further consideration because of the potential difficulties with its placement and anchoring, questionable reliability, poor aesthetics, and potentially adverse impact on aquatic habitat. A detailed evaluation of sediment containment options is presented in Appendix G.

Removal Options

Dry excavation and hydraulic dredging survived the initial screening. Hydraulic dredging was eliminated from further consideration because suspension and downstream transport of contaminated sediment would be difficult to control, verification of cleanup would be difficult, and the width and depth of the stream could limit the capabilities of commercially available dredges. Dry excavation was retained as representative of the removal general response action for sediment. A more detailed discussion is presented in Appendix D.

Disposal Options

Options considered technically feasible for disposal of sediment or treated sediment residues included sanitary landfilling, onsite RCRA landfilling, offsite RCRA landfilling, and onsite placement. Because delisting of treatment residues could be a lengthy procedure, sanitary landfilling of treatment residues was not considered as implementable as other options, nor was it considered significantly more effective. Sanitary landfilling or RCRA landfilling of untreated sediment would be difficult to implement because of the LDRs and public acceptance.

Onsite placement of untreated sediment was not considered an option because movement of sediment from the river back to the site without treatment would only increase the potential risk to human health from this material. Onsite placement of treated residues was the only option retained.

Treatment

Sediment treatment options that remained after initial screening included soil dewatering, soil washing, solvent extraction, flotation, media filtration, sediment flushing, slurry bioreactor, new biotechnologies, land treatment, incineration, and in situ bioreclamation.

Because they have been demonstrated on similar wastes, the slurry bioreactor, land treatment, and incineration options were retained for incorporation into the detailed alternatives. While not considered effective treatment technologies by themselves, solids dewatering and physical treatment of sediment were retained for further consideration in conjunction with other treatment technologies.

In situ biotreatment was not retained because of the low permeability of the sediment, implementing in situ treatment would be complicated by the geometry of the channel, the river would need to be rerouted and sediment treatment would take a long time, which would make it difficult to limit access in the park. Sediment flushing was not retained because it has not been proven to be effective on PAHs without the use of surfactants, which pose a subsequent treatment problem and could be disallowed per state ARARs related to underground injection.

GROUNDWATER OPERABLE UNIT

Institutional Controls

Use restrictions could be effective in preventing consumption of contaminated groundwater but are considered too unreliable to be used alone. Use restrictions were retained for use in conjunction with groundwater collection and treatment technologies.

Containment Options

As with institutional controls, the containment options were considered technically feasible, but they would be effective only when used in conjunction with collection technologies. Use of a geomembrane was retained for detailed alternatives.

Collection Options

Drains were considered more effective than wells for the collection of contaminated groundwater and were retained for detailed analysis of alternatives. Appendix E contains a detailed discussion of groundwater collection options.

Treatment Options

Groundwater treatment options that remained after initial screening included coagulation, oil/water separation, flotation, granular activated carbon treatment, oxidation, photolysis, aerobic processes, and land treatment (land application). Appendix F contains detailed discussion and evaluation of the potentially applicable process options. Although oxidation and photolysis processes may hold promise as an economical and effective means of treatment, these technologies are not as well demonstrated as treatment by granular activated carbon. Bench- and pilot-scale testing would be required to demonstrate these technologies as being more economical than and effective as carbon. Therefore, granular activated carbon treatment and the oil/water separator treatment were retained for detailed alternatives involving onsite treatment and discharge to the river.

Disposal Options

Disposal options that survived initial screening included reinjection, discharge to the POTW, and discharge to the Little Menomonee River. Reinjection was not retained because it would not be permitted by the Wisconsin DNR. Because discharge to the river could be more difficult to implement, discharge to the POTW was considered the preferred process option. Discharge to the river, however, was retained for detailed evaluation in case the POTW does not accept the discharge.

SUMMARY OF SECONDARY SCREENING

Soil

The containment technology retained for the soil operable unit is the soil cover for untreated and treated soil. Treatment technologies retained for soil are land treatment, slurry biotreatment, and incineration. Soil washing was also retained for use in conjunction with slurry biotreatment of soil. Excavation was the only removal technology retained and onsite placement was the only disposal technology retained.

Sediment

Containment technologies retained for the sediment operable unit included in-place containment in conjunction with river rerouting and onsite containment of treated residuals using a soil cover. Onsite containment of untreated sediment, through sediment removal and consolidation with contaminated soil and capping, was not retained since such an action would result in an increased risk to human health from these materials. Though consolidation of contaminated soil and sediment would reduce the level of long-term monitoring and use restrictions, this option was not considered significantly more effective than in-place containment.

Treatment technologies and process options retained for the sediment operable unit are basically the same as those for the soil operable unit. (Differences are identified in Figures 3-5 and 3-6.) Therefore, use of the same treatment technology for soil as for sediment for any alternative proposing treatment of both operable units is possibly the most cost-effective approach to treatment.

Groundwater

Until more information on the vertical extent of groundwater contamination is obtained, using drains to collect groundwater appears to be the most appropriate approach to removing contaminated groundwater and for preventing migration of contaminants to the river. The flow of collected groundwater and concentrations of contaminants in it are predicted to be relatively low, therefore, the most viable approach to managing the collected groundwater is to discharge it into the sanitary sewer. If this cannot be permitted, then treatment using oil/water separation and activated carbon and discharge to the river could achieve the desired goals. Because the groundwater treatment is not affected by the actions taken on other operable units and because groundwater treatment is a relatively small component of the alternative's overall cost, all alternatives in this FS incorporate onsite groundwater treatment with discharge to the river to minimize the number of alternatives evaluated in detail. Should the option to discharge to the POTW be acceptable to the POTW, then it should be pursued as the treatment option of choice.

An in situ biotreatment option was not developed because of the marginal hydraulic conductivities, the heterogeneity of permeabilities and contaminant mass, the very low contaminant concentrations (except for areas of free product where they are very high), slow degradation rates, and because much of the contaminant mass is near the ground surface.

DEVELOPMENT OF DETAILED ALTERNATIVES

Remedial action alternatives must consist of various process options that provide different levels of remediation. The range of alternatives must meet the minimal requirements of U.S. EPA directive No. 9355.0-19 (OSWER) by containing the following:

- A no action alternative
- At least one alternative that provides containment of waste with little or no treatment but protects human health and the environment by preventing potential exposure or by reducing the mobility of the contaminants in the waste
- Treatment alternatives ranging from one that would eliminate the need for long-term management at a site (including monitoring) to others

that would use treatment as a principal element to reduce the toxicity, mobility, or volume of contaminants

Figure 3-8 illustrates how the general response actions were combined to form alternatives that provide a range of levels of protection and alternatives required by the NCP. It is apparent in the figure that not all the possible combinations of general response actions were formulated into preliminary alternatives. Because the number of possible combinations would be very large, a reasonable number of alternatives that span a range of levels of remediation were assimilated.

Alternative 1 is the required no action alternative. It provides a basis for comparison of remedial actions against existing conditions and potential future conditions if no remedial action is undertaken.

Alternative 2 is the required alternative that provides containment of waste with little or no treatment. Since one containment technology was retained from secondary screening for both soil and sediment, and because containment technologies for groundwater were not retained for use without groundwater collection, only one "containment" alternative was developed. No variations of this alternative with different groundwater collection schemes were developed since only one collection scheme was retained from secondary screening. As discussed in the preceding section, discharge of groundwater to the POTW is considered the preferred groundwater management technology. However, all alternatives are developed as including treatment and discharge to the Little Menomonee River to permit detailed evaluation of a more complex option and to provide an equal basis for comparison.

Alternative 3 has two variations that propose the removal and onsite treatment of highly contaminated sediment and soil. Alternative 3 would treat the visibly contaminated soil and sediment. Because unacceptable residual risk would be present from contaminants in soil and sediment left untreated, in-place containment of these materials would be required. Alternative 3A proposes the use of the slurry bioreactor technology and Alternative 3B proposes land treatment of the sediment and soil. Treated residues would be placed back onsite. An incineration alternative for treating highly contaminated soil and sediment has not been developed since some hazardous substances exceeding health-based limits are contained in place and incineration would be more expensive than biotreatment.

Alternative 4 proposes removal and treatment of contaminated sediment with containment of contaminated soil. Contaminated sediment having carcinogenic PAH concentrations greater than maximum probable background levels would be removed and treated. Soil would be contained in place. River rerouting would not be required but some reconstruction would be necessary. Removal and treatment of sediment without treatment of soil is proposed for three reasons. First, the volume of contaminated sediment is much less than the volume of contaminated soil. Second, sediment removal benefits both human and aquatic life. Third, containment of contaminated soil can be more easily implemented than containment of sediment.

Alternative 5 combines key components of Alternatives 3A and 4. Under this alternative, visibly contaminated soil would also be removed and treated onsite as in Alternative 3A, and all contaminated sediment having carcinogenic PAH concentrations greater than maximum probable background levels would be removed

ALTERNATIVE	GENERAL RESPONSE ACTIONS												
	General		Soil				Sediment				Groundwater		
	No Action	Institution. Controls	Containm't	Removal	Disposal	Treatment	Containm't	Removal	Disposal	Treatment	Removal	Disposal	Treatment
1. No Action	X												
2. Containment of Soil & Sediment, and Treatment of Groundwater		X	X				X				X		X
3. Partial Removal and Treatment of Soil & Sediment, Containment of Soil, Sediment, and Treatment of Groundwater		X	X	X	X	X	X	X	X	X	X		X
4. Treatment of Sediment, Containment of Soil, and Treatment of Groundwater		X	X					X	X	X	X		X
5. Treatment of Sediment, Partial Removal and Treatment of Soil, Containment of Soil, and Treatment of Groundwater		X	X	X	X	X		X	X	X	X		X
6. Treatment of Soil and Sediment				X	X	X		X	X	X			

FIGURE 3-8
ALTERNATIVES DEVELOPMENT MATRIX
MOSS-AMERICAN FS

and treated as in Alternative 4. As in Alternative 4, some river reconstruction would be required but river rerouting would not.

Although land treatment and slurry bioreactor incineration treatment technologies were retained from secondary screening of sediment technologies, Alternatives 4 and 5 include the use of only the slurry bioreactor. No variations of these alternatives using land treatment or incineration were developed because the sediment would be removed in a form more amenable to treatment by a slurry bioreactor, and because high contaminant destruction efficiencies that could be achieved using an incinerator would provide only a marginal decrease in residual risk since some contaminated soil would remain untreated.

Alternative 6 is the required alternative which minimizes the need for long-term management. Under this alternative, all contaminated sediment with carcinogenic PAH concentrations above maximum probable background levels, all soil above the water table having contaminant concentrations exceeding 10^{-6} targets, and all soil below the water table having carcinogenic PAH concentrations greater than 10 mg/kg would be removed and incinerated onsite. Groundwater treatment would not be required (except during excavation) since source material would be removed. A soil cover would be used to sustain vegetation over the treated residues. No alternative was developed under which the 10^{-4} soil would be incinerated because the volumes of 10^{-4} and 10^{-6} soil are nearly the same.

Groundwater treatment was included in all alternatives to allow it to be evaluated in detail. Although it would not appear to be more cost-effective or reliable than discharge to the POTW, the potential exists for the POTW to not permit discharge to the sewer. By including groundwater treatment in all of the detailed alternatives, ARARs and technologies are evaluated in greater detail. Variations of these alternatives with discharge to the POTW were not developed because either groundwater disposal (POTW) or treatment can be pursued without having a significant effect on the other operable unit actions and, thus, on the cost of the alternatives.

ALTERNATIVE 1—NO ACTION

Alternative 1 was evaluated in detail to serve as a baseline for comparison against remedial action alternatives. It assumes that no corrective actions will be taken at the site and that no restrictions will be placed on access or future use of the site. The health endangerment assessment is based on the no action alternative.

ALTERNATIVE 2—CONTAINMENT OF SEDIMENT AND SOIL AND TREATMENT OF GROUNDWATER

Alternative 2 is the required alternative that provides containment with little or no treatment. This alternative would achieve remedial action goals by covering contaminated sediment and soil in place and by collecting and treating contaminated groundwater prior to discharge to the Little Menomonee River. Under Alternative 2, a new river bed would be cut parallel to the existing Little Menomonee River and the old riverbed drained and filled in with soil removed from the new excavation, thereby containing the contaminated sediment in place. Contaminated onsite soil would be contained in place by covering the soil with a vegetated soil cover. Some consolidation of contaminated soil would be performed to move contaminated surface soil out of the flood plain and to reduce the area requiring the soil cover. This alternative includes the removal and treatment of contaminated groundwater. Groundwater would be removed by installing drains parallel to the river and parallel to the former settling ponds. The collected groundwater would then be pumped to an onsite treatment system designed for removal of nonaqueous phase liquids using an oil/water separator and removal of semivolatiles using granular activated carbon.

The treatment system would be designed to achieve the discharge limits established by the Wisconsin DNR (see Appendix F). Pure phase liquids collected would be hauled offsite for treatment, such as in a RCRA incinerator. The activated carbon would periodically be removed and recharged (thermally treated) offsite as well. The proposed extent of the cap and locations of the drains and groundwater treatment system are shown in Figure 3-9.

The time period over which groundwater treatment will be required is difficult to predict because of the heterogeneities in subsurface soil, the relatively low mobility of the contaminants of concern (PAHs), and the low hydraulic conductivities observed on site. Treatment times could potentially last more than 100 years if the highly contaminated areas provide a long-term source of PAHs to the groundwater.

This alternative also includes the removal and offsite incineration of contaminated soil in the Northeast Landfill area. This action would eliminate the need for long-term maintenance of property east of the river. Because this material is considered a K001 waste, its management requires treatment to comply with LDR regulations if removed from the area of contamination.

The proposed river relocation is illustrated in Figure 3-10. The actual river realignment would require a detailed design study to assess the river hydraulics, effects on the wetland environment, and the effects on existing parkland and utilities. Consideration for enhancement of environmental quality and aesthetics could be addressed as well in the preliminary design phase. For the purpose of this FS, however, construction of a channel that complies with the guidance established by the Wisconsin DNR is proposed.

Construction of the new riverbed would proceed from the confluence of the Little Menomonee River upstream to the railroad tracks just south of Brown Deer Road to the confluence with the Little Menomonee River. A discussion of possible construction techniques and approach is presented in Appendix B (see Permanent River Relocation). (Appendix B discusses the bases for the cost estimate and is not for the purpose of directing the course or methods of the design.)

Because hazardous substances would be left in place, a soil admixture would be mixed into visibly contaminated sediment to reduce the hydraulic conductivity of the mix before the sediment is covered with soil. The admixture would reduce the mobility of the contaminants by reducing the hydraulic conductivity and by increasing the sorptive capacity of the mixture. An appropriate admixture would be determined during design phase. A low-permeability backfill would be placed in areas just upgradient of intersections of the old and new riverbeds to reduce preferential migration of contaminants to the new river. Based on the rate of river recharge from groundwater and the relatively low mobility of the contaminants of concern, migration of

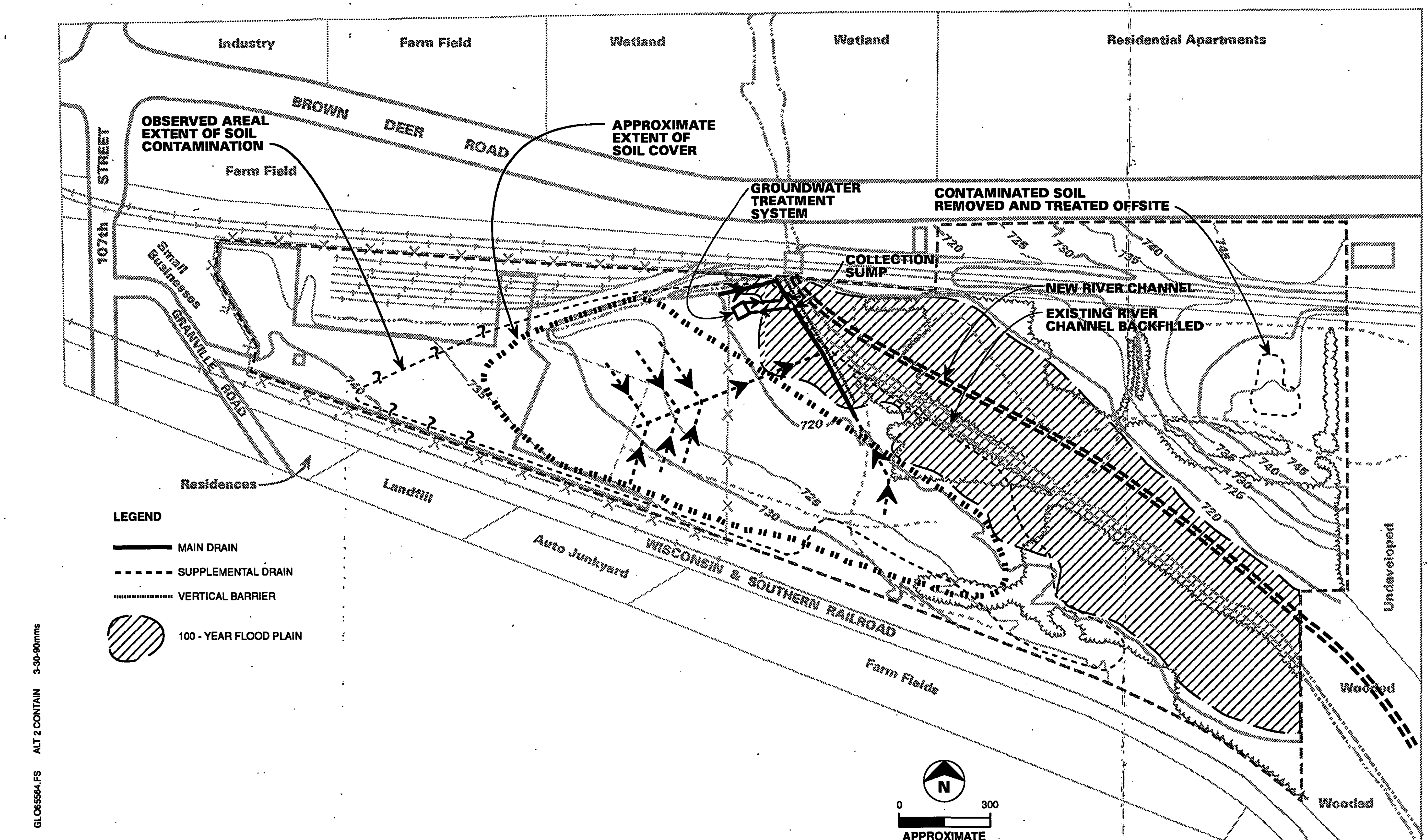

FIGURE 3-9
ALTERNATIVE 2 - CONTAINMENT OF SOIL AND SEDIMENT AND TREATMENT OF GROUNDWATER
MOSS-AMERICAN FS

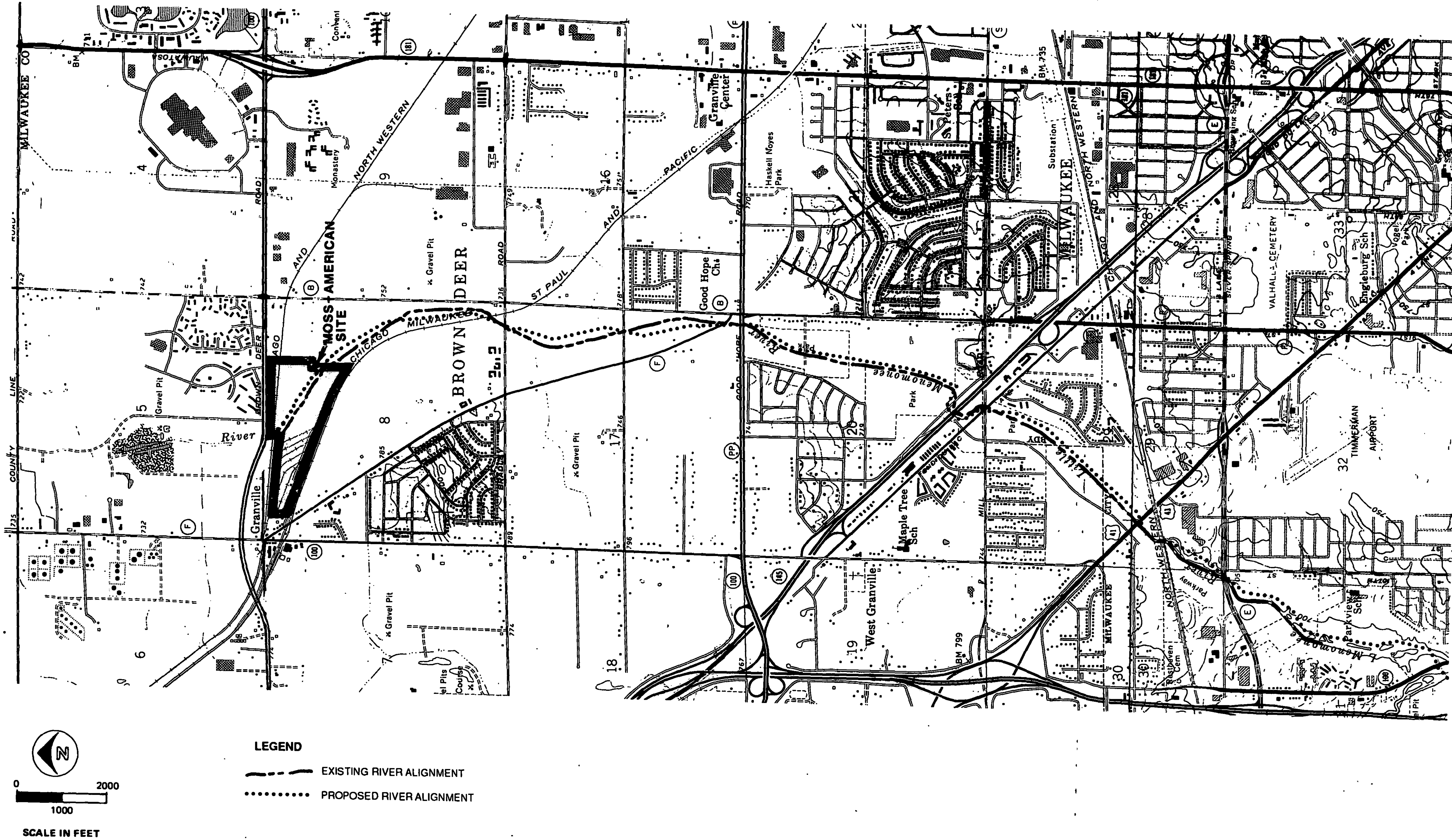

FIGURE 3-10
PERMANENT RIVER RELOCATION
MOSS-AMERICAN FS

contaminants back to the river is expected to occur at a rate slow enough to protect human health and the environment. The potential for contaminant migration from the buried bed to the new channel should be evaluated in the predesign through hydrogeologic characterization and bench-scale testing.

Under Alternative 2 and the following alternatives, groundwater monitoring would be conducted in the area of the contained soil. About four wells would be sampled on a quarterly basis and eight others would be sampled annually.

ALTERNATIVE 3A—PARTIAL REMOVAL AND BIOSLURRY TREATMENT OF CONTAMINATED SEDIMENT AND SOIL, CONTAINMENT OF REMAINING SEDIMENT AND SOIL, AND TREATMENT OF GROUNDWATER

Under Alternative 3A, visibly contaminated soil and sediment would be removed and treated onsite using the slurry bioreactor technology. In addition, the Little Menomonee River would be rerouted and the remaining contaminated sediments contained in place by covering them with the soil excavated from the new channel. Contaminated soil that is not removed would be consolidated and contained in place by covering it with a vegetated 2-foot soil cover.

Alternative 3A proposes the removal and slurry biotreatment of soil and sediment containing traces of creosote. The removal criterion would be visible evidence of creosote in the soil or sediment matrix. A quantitative criterion (1,000 mg/kg extractable organics) could be used in the field to decide instances where visual observation is debated or inconclusive. (Visible evidence of contamination was correlated with extractable organics concentration in the RI. See Appendix C of this FS.) Based on field observations of samples, the volume of contaminated sediment containing visible traces of pure phase is estimated to be 5,200 cubic yards. The volume of visibly contaminated soil to be treated is estimated to be 80,000 cubic yards. Before slurry biotreatment, the soil would be screened to remove oversize debris and then washed in an attrition scrubber to try to reduce the volume of soil requiring slurry biotreatment. Oversize material (e.g., railroad ties, rubble) would not be considered to be derived from hazardous substance releases or disposal practices and therefore would be hauled offsite for disposal in a special waste landfill. The volume of this material (based on very limited information) is estimated to be about 3,000 cubic yards.

Because the water table sometimes rises above the 2- to 4-foot depth where much of contaminant mass in soil is located, some site dewatering may be necessary before or during excavation of contaminated soil. Predesign investigations could determine whether the groundwater collection system would provide sufficient site dewatering for excavation purposes. This FS assumes that some dewatering would be required and that this water would be treated onsite before discharge to the river or POTW.

Figure 3-11 depicts a conceptual treatment process for the soil washing and slurry bioreactors. Contaminated soil and sediment would be placed directly into the treatment train or stockpiled. The stockpiling area would be designed to collect and contain any leachate. Soil washing is assumed to be used predominantly for soil since most of the contaminated sediment consists of fine grain material that would not be expected to "wash" well but would stay in suspension in a slurry bioreactor. Very little of the sediment is expected to be removed in the screw classifier as granular

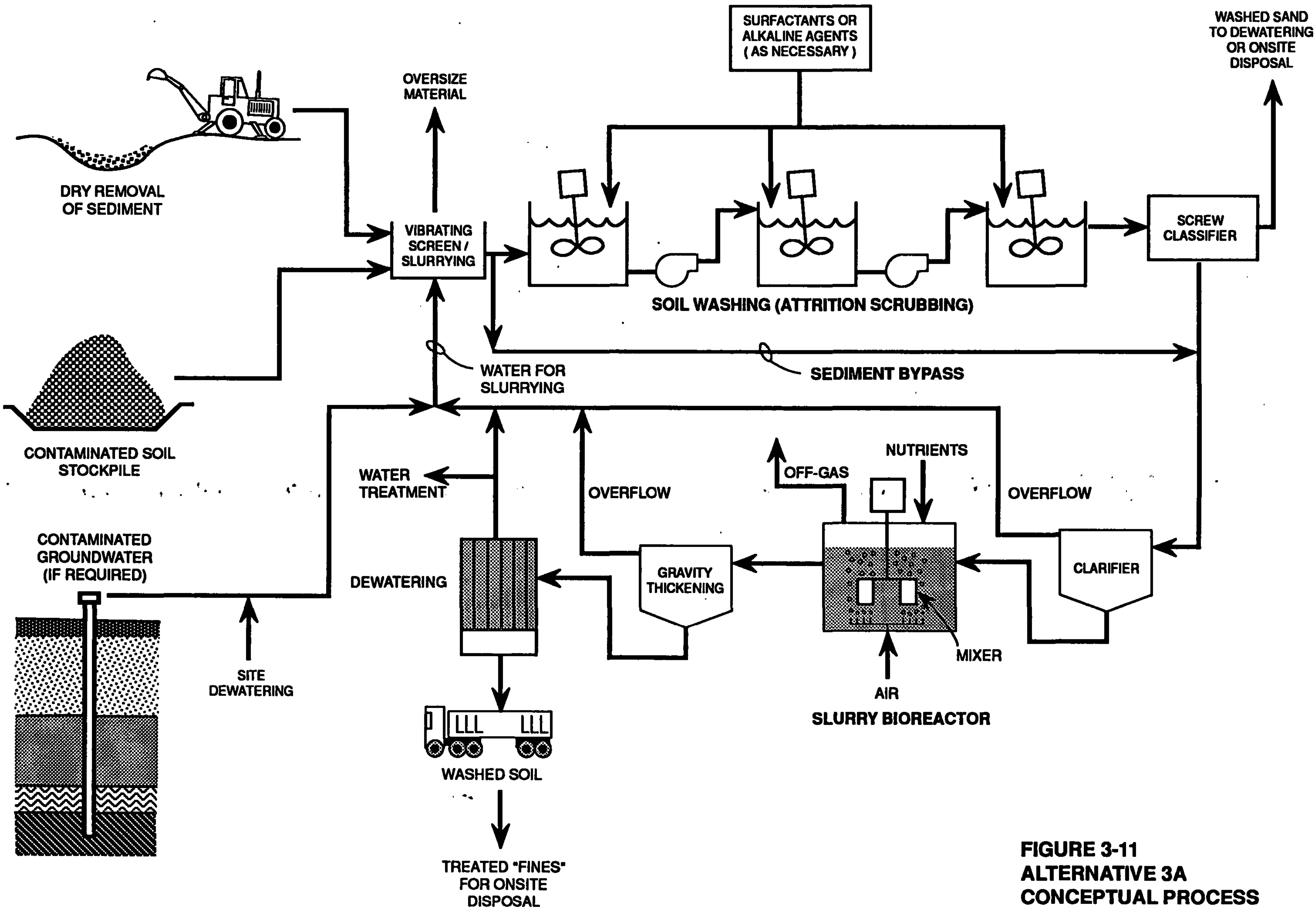

FIGURE 3-11
ALTERNATIVE 3A
CONCEPTUAL PROCESS
FLOW SCHEMATIC
MOSS-AMERICAN FS

material (greater than a 20 mesh screen). About half of the contaminated soil onsite, however, is classified as a coarser granular material. Coarse soil would be washed in the attrition scrubber and then separated from the rest of the material in the screw classifier. The washed soil would be placed back onsite for containment if concentrations of contaminants were reduced below levels established by the treatability variance. The remaining soil fines would be pumped to the slurry bioreactor along with the sediment for treatment. Wood chips or other debris that floats to the surface of the soil washing scrubbers would be managed with the oversize material.

After treatment in the bioreactor, the slurry would be discharged to a settling tank where solids would be separated from the slurry water. The settleable solids would then be pumped from the bottom of the tank and dewatered in a filtering device such as a filter press. Dewatered, treated soil, and sediment having contaminant concentrations below the limits set by the treatability variance (see Appendix A) would be placed onsite, covered with clean soil, and planted with vegetation. Treated soil and sediment that do not achieve the treatment goal would be retreated in the bioreactor until the desired levels are achieved. This alternative is depicted in Figure 3-12.

Under this alternative, the new river channel would be constructed parallel to the existing channel as in Alternative 2. The river would then be diverted to the new channel. Following the diversion of the river, the old channel would be drained and visibly contaminated sediment removed by backhoe or end loader before backfilling the old channel. Visibly contaminated sediment would be loaded into lined trucks for hauling to the original property for treatment.

Because the excavation equipment will have physical limitations in attempting to remove only contaminated sediment (i.e., some sediment that is *not* visibly contaminated will also be removed), the total volume of sediment removed for treatment is assumed to be 25 percent greater than the estimated volume of visually contaminated sediment, or about 6,500 cubic yards.

During the predesign phase, a more refined estimate of the volume of visibly contaminated soil and sediment should be performed through a sampling survey. Field verification methods should also be more clearly defined. Correlations between visual contamination and quantitative criteria to be used for verification should be explored in greater detail.

The contaminants of concern discussed in Chapter 2 are the carcinogenic PAHs. Since the contaminants have existed in the sediment and soil for many years, it is likely that microbial populations have already been acclimated to those contaminants. A slurry bioreactor would be used to optimize the environmental conditions important to their growth. The microbial community would be enhanced by providing sufficient oxygen and such nutrients as nitrogen and phosphorus and by controlling temperatures. By providing close contact between the microbes and the contaminants, treatment of the sediment and soil in a bioreactor results in a faster rate of biodegradation than under natural conditions.

Because contaminated sediment and soil is considered a K001 waste, its treatment must comply with LDRs. At this time, the U.S. EPA is developing treatment standards for debris contaminated with K001 wastes. It is assumed for now that the treatment standard will be derived from a Treatability Variance as outlined in 40 CFR 268.44 and OSWER Directive 9347.3-O6FS, and that this alternative will comply with the LDRs through the variance.

It should be noted that, while high percentage removals of noncarcinogenic PAHs (i.e., greater than 95 percent) have been demonstrated for a variety of biological treatment systems, similar percentage reductions in carcinogenic PAHs typically require significantly greater time. Under this alternative, wastes would be treated until concentrations of constituents restricted in the LDRs are below the limits set by the Treatability Variance, and concentrations of carcinogenic PAHs are below health-based targets (1×10^{-4} excess lifetime cancer risk) for soil (see Chapter 4 for specific treatment levels).

With the exception of soil removed from the Northeast Landfill, residues generated from the slurry bioreactor and contaminated soil exceeding the 10^{-6} target concentrations would be contained onsite by covering it with 2 feet of soil and 6 inches of topsoil. Residues generated from treatment of contaminated soil from the Northeast Landfill (approximately 1,000 cubic yards) would require offsite disposal in a RCRA landfill since land disposal restrictions would be applicable for this material transferred from another "area of contamination." An estimated 130,000 cubic yards of untreated contaminated soil would require containment. Contaminated soil on the original property in the flood plain that is not to be removed for treatment but is above the water table would be moved out of the flood plain before containment. Consolidation of the soil to limit the extent of the cover could be performed if it did not adversely affect future use of the site. The cover would be vegetated to reduce erosion and improve aesthetics. To further reduce the likelihood for exposure to the contained soil and residues, deed restrictions would be placed on the site to prevent its development and the area of contained soil would be fenced. It is estimated Alternative 3A would take 3 to 4 years to implement (excluding design).

Concurrent with the removal of contaminated sediment, the Little Menomonee River would be rerouted and the contaminated sediment not removed would be contained in place as under Alternative 2. Since most of the pure phase contaminants would be removed, admixtures would not be required to reduce the mobility of contained contaminants. Low permeability backfill would be used just upgradient of the intersections of the old and new riverbeds, as in Alternative 2. The potential for contaminant migration from the buried sediment to the new channel should be investigated in greater detail in the predesign through hydrogeologic characterization and bench-scale tests.

As with Alternative 2, contaminated groundwater would be collected and treated before discharge to the Little Menomonee River (unless untreated groundwater can be discharged to the POTW). The groundwater collection system, however, would not include supplemental drains extending toward the process area since the soil in that area would be removed. Because most of the source material would be removed, a groundwater collection and treatment system might not be necessary to protect the Little Menomonee River from an exceedance in NR 105 surface water quality standards. This FS assumes that groundwater collection and treatment would still be required to achieve Wisconsin's groundwater quality enforcement standards listed in NR 140, until it could be demonstrated that collection and treatment would

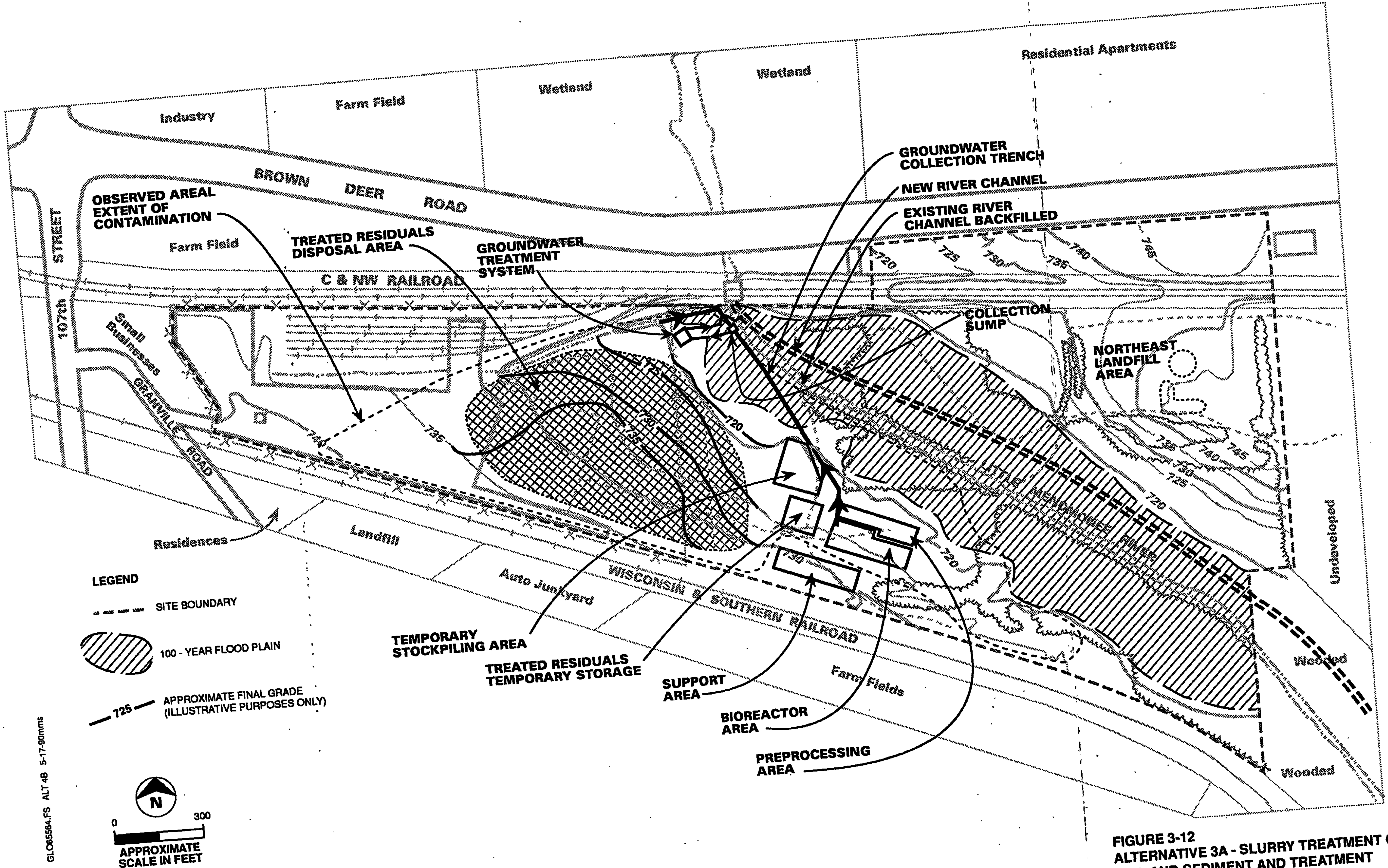

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FIGURE 3-12
ALTERNATIVE 3A - SLURRY TREATMENT OF SOIL AND SEDIMENT AND TREATMENT OF GROUNDWATER
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no longer be necessary. The period of groundwater collection and treatment is estimated to be less than 10 years. During the period of soil treatment some of the contaminated groundwater could be used to slurry soil.

Under Alternative 3A, groundwater would be passed through an oil/water separator to remove nonaqueous phase liquids before treatment with granular activated carbon. If an appreciable amount of free product is collected, it will be transported offsite for thermal treatment. Activated carbon beds would be periodically regenerated offsite. Transportation of this material to the regeneration facility would require the proper manifest documentation for hazardous wastes.

ALTERNATIVE 3B—PARTIAL REMOVAL AND LAND TREATMENT OF SOIL AND SEDIMENT, CONTAINMENT OF REMAINING SOIL AND SEDIMENT, TREATMENT OF GROUNDWATER

Alternative 3B differs from Alternative 3A only in terms of the treatment technology used. Visibly contaminated soil and sediment would be removed and placed on land treatment beds to biologically degrade the contaminants of concern. Quantitative criteria (e.g., extractable organics) would be used to verify visual observations as described for Alternative 3A. An estimated 80,000 cubic yards of soil and 6,500 cubic yards of sediment would be removed and treated over the course of 8 to 15 years. Alternative 3B also includes onsite containment (soil cover) of soil having contaminant concentrations exceeding the 10^{-6} excess lifetime cancer risk target concentrations and includes collection, treatment, and discharge of contaminated groundwater to the Little Menomonee River.

The location proposed for the treatment beds is west of the river, over the old storage and disposal areas. The 10-acre treatment area is illustrated in Figure 3-13. At a soil application thickness of 1 foot, it would be possible to treat about 16,000 cubic yards of soil at a time. Because soil there is already contaminated, a temporary soil stockpiling area would be constructed to accommodate the material while the treatment beds are being constructed. The proposed location of the stockpiling area is shown in Figure 3-13. The stockpiling area would be designed to contain and collect leachate from the pile.

Before stockpiling, soil would be screened to remove oversize objects. This material would be hauled offsite for disposal in a special waste landfill. This would not include the wood chips removed with contaminated soil. This material would be managed along with the contaminated soil in the treatment beds.

The land treatment system is depicted in Figure 3-14. The treatment beds would consist of a layer of clay overlain by a synthetic liner in turn overlain by a sand layer, a primary synthetic liner, and another sand layer. The beds would contain drains for collecting leachate generated during treatment. A 1-foot layer of contaminated soil and dewatered sediment placed on the beds would be periodically tilled using standard agricultural tillers. Tilling would be performed to maintain aerobic conditions in the soil. To provide nutrients for the micro-organisms and to increase the micro-organism population, sewage sludge, manure, or another suitable material could be tilled into the soil. A soil amendment could also be added to improve the physical properties of the clayey soil to make it easier to till and aerate. Leachate collected from the treatment beds would be conveyed to a holding tank where it would either be recycled or discharged to a sanitary sewer.

Average soil carcinogenic PAH concentrations are estimated to be 500 to 600 mg/kg and average sediment carcinogenic PAH concentrations 200 to 400 mg/kg. The length of time needed for biodegradation depends on the cleanup goals and is difficult to predict. It is expected that the 2- and 3-carbon ring PAHs will degrade faster than the 4- and 5-carbon ring PAHs. Results of a treatability test (see Appendix K) indicate that 6 to 12 months of treatment would be required to reduce the concentrations of 4- and 5-carbon ring PAHs by 95 percent. Actual residual PAH concentrations that are achievable and the length of time it would take to achieve them could be better established after pilot-scale testing. This FS report assumes that cold temperatures would limit the treatment season to May through September and that the soil residence time in each cell would be approximately 1 to 1½ treatment seasons. Based on these assumptions it is estimated land treatment would last about 8 to 15 years.

Treated soil and sediment would be placed in a lined storage bed west of the river. The treated soil would be placed there temporarily until all contaminated soil and sediment could be treated. This alternative would comply with LDR treatment requirements through a Treatability Variance. Contaminated soil and sediment would be treated until the residues have concentrations less than health-based limits (10^{-4} excess lifetime cancer risk) for soil, and meet the limits established in the Treatability Variance for restricted constituents (see Chapter 4 for specific treatment levels). Once all the soil and sediment has been treated, the stockpiled (treated) soil and sediment would be placed back on the treatment beds, covered with soil, and planted with vegetation. Leachate from the treatment beds would continue to be collected, treated, and monitored. As with Alternative 3A, treated soil from the Northeast Landfill would be disposed of offsite in a RCRA landfill to comply with LDR regulations.

As part of Alternative 3B, groundwater would be removed, treated, and discharged to the Little Menomonee River as in Alternative 3A. Treatment would continue until it was demonstrated to no longer be required to achieve discharge limits. The estimated treatment period is less than 10 years. The management of residuals generated by groundwater treatment would be the same as for Alternative 3A with the exception that oil sludge and skimmings could be treated in the onsite treatment beds.

ALTERNATIVE 4—SLURRY BIOTREATMENT OF SEDIMENT, CONTAINMENT OF SOIL, AND TREATMENT OF GROUNDWATER

Under Alternative 4, contaminated sediments with concentrations of contaminants exceeding background carcinogenic PAH levels would be removed and transported back to the original site for treatment using a slurry bioreactor. Residues from the slurry bioreactors would be consolidated with contaminated onsite soil and contained under a soil cover. Unlike Alternatives 3A and 3B, the Little Menomonee River would not be rechannelized and no soil other than that in the Northeast Landfill would be treated. Contaminated groundwater would be removed, treated, and discharged to the Little Menomonee River. It is believed that removal of sediment exceeding background carcinogenic PAH levels would eliminate acute exposure risks

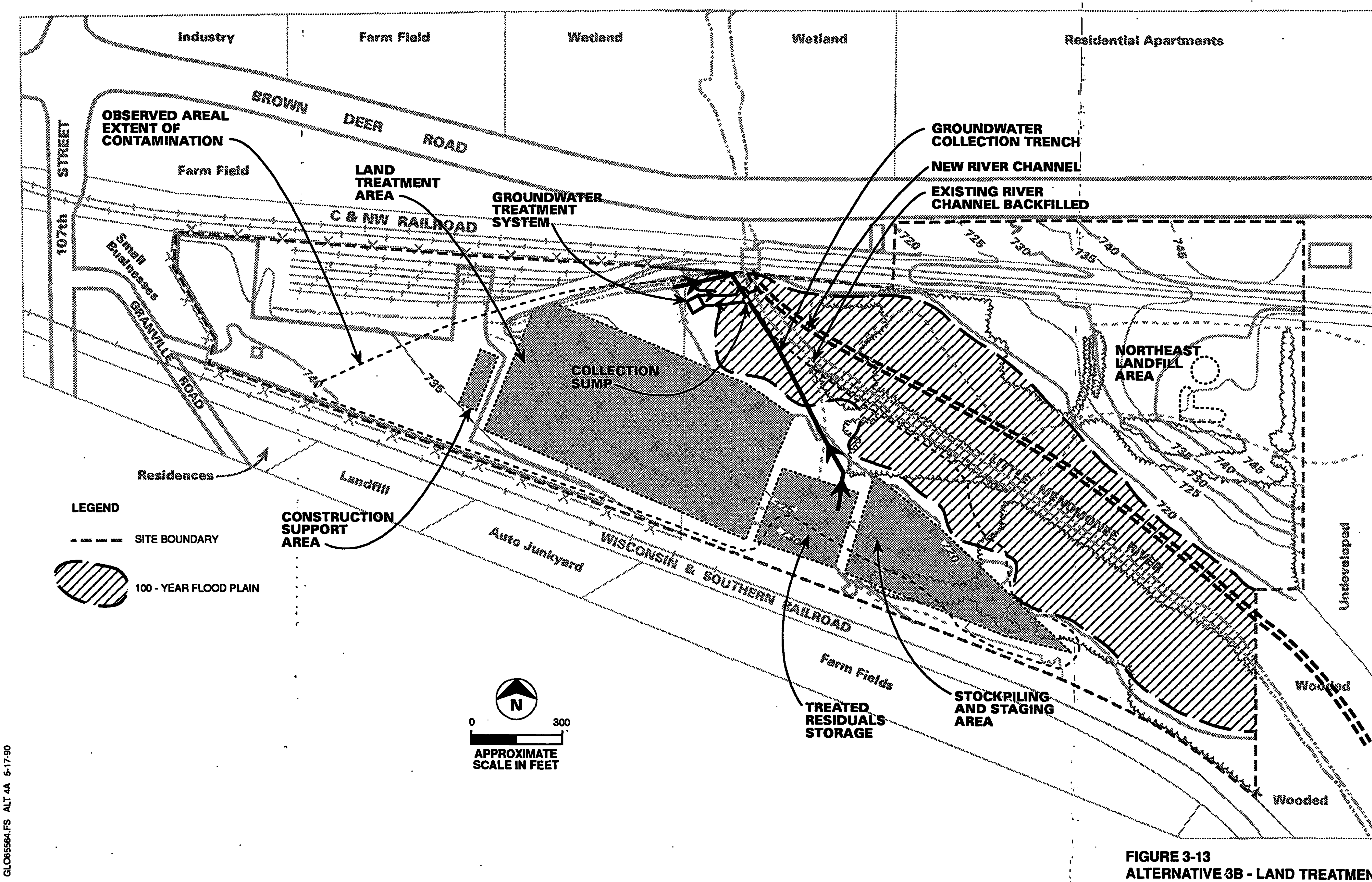

FIGURE 3-13
ALTERNATIVE 3B - LAND TREATMENT OF SOIL AND SEDIMENT AND TREATMENT OF GROUNDWATER
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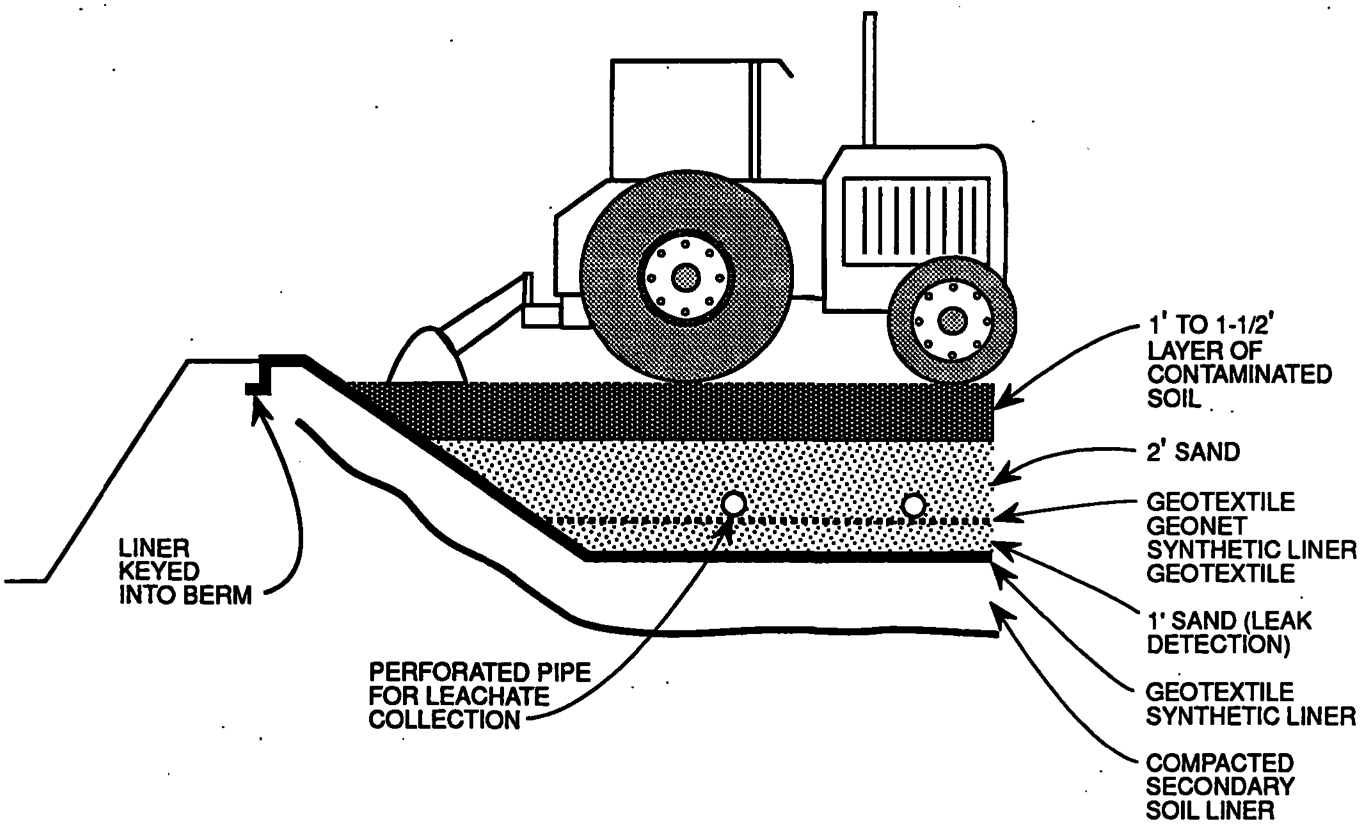

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FIGURE 3-14
CONCEPTUAL CROSS SECTION OF LAND TREATMENT BED
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to humans and significantly reduce chronic effects on aquatic life. The calculated residual risk to humans posed by the remaining contaminants would be less than 10^{-5} excess lifetime cancer risk.

This FS assumes that sediment removal would be performed using dry excavation methods. Sections of the river would be hydraulically isolated (dammed) and drained, and sediment then removed using backhoe or end loader (see Appendix B). This removal method is considered to be more easily implemented and reliable than hydraulic dredging (see Appendix D) and would be more conducive to visual inspection for contaminated sediment. Hydraulic dredging or other means of removal that could provide effective removal with less destruction to the riverbanks, however, could be reconsidered during the predesign phase. Dredging may be more appropriate in areas that are difficult for heavy equipment to access (e.g., under bridges or heavily forested areas).

During the period of removal, the river would be bypassed around the work area (see Appendix B). The dry excavation process would require damming sections of the river, routing the river around the isolated sections, and dewatering them so that the sediment could be removed using a backhoe. The removal equipment would load the sediment into a lined truck for hauling to the original property.

Under Alternative 4, 33,000 cubic yards of sediment would be excavated for treatment. This estimate assumes that about 25 percent more sediment will be removed than is necessary because of the irregular distribution of contaminants and physical limitations of the removal equipment. This alternative would comply with LDR treatment requirements through a Treatability Variance. Contaminated sediment would be treated until the residues have concentrations less than health-based limits (10^{-4} excess lifetime cancer risk) for soil, and meet the limits established in the Treatability Variance for restricted constituents (see Chapter 4 for specific treatment levels).

Because the background level concentrations of carcinogenic PAHs in sediment approaches the detection limits, field verification methods should be developed before the remedial action takes place. In some instances, it may be difficult to quantify concentrations in samples that have residual risks less than 10^{-5}.

Under Alternative 4 the existing river alignment would remain the same. Some reconstruction and modifications to the channel, however, would be necessary to provide stable banks and to mitigate impacts on wetlands. Appendix B describes the requirements of channel reconstruction.

Except for the contaminated soil in the Northeast Landfill area, all contaminated soil would be contained in place beneath a soil cover. As with Alternative 3A, contaminated soil in the Northeast Landfill area would be treated onsite and the residues disposed of offsite in a RCRA landfill.

Contaminated groundwater would be collected and treated as under Alternative 2. Groundwater collection and treatment could last for more than 100 years. A process flow schematic of Alternative 4 is shown in Figure 3-15.

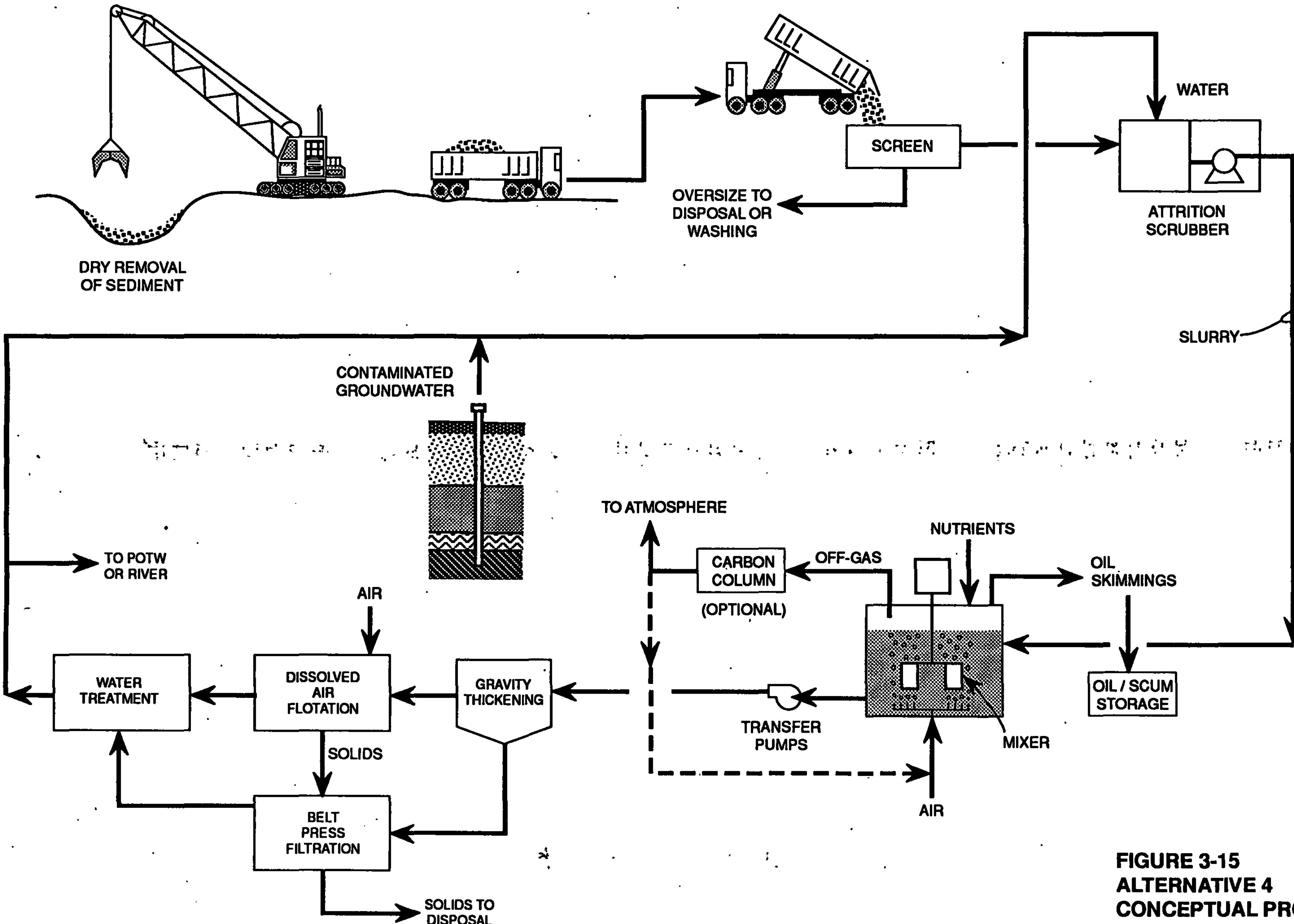

FIGURE 3-15
ALTERNATIVE 4
CONCEPTUAL PROCESS FLOW SCHEMATIC
MOSS-AMERICAN FS

ALTERNATIVE 5—SLURRY BIOTREATMENT OF SOIL AND SEDIMENT, CONTAINMENT OF SOIL, AND TREATMENT OF GROUNDWATER

Alternative 5 combines certain components of Alternatives 3A and 4. Sediment having concentrations of contaminants exceeding background carcinogenic PAH levels and visibly contaminated soil would be removed and treated onsite using soil washing and slurry bioreactor technologies. Treated soil and sediment would be replaced onsite, covered with a soil cover, and planted with vegetation. Oversize material (screenings, rejects, and other bulk objects such as railroad ties) would be disposed offsite in a special waste landfill. Groundwater would be collected, treated, and discharged to the river.

Sediment would be removed using dry excavation methods, and the river would be temporarily bypassed around segments to be excavated. This would be achieved by damming the upstream end and bypassing or pumping water around the area of excavation during the removal (see Appendix B). Removal would be performed using a front end loader or backhoe.

Alternative 5 would treat approximately 33,000 cubic yards of sediment and 80,000 cubic yards of contaminated soil from onsite. This alternative would comply with LDR treatment requirements through a Treatability Variance. The contaminated soil and sediment would be treated until the residues have concentrations less than health-based limits (10^{-4} excess lifetime cancer risk) for soil and meet the limits established in the Treatability Variance for restricted constituents (see Chapter 4 for specific treatment levels). While all the sediment is expected to be excavated in a year, treatment of soil and sediment would continue for about 4 to 6 years. It is not expected that treatment would continue during the winter. As in Alternatives 2 through 4, visibly contaminated soil in the Northeast Landfill area would be treated onsite and the residues disposed of offsite in a RCRA landfill.

As with Alternative 4, the Little Menomonee River would not be rerouted since contaminants in the sediment would be removed to background levels. As part of the river remediation plan, however, some reconstruction of the river would be required to provide stable banks and to mitigate impacts on wetlands. Methods for channel redesign and wetlands mitigation are described in greater detail in Appendix B.

As in Alternative 3A, the estimated 3,000 cubic yards of oversize material removed with contaminated soil would be disposed of offsite in a special waste landfill.

Also under Alternative 5, contaminated groundwater would be collected, treated, and discharged to the Little Menomonee River. The groundwater treatment system and groundwater treatment residuals management would be as described for Alternative 3A. The groundwater treatment period is estimated to be less than 10 years.

ALTERNATIVE 6—INCINERATION OF SOIL AND SEDIMENT

Under Alternative 6, soil exceeding the 10^{-6} excess lifetime cancer risk target concentrations and sediment exceeding background carcinogenic PAH levels would be excavated and incinerated onsite using a mobile incinerator. Soil and sediment would be treated to levels less than the 10^{-6} targets. Treated soil and sediment would be replaced onsite and covered. It is presumed that the material would eventually be delisted. Groundwater collection and treatment would not be required following the removal of source material. Incineration of soil and sediment is proposed as an alternative because it is the most reliable and perhaps the only technology capable of reducing the level of contaminants in treated residuals to levels that would not require subsequent management to prevent significant risk to human health.

Contaminated sediment would be removed by temporarily diverting the river around several 100-foot segments and then excavating the sediment. To decrease the cost of incineration and to increase the processing rate, the sediment would be dewatered before incineration. Blending wet sediment with dry soil to improve handleability was not considered feasible because it could result in some dilution of contaminants in the material fed to the incinerator. An estimated 33,000 cubic yards of sediment would be incinerated.

Soil above the water table with contaminant levels exceeding the 10^{-6} targets and soil below the water table with carcinogenic PAH concentrations greater than 10 mg/kg would also be excavated and incinerated. This would include contaminated soil in the Northeast Landfill area. It is estimated that the maximum depth of excavation will be about 20 feet. About 130,000 cubic yards of soil would be removed. Because the proposed location for the treatment facility is over contaminated soil, the first phase of the project would require temporary relocation (stockpiling) of the soil underneath the location of the treatment system. As in Alternatives 3B and 5, the stockpile area would be designed to collect any leachate or runoff from the area and to direct the leachate to a treatment system. Figure 3-16 illustrates a conceptual layout for the alternative.

Oversize material would be disposed of offsite in a special waste landfill. This would not include wood chips separated from contaminated soil that could be incinerated onsite.

Based on the large volume of contaminated soil and sediment (about 160,000 cubic yards total), it is estimated that onsite remediation activities for soil and sediment would last 4 to 5 years if two incinerators were used. Operation would continue through the winter. Approximately 100,000 cubic yards of treated soil (ash) would be generated from the incineration. Residues generated from the treatment of materials removed from the Northeast Landfill would also be disposed of onsite since all residuals generated from thermal treatment are assumed to be delisted.

Treated soil and sediment would be replaced in the former storage area. Since the concentrations of contaminants in soil and sediment would be reduced to below the 10^{-6} target, long-term management of these residues would not be required for the protection of human health. Therefore, it is assumed that this material would be delisted. The area would be covered with soil and planted with vegetation. Groundwater collection and treatment would not be required beyond the period of remedial action construction to achieve NR 140 standards or to protect surface water quality per NR 105 standards. Since soil at depths of 5 to 10 feet below the water table would be removed, some site dewatering during construction would be required. This water would be treated onsite and discharged to the river or POTW.

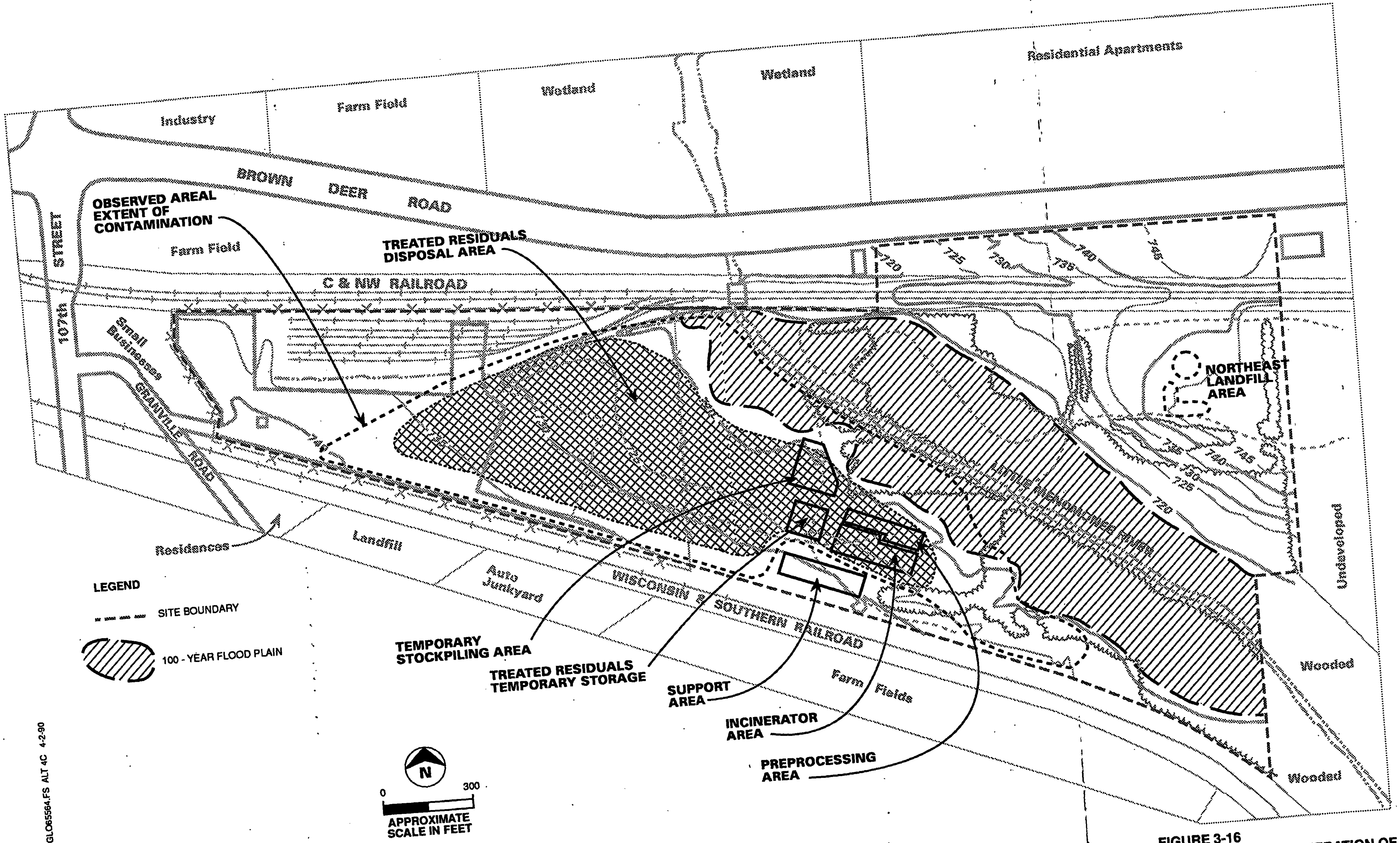

FIGURE 3-16
ALTERNATIVE 6 - INCINERATION OF SOIL AND SEDIMENT AND TREATMENT OF GROUNDWATER
MOSS-AMERICAN FS

Chapter 4
DETAILED EVALUATION OF ALTERNATIVES

Chapter 4
DETAILED EVALUATION OF ALTERNATIVES

In the detailed evaluation, remedial alternatives are evaluated using the seven evaluation criteria described in the U.S. EPA RI/FS Guidance (U.S. EPA 1988). Following this, a comparative analysis of alternatives based on each of the criteria is presented.

EVALUATION CRITERIA

The evaluation criteria are described briefly below and summarized in Table 4-1.

- **Short-term Effectiveness** addresses the impacts an alternative will have during construction and implementation until remedial response objectives are met. Alternatives are evaluated with respect to their effects on human health and the environment during implementation of the remedial action and until protection is achieved.

- **Long-term Effectiveness and Permanence** addresses the results of a remedial action in terms of the risk remaining at the site after response objectives have been met. The focus of this evaluation is the effectiveness of the controls that will be applied to manage risks posed by treatment residues or untreated wastes.

- **Reduction of Toxicity, Mobility, or Volume** addresses the statutory preference for remedial actions that employ treatment technologies as their principal element that permanently and significantly reduce toxicity, mobility, or volume of the hazardous substance. This preference is satisfied when the treatment used reduces the principal threats at the site through destruction of toxic contaminants, irreversible reduction in contaminant mobility, or reduction of total volume of contaminated media.

- **Overall Protection of Human Health and the Environment** provides a check to assess whether an alternative meets the requirement that it protects of human health and the environment. The overall assessment of protection is based on a composite of factors assessed under other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.

- **Implementability** addresses the technical and administrative feasibility of implementing an alternative and the availability of various services and materials required during its implementation.

- **Estimated Cost** estimates the capital cost, annual operation and maintenance cost, and total present worth of each alternative. The cost estimates are considered order-of-magnitude level and are expected to

Table 4-1
FACTORS USED IN DETAILED ANALYSIS OF ALTERNATIVES

SHORT-TERM EFFECTIVENESS

- Protection of community during remedial action
- Protection of workers during remedial action
- Time until objectives and protection are achieved
- Environmental impacts

LONG-TERM EFFECTIVENESS

- Magnitude of residual risk
- Adequacy and reliability of controls

REDUCTION OF TOXICITY, MOBILITY, AND VOLUME

- Treatment process used and materials treated
- Amount of hazardous materials destroyed or treated
- Type and quantity of residue remaining after treatment
- Degree of expected reductions in toxicity, mobility, and volume
- Degree to which treatment is irreversible

IMPLEMENTABILITY

- Technical feasibility
- Availability of services and materials
- Administrative feasibility

ESTIMATED COSTS

- Total capital costs
- Operation and maintenance costs
- Total present worth at 5 percent discount rate

COMPLIANCE WITH ARARs

- Compliance with contaminant-specific, action-specific, and location-specific ARARs

OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

- Elimination, reduction, or control of risks

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be accurate within +50 to -30 percent for the identified scope of the remedial action.

- **Compliance with ARARs** determines how each alternative complies with applicable or relevant and appropriate federal and state requirements as defined in CERCLA Section 121.

The assessments of two additional criteria, state acceptance and community acceptance, are performed as part of the preparation of the proposed plan following receipt of comments from the state and community.

DETAILED EVALUATION OF ALTERNATIVES

The basic components of each alternative are listed in Figure 4-1. Detailed comments regarding each of the seven criteria are presented for each operable unit in an evaluation table (see Table 4-2).

The cost estimates presented in this section consist of total capital cost, which include the costs for construction, allowances, contingencies, permitting, legal advice, and services during construction, as well as the present worth of operating and maintenance (O&M) cost determined over an estimated remediation period at a 5 percent discount rate. Allowances account for known items to be included in the final design but not quantified in the FS cost estimates. Contingencies, such as bid and scope contingencies, account for unforeseeable circumstances. Permitting and legal costs account for legal fees to obtain licenses and construction permits and to negotiate contracts. Cost for services during construction account for administration, inspection, and additional design cost during construction.

Bid and scope contingencies are not necessarily uniform for all alternatives. Bid contingencies account for costs associated with constructing a given project, such as general economic conditions at the time of bidding, adverse weather conditions, strikes by material suppliers, and geotechnical unknowns. Scope contingencies cover changes that invariably occur during final design and implementation. Scope contingencies include provisions for items such as inherent uncertainties in characterizing wastes and regulatory or policy changes that may affect FS assumptions. Scope contingencies also reflect the performance history or complexity of the remedial technology. Neither scope nor bid contingencies provide for significant increases in the volume of material to be managed.

The cost estimates were prepared for guidance in project evaluation and implementation from the information available at the time of the estimate. The cost of the selected alternative will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final project schedule, the firm selected for final engineering design, and other variable factors. The final cost will vary from the estimates presented in this report, so funding needs must be carefully reviewed before making specific financial decisions or establishing final budgets.

ALTERNATIVE 1
- No action

ALTERNATIVE 2
- Reroute river
- Cover contaminated sediment in place
- Cover contaminated soil
- Collect contaminated groundwater, treat, and discharge to river
- Remove contaminated soil in Northeast Landfill and incinerate offsite

ALTERNATIVE 3A
- Remove and treat visibly contaminated sediment and soil in onsite slurry bioreactor
- Reroute river
- Cover contaminated sediment in place
- Cover contaminated soil
- Collect contaminated groundwater, treat, and discharge to river
- Offsite disposal of residues from treatment of Northeast Landfill soil

ALTERNATIVE 3B
- Remove and treat visibly contaminated sediment and soil in onsite land treatment beds
- Reroute river
- Cover contaminated sediment in place
- Cover remaining contaminated soil
- Collect contaminated groundwater, treat, and discharge to river
- Offsite disposal of residues from treatment of Northeast Landfill soil

ALTERNATIVE 4
- Remove and treat sediment having contaminant concentrations greater than background using onsite slurry biorector
- Replace and cover residues onsite with soil
- Cover contaminated soil
- Collect and treat contaminated groundwater and discharge to river
- Offsite disposal of residues from treatment of Northeast Landfill soil

ALTERNATIVE 5
- Remove and treat sediment having contaminant concentrations greater than background and visibly contaminated soil using slurry bioreactor technology
- Replace and cover residues onsite with soil
- Cover remaining contaminated soil
- Collect and treat contaminated groundwater and discharge to river
- Offsite disposal of residues from treatment of Northeast Landfill soil

ALTERNATIVE 6
- Remove and treat sediment having contaminant concentrations greater than background and soil having contaminant concentrations $>10^{-6}$ targets using onsite incineration
- Replace and cover residues onsite with soil

FIGURE 4-1
ALTERNATIVE COMPONENTS
MOSS-AMERICAN FS

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DETAILED EVALUATION OF ALTERNATIVES

EVALUATION CRITERIA	ALTERNATIVE 1 No Action	ALTERNATIVE 2 Containment of Sediment and Soil, Treatment of Groundwater	ALTERNATIVE 3A Partial Removal and Treatment of Contaminated Sediment and soil, Containment of Remaining Sediment and Soil, and Treatment of Groundwater	ALTERNATIVE 3B Partial Removal and Land Treatment of Soil and Sediment, Containment of Remaining Soil and Sediment, Treatment of Groundwater	ALTERNATIVE 4 Treatment of Sediment, Containment of Soil, Treatment of Groundwater	ALTERNATIVE 5 Slurry Biotreatment of Soil and Sediment, Treatment of Groundwater	ALTERNATIVE 6 Incineration of Soil and Sediment
SHORT-TERM EFFECTIVENESS							
• PROTECTION OF COMMUNITY DURING REMEDIAL ACTION	Not applicable.	Since waste would be left in place, chemical hazard to the community during RA would be limited to dust, which could be managed using common construction practices. Some nuisance to community through excavation activities, heavy vehicular traffic on local roads, and construction-related dust and noise. About 2,000 truckloads of material would be brought onsite for soil cover construction. Recreational use of river and surrounding park land would not be allowed during RA.	Nuisance to community would be similar to Alternative 2. In addition to 2,000 truckloads of material for cap construction, 1,600 truckloads of contaminated sediment would be transported from river to site for treatment. Because the primary pollutants onsite are from creosote, the main air exposure route would likely be inhalation of contaminated particles. Monitoring for particulates and volatiles would be performed as part of RA activities to help mitigate impacts. Recreational use of river and surrounding park land would not be allowed during RA.	Effects on community from sediment removal and transport similar to Alternative 3A. Additional concern for emission of contaminated particulates during land treatment of soil. Airborne contaminants might have to be mitigated through special excavation and land treatment techniques. Volatile emissions are not expected to be a concern because of their low concentrations in soil.	Nuisance effects greater than Alternatives 3A and 3B due to increased truck traffic. Temporary inconvenience on local roads because of 5,000 truckloads of excavated sediment and 2,000 truckloads of material for cover. Risks to the community would be less than Alternative 3B because slurry bioreactor would result in fewer emissions of dust than land treatment.	Risks and nuisance to the community would be small because slurry bioreactor could contain and treat potential emissions of volatiles or dust.	Risks and nuisance to the community during sediment and soil removal and transport similar to Alternative 5. Risks from incinerator emissions would be mitigated through stack emissions controls.
• PROTECTION OF WORKERS DURING REMEDIAL ACTION	Not applicable.	Potential for direct contact with hazardous material during consolidation of contaminated soil, installation of groundwater collection drain, and filling of old river bed. Level D work expected, level C possible. Typical risks associated with heavy construction would be present.	Greater potential for worker exposure to hazardous waste than Alternative 2 because of contaminated sediment excavation and transport and excavation of onsite soil. Level D work expected. Risks associated with heavy construction, vehicular traffic, and working around water would also be present. Adhering to a strict health and safety plan would help mitigate these risks.	Risks to workers during sediment excavation and installation of groundwater collection system same as Alternative 3A. Additional potential for chemical exposure during excavation of onsite soil, operation of land treatment system. Level D work expected. Adhering to a stringent health and safety plan would help mitigate risks.	Risks to workers similar to Alternative 3A, except slightly increased since volume treated would be less, resulting in shorter exposure.	Both chemical hazards and normal construction risks are expected to be less than those for Alternative 3B (where workers would be in close contact with contaminated soil and air emissions), but greater than those for Alternative 4 because of the larger volume of soil excavated.	Both chemical hazards and construction risks are expected to be similar to Alternative 5.
• TIME UNTIL REMEDIAL OBJECTIVES ACHIEVED	Not applicable.	Construction of new river channel expected to take 1 to 2 years. Time to prepare design estimated to take 2 years. Restoration of aquatic habitats could take several more years. Collection and treatment of groundwater for more than 100 years may be required to protect surface water quality.	Construction activities would be completed in about 3 to 4 years. Collection and treatment of groundwater expected to be less than 10 years.	Sediment excavation expected to take 1 year. Excavation of onsite soil and treatment of soil and sediment expected to last 8 to 15 years. Collection and treatment of groundwater expected to be less than 10 years.	Construction and treatment would be completed in about 2 years. Collection and treatment of groundwater for more than 100 years may be required to protect surface water quality.	Sediment excavation should take 1 year. Excavation of onsite soil and treatment of soil and sediment should last about 4 to 5 years. Collection and treatment of groundwater expected to be less than 10 years.	Sediment excavation expected to take 1 year. Excavation of onsite soil and treatment of soil and sediment expected to last 4 to 5 years. Protection of groundwater and surface water would be achieved by removing contaminated sediment and soil.
• ENVIRONMENTAL IMPACTS	Not applicable.	Existing aquatic life habitat and much aquatic and terrestrial life in and adjacent to the river would be eliminated during RA and would require restoration.	Existing aquatic life habitat and much aquatic and terrestrial life in and adjacent to the river would be eliminated during RA and would require restoration.	Impacts on river similar to Alternative 3A.	Nearly all of the existing aquatic life habitat would be impaired during RA and would require restoration. Siltation during soil excavation could damage aquatic life habitats if not controlled.	Similar to Alternative 4.	Similar to Alternative 4. Impacts on environment from incinerator emissions could be mitigated through pollution control equipment.
LONG-TERM EFFECTIVENESS							
• MAGNITUDE OF RESIDUAL RISK	Residual risk defined in baseline risk assessment in the RI.	Potential for direct human exposure to contaminated soil or sediment greatly reduced. Potential for ingestion of contaminated groundwater very small due to	The potential for exposure resulting in skin irritation would be eliminated. Residual contamination in the sediments should be relatively immobile	The potential for exposure resulting in skin irritation would be eliminated. Residual contamination in the sediments should be relatively	Residual carcinogenic risk from the sediments would be reduced to less than background. Threat of residual contamina-	Residual carcinogenic risk from the river sediment would be reduced to less than background. Residual risk in the	Residual risk from onsite soil and sediment is expected to be less than 10^{-6}. No residual risk from groundwater.

DETAILED EVALUATION OF ALTERNATIVES

EVALUATION CRITERIA	ALTERNATIVE 1 No Action	ALTERNATIVE 2 Containment of Sediment and Soil, Treatment of Groundwater	ALTERNATIVE 3A Partial Removal and Treatment of Contaminated Sediment and soil, Containment of Remaining Sediment and Soil, and Treatment of Groundwater	ALTERNATIVE 3B Partial Removal and Land Treatment of Soil and Sediment, Containment of Remaining Soil and Sediment, Treatment of Groundwater	ALTERNATIVE 4 Treatment of Sediment, Containment of Soil, Treatment of Groundwater	ALTERNATIVE 5 Slurry Biotreatment of Soil and Sediment, Treatment of Groundwater	ALTERNATIVE 6 Incineration of Soil and Sediment
		the characteristics of the aquifer and the availability of city water. Risk for discharge of contaminated groundwater into the river would be greatly reduced. Contained contaminated soil and sediment pose potential for leaching contaminants to the groundwater, but effects of river dilution should make this incremental risk negligible. Risks associated with future site development are dependent on enforcement of land use restrictions to limit development in areas where contaminants are contained. Monitoring of contaminants downgradient of contaminant areas required. Covering contaminated soil with clean soil cover should greatly reduce potential future exposure to contaminants in soil.	and not affect aquatic life of new river. Potential for direct human contact with contaminated soil or ingestion of contaminated soil would be greatly reduced. Risk associated with future site development would depend on enforcement of use restrictions. Monitoring of residual contaminants in the river would still be required. Potential for discharge of contaminated groundwater into the river would be prevented.	immobile and not affect aquatic life of new river. Potential for direct human contact with contaminated soil or ingestion of contaminated soil would be greatly reduced. Risk associated with future site development would depend on enforcement of use restrictions. Monitoring of residual contaminants in the river would still be required. Potential for discharge of contaminated groundwater into the river would be prevented.	tion to aquatic life of the river should be insignificant. Potential for human contact with or ingestion of contaminated soil onsite would be greatly reduced. Potential for future risks would be greatly diminished should the site be developed or should the cover not be maintained. Potential for discharge of contaminated groundwater into the river would be prevented.	onsite soil would be the same as Alternatives 3A and 3B. Potential would exist for future risks would be greatly diminished should the site be developed or should the cover not be maintained. Potential for the leaching of contaminants into the groundwater prevented.	
• ADEQUACY AND RELIABILITY OF CONTROLS	Not applicable.	The adequacy and reliability of the site cover, cover over the sediment, and groundwater collection system would depend on proper and regular maintenance and the reliability of use restrictions preventing site development. Although potential would exist for migration of contaminants from the buried sediment into the groundwater with eventual discharge into the new river channel, it is not likely that this would cause water quality standards in the river to be exceeded in the future. Long-term monitoring of the groundwater around the site would be required to assess the adequacy of the groundwater collection system. The technologies proposed for cover construction, groundwater collection, and rerouting the river have been well demonstrated.	Long-term reliability and adequacy of the cover and groundwater collection system would be similar to Alternative 2. Sediment and soil removal and treatment would require pilot testing to assess the effectiveness of slurry bioreactors.	Same as Alternative 3A for sediment removal and soil cover. The percent reductions of contaminants achieved through land treatment and the length of time land treatment takes to achieve treatment goals unknown until pilot tests have been completed. Technologies such as soil tilling used in land treatment are well understood and reliable.	Reliability of sediment action should be better than Alternative 3A since less residual contamination would be left in the river. Reliability of soil action would be less than for 3A for the same reason. Monitoring of the site and groundwater would be required.	Same as Alternative 4 for sediment removal and soil cover. The percent of contaminant reductions achieved through a slurry bioreactor and the length of time remediation requires would not be known until pilot tests have been completed. Several pilot tests would be required for these technologies to determine proper methods of soil washing, biodegradation, and soil dewatering. Treatment would likely be quicker and more effective than land treatment.	Same as Alternative 4 for sediment removal. Incineration is a well established technology compared to either land treatment or slurry bioreactors and greater levels of contaminant removal will be achieved (e.g., 99.99% versus 90% to 95%). As with slurry bioreactors, significant effort would go into mobilization and startup.
REDUCTION OF TOXICITY, MOBILITY, AND VOLUME							
• TREATMENT PROCESS USED AND MATERIALS TREATED	None.	Offsite treatment for contaminated soil from the Northeast Landfill. Groundwater treated using an oil-water separator and GAC.	Biological treatment through soil washing and slurry bioreactor for visibly contaminated sediment and soil. Groundwater treated using an oil-water separator and GAC.	Biological treatment through land treatment of visibly contaminated soil and sediment. Groundwater treated using an oil-water separator and GAC.	Biological treatment through use of slurry bioreactors for contaminated sediment having carcinogenic PAH concentrations above background levels. Groundwater treated using an oil-water separator and GAC.	Physical and biological treatments through soil washing, slurry bioreactors, and soil dewatering on soil that is visibly contaminated and sediment that exceeds background. Groundwater treated using an oil-water separator and GAC.	Incineration of contaminated soil above the water table that exceeds a 10^{-6} risk and soil below the water table with carcinogenic PAH concentrations greater than 10 mg/kg, and sediment with carcinogenic PAH levels above background.
• AMOUNT OF HAZARDOUS MATERIALS DESTROYED OR TREATED		None for sediment. About 1,000 cubic yards of soil. About 500,000 gallons of contaminated groundwater collected and treated each year.	Soil washing had been reported to remove more than 90% of the PAHs from sandy soil. Most contaminants separated from soil through washing	Actual mass of contaminants destroyed unknown until pilot tests have been completed. Some studies show degradation of PAHs to	Actual mass of contaminants destroyed unknown until pilot tests have been completed. Some studies shown degrada-	Soil washing had been reported to remove more than 90% of the PAHs from sandy soil. Most contaminants separated from	Incineration routinely destroys more than 99.99% of the contaminant mass.

TABLE 4-2 (Sheet 3 of 5)
DETAILED EVALUATION OF ALTERNATIVES

EVALUATION CRITERIA	ALTERNATIVE 1 No Action	ALTERNATIVE 2 Containment of Sediment and Soil, Treatment of Groundwater	ALTERNATIVE 3A Partial Removal and Treatment of Contaminated Sediment and soil, Containment of Remaining Sediment and Soil, and Treatment of Groundwater	ALTERNATIVE 3B Partial Removal and Land Treatment of Soil and Sediment, Containment of Remaining Soil and Sediment, Treatment of Groundwater	ALTERNATIVE 4 Treatment of Sediment, Containment of Soil, Treatment of Groundwater	ALTERNATIVE 5 Slurry Biotreatment of Soil and Sediment, Treatment of Groundwater	ALTERNATIVE 6 Incineration of Soil and Sediment
			would be biodegraded in slurry bioreactors. Actual mass of contaminants destroyed unknown until pilot tests have been completed. Some studies show degradation of PAHs to below detectable levels. Reductions in carcinogenic PAHs likely to be less than other PAHs and, therefore, reductions in residual risk will be less than reduction in contaminant mass. About 500,000 gallons of contaminated groundwater collected and treated each year.	below detectable levels. Reductions in carcinogenic PAHs likely to be less than other PAHs and, therefore, reductions in residual risk will be less than reduction in contaminant mass. About 500,000 gallons of contaminated groundwater collected and treated each year.	tion of PAHs to below detectable levels. Reductions in carcinogenic PAHs likely to be less than other PAHs and, therefore, reductions in residual risk will be less than reduction in contaminant mass. About 500,000 gallons of contaminated groundwater collected and treated each year.	soil through washing would be biodegraded in slurry bioreactors. The actual amount of contaminant reduction would be determined after pilot tests have been completed. Reductions in carcinogenic PAHs likely to be less than other PAHs and, therefore, reductions in residual risk will be less than reduction in contaminant mass. About 500,000 gallons of contaminated groundwater collected and treated each year.	
• EXPECTED REDUCTIONS IN TOXICITY, MOBILITY, AND VOLUME		None for sediment. Reduces volume of contaminated soil onsite by 1,000 cubic yards. Most organic contaminants in groundwater would be destroyed through onsite treatment and carbon regeneration.	Contaminant reduction goal for an estimated 87,000 cubic yards of visibly contaminated soil and sediment would be set by health-based targets and levels established by treatability variance. Volume of groundwater treated less than Alternative 2 since duration of treatment is less.	Contaminant reduction goals for the 87,000 cubic yards of contaminated soil and sediment would be set by health-based targets and levels established by treatability variance. Volume of groundwater treated less than Alternative 2 since duration of treatment is less.	Contaminant reduction goal for the 33,000 cubic yards of contaminated sediment would be set by health-based targets and levels established by treatability variance. Volume of groundwater treated less than Alternative 2 since duration of treatment is less.	Contaminant reduction goals for the 80,000 cubic yards of contaminated soil and 33,000 cubic yards of contaminated sediment would be set by health-based targets and levels established by treatability variance. Volume of groundwater treated less than Alternative 2 since duration of treatment is less.	Approximately 130,000 cubic yards of soil and 33,000 cubic yards of sediment should be treated to the extent that they no longer pose significant threats to human health or the environment.
• IRREVERSIBILITY OF TREATMENT		Thermal oxidation is not reversible.	Biological treatment is not reversible. Thermal oxidation is not reversible.	Biological treatment is not reversible. Thermal oxidation is not reversible.	Biological treatment is not reversible. Thermal oxidation is not reversible.	Biological treatment is not reversible. Thermal oxidation is not reversible.	Incineration is not reversible.
• TYPE AND QUANTITY OF TREATMENT RESIDUAL		None for sediment and soil. Insignificant additional amounts through groundwater treatment. Some pure phase product may be collected in oil-water separator and recycled or treated at a RCRA facility. Groundwater treatment would require long-term offsite regeneration of activated carbon.	About 87,000 cubic yards of treated sediment and soil with reduced concentrations of PAHs would be contained on site with a soil cover.	About 87,000 cubic yards of treated sediment and soil with reduced levels of PAHs would be contained onsite under a soil cover.	33,000 cubic yards of treated sediment with reduced concentrations of PAHs would be placed under the soil cover. About 1,000 cubic yards of treated soil from Northeast Landfill would be disposed of in RCRA landfill offsite. Groundwater treatment would require long-term offsite regeneration of activated carbon.	About 113,000 cubic yards of treated sediment and soil with reduced levels of PAHs would be placed under the soil cover.	Approximately 100,000 cubic yards of ash and 10 gpm flow of wastewater would be generated during incineration of the soil and sediment. Ash would be replaced onsite. Any residual contaminants on the ash are not expected to pose a health threat. Ash is expected to be considered a RCRA waste and would require delisting.
OVERALL PROTECTION OF HUMAN HEALTH AND ENVIRONMENT	Described by baseline risk assessment in RI report.	Protectiveness would be achieved through containment of wastes onsite and in the old river bed. Only a small reduction in contaminant mass would be achieved. Alternative 2 would offer protectiveness only to the extent the contaminated material remains contained. Probability that contaminants will remain	Protectiveness would be achieved through removing and treating the most highly contaminated sediment and soil, and then containing the remaining sediment and soil in place. Overall protectiveness for onsite soil and groundwater would be the same as Alternative 2. Long-term protectiveness would be	Protectiveness would be achieved through treating onsite the highly contaminated soil and sediment and then containing the remaining sediment and soil in place. Overall protectiveness of the alternative would be similar to Alternative 3A.	Protectiveness would be achieved through covering onsite soil and treating most of the contaminated sediment. Overall protectiveness for onsite soil and groundwater would be the same as Alternative 2. Overall protectiveness for sediment	Protectiveness would be achieved through treating onsite contaminated soil and most contaminated sediment. Overall protectiveness of the alternative would be better than previous alternatives since treatment instead of containment would	Alternative 6 provides the most overall protectiveness since thermal destruction of contaminants in soil and sediment is expected to result in treated material with less than 10^{-6} risk.

TABLE 4-2 (Sheet 4 of 5)
DETAILED EVALUATION OF ALTERNATIVES

EVALUATION CRITERIA	ALTERNATIVE 1 No Action	ALTERNATIVE 2 Containment of Sediment and Soil, Treatment of Groundwater	ALTERNATIVE 3A Partial Removal and Treatment of Contaminated Sediment and soil, Containment of Remaining Sediment and Soil, and Treatment of Groundwater	ALTERNATIVE 3B Partial Removal and Land Treatment of Soil and Sediment, Containment of Remaining Soil and Sediment, Treatment of Groundwater	ALTERNATIVE 4 Treatment of Sediment, Containment of Soil, Treatment of Groundwater	ALTERNATIVE 5 Slurry Biotreatment of Soil and Sediment, Treatment of Groundwater	ALTERNATIVE 6 Incineration of Soil and Sediment
		contained until naturally biodegraded is high since much of the land is Milwaukee County park land. Overall protectiveness for groundwater is good as long as use restrictions apply. Some contaminant migration may occur from buried sediment to groundwater, but the extent is not expected to result in an exceedance of river water quality criteria.	better than Alternative 2 because the most contaminated sediment and soil would be treated and would not pose a threat if future development should occur. Less contaminated sediments would be allowed to degrade naturally.		would be similar to Alternative 2, 3A, or 3B.	be used to prevent exposure. Less reliance is put on cap or cover to prevent exposure. Residual risk would similar to Alternatives 3A and 3B and less than Alternative 4.	
IMPLEMENTABILITY • TECHNICAL FEASIBILITY	Not applicable.	The technical feasibility of cover construction, and treatment and groundwater extraction is well understood.	Same as Alternative 2 for cover construction, and groundwater extraction and treatment. Slurry bioreactors have been successfully implemented at other wood preserving sites. Some optimizing of process rates and conditions would be required. Technology is flexible for changes in volumes of contaminated material. Would not treat wood chips separated from contaminated soil or pure phase collected by groundwater extraction.	Same as Alternative 3A for cover construction, sediment removal, and groundwater extraction and treatment. Land treatment has been successfully applied to other wood preserving sites. Some optimization of process requirements will be required during the RA. Because of the limited area on site for land treatment, additional amounts of contaminated soil would probably result in longer remediation periods. Has advantage of being able to treat wood chips separated from contaminated soil and pure phase collected by groundwater extraction.	Same as Alternative 3A for cover construction, sediment removal, and groundwater extraction and treatment. Slurry bioreactors have been successfully implemented at other wood preserving sites. Some optimizing of process rates and conditions would be required. Technology is flexible for changes in volumes of contaminated material. Vendor and consulting services for slurry bioreactors are available but not widespread.	Same as Alternative 3A for cover construction, sediment removal, and groundwater extraction and treatment. Slurry bioreactors have been successfully implemented at other wood preserving sites. Some optimizing of process rates and conditions would be required. Technology is flexible for changes in volumes of contaminated material. Vendor and consulting services for slurry bioreactors are available but not widespread.	Incineration is proven as a technology and well demonstrated for destruction efficiencies of PAHs. Test burns would be required to demonstrate effectiveness. Technical feasibility for rest of RA similar to Alternatives 4 and 5.
• AVAILABILITY OF SERVICES AND MATERIALS	Not applicable.	Most services and materials would be locally available.	Vendor and consulting services for slurry bioreactors are available but not widespread. Materials for slurry bioreactors mostly available locally. Availability of materials and services for rest of RA same as Alternative 2.	Materials and services for land treatment are available locally. Materials and services for rest of RA area same as Alternative 2.	Materials for slurry bioreactors mostly available locally. Availability of materials and services for rest of RA same as Alternative 2.	Materials for slurry bioreactors mostly available locally. Availability of materials and services for rest of RA same as Alternative 2.	Numerous mobile incinerator vendors are available. Availability of services and materials for the rest of the RA is similar to Alternative 2.
• ADMINISTRATIVE FEASIBILITY		Monitoring of the groundwater would be required by state or local agencies. Easements and permits would likely be required for work in the river and for restoration of the wetlands. Sediment removal actions would have to be coordinated with several agencies. Discharge of treated groundwater to the Little Menomonee River would require NPDES permit.	No administrative problems specific to slurry bioreactors anticipated. Administrative feasibility for the rest of RA is the same as for Alternative 2.	No administrative problems specific to land treatment are anticipated. Administrative problems for the rest of the RA are similar to those for Alternative 2.	No administrative problems specific to slurry bioreactors anticipated. Administrative feasibility for the rest of the RA is the same as for Alternative 2.	No administrative problems specific to slurry bioreactors anticipated. Administrative feasibility of the rest of the RA is the same as for Alternative 2.	A permit would not be required for the incinerator, but procedures for trial burns would have to be followed. Administrative feasibility of the rest of the RA is similar to that of Alternative 2. Delisting of ash may be difficult. Groundwater discharge permit may be required for water collected and treated during site dewatering during construction.
COMPLIANCE WITH ARARS	Would not comply.	Would be in compliance with ARARs. State ARARs for final cover would be waived. Northeast Landfill incinerated offsite to comply with LDRs.	Would be in compliance with ARARs. State ARARs for final cover would be waived. Treatability variance would be obtained to comply with LDRs.	Would be in compliance with ARARs. State ARARs for final cover would be waived. Treatability variance would be obtained to comply with LDRs.	Would be in compliance with ARARs. State ARARs for final cover would be waived. Treatability variance would be obtained to comply with LDRs.	Would be in compliance with ARARs. State ARARs for final cover would be waived. Treatability variance would be obtained to comply with LDRs.	Expected to be in compliance with ARARs. Delisting of ash required.

DETAILED EVALUATION OF ALTERNATIVES

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ESTIMATED COST							
• CAPITAL COST DURING OPERATION	$0	$15,000,000	$25,000,000	$22,000,000	$17,000,000	$23,000,000	$89,000,000
• ANNUAL O&M DURING OPERATION	$0	$130,000	$130,000	$500,000	$130,000	$130,000	$18,000
• PRESENT WORTH	$0	$18,000,000 (5%, 100 years)	$26,000,000 (5%, 10 years)	$26,000,000 (5%, 10 years)	$20,000,000 (5%, 100 years)	$24,000,000 (5%, 10 years)	$89,000,000 (5%, 30 years)

COMPARATIVE ANALYSIS OF ALTERNATIVES

SHORT-TERM EFFECTIVENESS

Because they involve the handling of contaminated sediment and soil, Alternatives 3A through 6 could have a slight, temporary increase in risk to the community because of the potential for inhalation of windblown soil, or direct contact with contaminated sediment transported offsite. Because it includes the excavation and placement of contaminated soil in the flood plain, the amount of contaminated soil moved in Alternative 2 is less, but not significantly less, than the other alternatives. The increased risk could be mitigated through the use of dust suppressants, limiting earthmoving and grading activities on windy days, and downwind monitoring during construction activities. Alternative 6 could result in a temporary decrease in air quality in the community because of incinerator emissions, although the emissions would be in compliance with RCRA and Wisconsin DNR standards. The increased risk from emissions is not considered significant since ARARs would limit the possible emissions from the facility. Alternative 2 would present the least nuisance to the surrounding community because it does not require the hauling of removed sediment through local access roads. Only a small volume of soil from the Northeast Landfill would be hauled offsite. Alternatives 3B and 6 are expected to be the greatest nuisance, since land treatment (Alternative 3B) could result in odors downwind of the site, and the incinerator (Alternative 6) could result in a steam plume and potential odors. Alternatives 4 through 6 would result in about the same amount of truck traffic on city roads.

Because worker exposure from direct contact and dust inhalation is a function of the amount of contaminated sediment and soil removed, potential for worker exposure during excavation would be similar for Alternatives 3A through 6 but could be the greatest for Alternative 3B, since workers would till the contaminated soil periodically for several years. The difference between alternatives could be insignificant with proper health and safety precautions.

Short-term environmental impacts would be significant for all alternatives, since all would destroy existing aquatic habitats (for long-term improvement). Alternatives 2, 3A, and 3B would cause the most damage because the entire 5-mile length of stream habitat would be destroyed. Restoration of these habitats is anticipated to take longer than habitat restoration for Alternatives 4 through 6. Adverse impacts on aquatic life might not be limited to the Little Menomonee River if resuspension of sediments and erosion are not controlled and lead to migration of contaminants into the Menomonee River.

The time required to achieve remedial action goals for soil and sediment will be the least for Alternative 2. This alternative is estimated to require 1 to 2 years of remedial action construction. Design time would be the shortest for Alternative 2 because no pilot testing would be required and construction techniques would be straightforward. Design and predesign activities for Alternatives 3A and 4 would require 1 or 2 additional years. Alternatives 3B, 5, and 6 would take the longest to achieve remedial action goals—perhaps 5 years for Alternatives 5 and 6 and 15 years for Alternative 3B. Considering the time required to perform the RD and construct the RA, the time period to achieve the remedial actions for soil and sediment are not significantly different except for Alternative 3B. The time required to achieve the groundwater remedial action goals could be more than 100 years for Alternatives 2 and 4, but could be less than several years for all other alternatives. Remedial action goals for groundwater would be achieved during the construction period of Alternative 6. Protection of the river from contaminated groundwater, however, could be achieved in the first several years of the construction period for all alternatives except Alternatives 1 and 2.

In summary, none of the alternatives provides significantly better short-term effectiveness than other alternatives. Each will have adverse short-term environmental impact, and require several years to achieve remedial action goals for soil and sediment.

LONG-TERM EFFECTIVENESS

Alternatives 2 through 6 provide decreasing levels of residual risk. Although Alternatives 2, 3A, and 3B do not require removal of all the contaminated sediment, the residual risk from buried sediment is less than for buried onsite soil. The potential for skin irritation from direct contact with sediment should be eliminated after completing any alternative. Long-term residual risk is greatest for Alternative 2 since no treatment is performed. If institutional controls are effective, residual risk should be negligible in all alternatives except 1, 3A, and 3B. If contaminant movement from buried sediments is retarded to the extent anticipated, then the residual risk for Alternatives 3A and 3B should also be negligible.

Alternatives 3A through 6 reduce residual risk from exposure to sediment and soil through treatment. In addition, residential developments can be prevented by imposing deed restrictions in Alternatives 3A through 5. Deed restrictions would not be required for Alternative 6.

While all alternatives significantly reduce residual risks, only Alternative 6 reduces residual risk to less than 1×10^{-6}. Because it is the only alternative that achieves clean closure and does not rely on institutional controls, the long-term reliability of Alternative 6 would be greater than any other alternative. Because it does not reduce the volume of contaminants (except for the Northeast Landfill), Alternative 2 provides the least reliable alternative over the long-term. Alternative 3B may be slightly more reliable than Alternatives 3A, 4, and 5 because it provides a lined bed underneath treated soil and sediment.

Greater degrees of reliability are offered by the more treatment-intensive alternatives, since institutional controls are relied upon to a lesser extent. Long-term effectiveness for Alternatives 2 through 5 depend upon institutional controls to remain effective over the long-term. If institutional controls were to be weakened by future legal or regulatory changes or disregarded by future property owners and the site developed for residential use, the risk to human health (as estimated in the risk assessment) would be significant. However, several factors could help to diminish this estimated risk:

- Natural degradation of carcinogenic PAHs will likely occur slowly over an extended period of time, and result in lower residual concentrations and risks.

- Site development could result in mixing of uncontaminated soil used in the closure cover with underlying soil, resulting in lower contaminant concentrations than those used in the risk assessment.

- Closure cover soil would likely be reused on the new surface to promote vegetative growth, thus limiting the exposure of residents to contaminated soil.

Failure of the cover, should it occur, is not likely to cause increased risks to public health and the environment because contaminant migration to groundwater would be contained by the groundwater collection system, and because portions of the site where soil is covered would be fenced off. All the alternatives except Alternatives 1 (No Action) and 6 would include groundwater collection, although only Alternatives 2 and 4 could require it for more than 100 years.

In summary, all alternatives are effective over the long-term by treating or containing wastes and monitoring them. Alternative 2 provides the least reliable alternative because it does not reduce the toxicity or volume of contaminants, and depends on monitoring of potential contaminant movement and enforcing institutional controls. Alternative 6 provides the most effective alternative over the long-term since nearly all of the contaminant mass would be destroyed. Alternatives 3A through 5 are similar in terms of reliability and effectiveness.

USE OF TREATMENT IN THE REDUCTION OF TOXICITY, MOBILITY, AND VOLUME

All alternatives achieve some level of reduction of toxicity or mobility of contaminants. Alternative 2 reduces the toxicity of a small volume of soil from the Northeast Landfill through offsite incineration. (All alternatives include treatment of the soil from the Northeast Landfill.) Mobility of contaminants in buried sediment is also reduced through in situ addition of low permeability soil. Alternatives 3A and 3B will achieve greater reductions in the toxicity and volume of contaminated media than Alternative 4 since no soil is treated in Alternative 4. Alternatives 3A and 3B treat less material than Alternatives 5 and 6, but treat the more heavily-contaminated sediment and soil and therefore treat a significant fraction of the contaminant mass. Compared to other alternatives, Alternative 6 achieves the greatest level of reduction and could achieve the lowest levels of residual contamination. It is anticipated that more than 99.99 percent of the contaminant mass in the treated material would be destroyed under Alternative 6. Alternatives 3A and 3B would achieve lesser, but significant reductions in the toxicity of contaminants of concern. Reductions as high as 95 percent for total PAHs could be achieved in the slurry bioreactor, and in the land treatment facility, depending on length of treatment and initial concentration. Reductions in carcinogenic PAHS are expected to be less than for total PAHs, but 90 percent reductions might still be achievable given sufficient time. While significant reductions are achieved in Alternatives 3A through 5, they will not reduce residual risk levels to less than 1×10^{-6}. For all alternatives that include onsite biological treatment, treatment will continue until the levels of hazardous substances have been reduced to the levels defined in the Treatability Variance, or to below the 1×10^{-4} risk-based target concentrations.

Groundwater treatment proposed under Alternatives 2 through 5 will remove most toxic organic compounds from groundwater through adsorption and destruction of these contaminants during subsequent thermal treatment of the carbon used for adsorption in the regeneration phase.

IMPLEMENTABILITY

Implementation will be difficult for all alternatives. The most difficult implementation aspect relates to work on the river, which is included in all alternatives. Because its construction would be straightforward, Alternative 2 is probably the easiest to implement. This alternative could be complicated if soil borings from the proposed river location reveal contaminated soil there. Review of early topographic maps suggests the old river alignment and buried sediment should not affect this alternative. The implementability of other alternatives is similar. All alternatives use demonstrated technologies that are available.

While the technologies proposed for remediation are innovative, they should have been used enough times by the time of implementation to not be overly difficult to design or implement. Construction work on the river is expected to be a difficult aspect of remediation because it involves excavating a new channel, trucking contaminated sediments to the treatment site (for Alternatives 3A through 6), and replanting and rebuilding wetlands. Work in the river area will require careful design and planning as well as coordination with numerous agencies, including Milwaukee County, the Milwaukee Metropolitan Sewerage District, the City of Milwaukee, and the WDNR. This difficulty exists for all alternatives except the No Action Alternative, and to a lesser extent for Alternative 2 since no sediments would be removed.

Bids for Alternative 2 should be more consistent than for the other alternatives, since the quantities of soil to be moved and the construction methods to perform the remedial action could be more accurately defined.

OVERALL PROTECTIVENESS OF HUMAN HEALTH AND THE ENVIRONMENT

With the exception of Alternative 1, all alternatives achieve the remedial action goals established for protection of public health and the environment. The technologies employed for treatment alternatives are considered reliable, and would be pilot- or field-tested to demonstrate their effectiveness.

Alternative 2 adequately protects human health and the environment, but is considered the least reliable since all the contaminant mass is contained in place. Contaminants in sediment could migrate back to the new river, and contaminants in contained soil could be exposed in the future if deed restrictions are not in effect. It is likely, however, that contaminants in soil will remain contained until naturally biodegraded because much of the land is Milwaukee County parkland and deed restrictions would help to prevent development. Based upon observations at the site and limited research information, the potential for contaminant migration from buried sediment is believed to be sufficiently small as to have a negligible impact on the new river bed. The uncertainty in the protectiveness provided by Alternative 2 could be reduced by gaining a better understanding of hydrogeology near the river and by conducting leachability tests in the laboratory on contaminated sediment, mixtures of contaminated sediment, and admixtures proposed for reducing in situ hydraulic conductivity.

All alternatives should adequately protect aquatic life and should eliminate concerns regarding acute exposure risk to humans. Alternative 6 provides increased reliability of protectiveness in the short-term by destroying a greater mass of contaminants.

COMPLIANCE WITH ARARS

All alternatives except the No Action Alternative would comply with ARARs. The No Action alternative would not comply with several ARARs, such as state groundwater quality standards.

Several of the more significant ARARs pertain to federal and state ARARs for closure of solid and hazardous waste treatment or disposal units and to federal ARARs for treatment of RCRA hazardous waste. Because soil and sediment is left in place under Alternative 2, federal ARARs for closure are not applicable. The U.S. EPA has determined that a RCRA-type closure would not be relevant and appropriate since the nature of the waste, its distribution, and the principal route of exposure indicate that a closure according to RCRA would provide no significant benefit over a soil cover. Several state ARARs for closure and final cover would not be met using the soil cover proposed under Alternative 2. This FS assumes that the state requirements would be waived based upon an Equivalent Standard of Performance waiver. The soil cover is considered equally as effective in limiting soil ingestion and would permit some degree of flushing (to the groundwater collection system) and biodegradation of hazardous substances in the vadose zone.

Similarly, the waiver would be applied for Alternatives 3A, 3B, 4, and 5 to have these alternatives comply with state ARARs for final covers. Federal ARARs for closure covers could become applicable, however, if hazardous substances are "disposed of" as part of the CERCLA action. Since the Northeast Landfill is considered a separate area of contamination, the removal of the soil would trigger RCRA, including treatment and disposal requirements provided in the Land Disposal Restrictions (LDRs). Under Alternatives 2 through 5, residues generated from treatment of the Northeast Landfill soil would be disposed of in an offsite RCRA landfill to comply with the LDRs.

RCRA closure ARARs could be triggered if the hazardous substances are managed in "intervening units," even if such units are within the area of contamination. The U.S. EPA has clarified this issue as it pertains to Alternatives 3A through 5. The U.S. EPA has determined that when CERCLA soil and debris are treated according to the standards of the Treatability Variance, the residue from that treatment can be replaced into the area of contamination in a unit that does not meet minimum technology requirements (MTRs), e.g., requiring a multi-layer cap for RCRA landfill closures. Since the MTRs apply only to new units, replacement units, and lateral expansions of existing landfills and surface impoundments, an existing landfill or area of contamination would not be subject to MTRs even when hazardous waste is replaced within the area of contamination as part of a CERCLA action.

The Land Disposal Restrictions (LDRs) are ARARs for six of the seven remedial action alternatives being considered. Alternative 1 does not include disposal and therefore would not be subject to LDRs. Alternative 2 would comply with LDRs by having the Northeast Landfill treated and disposed of offsite according to the standards established in the LDRs. Alternatives 3A, 3B, 4, and 5 would comply with the LDRs' treatment standards through a Treatability Variance. Alternative 6 would comply with the treatment standards set in the LDRs.

Concentrations of the following contaminants are restricted by the LDRs for K001 wastes: napthalene, pentachlorophenol, phenanthrene, pyrene, toluene, xylenes, and lead. Table 4-3 lists the treatment level ranges attained by biotreatment technologies proposed in Alternatives 3A, 3B, 4, and 5 for each of these restricted constituents. Table 4-3 also lists the primary contaminants of concern in soil and sediment as identified in the baseline risk assessment. For the restricted organic constituents, reductions in concentrations of 95 percent would be achieved if initial concentrations exceeded the threshold concentration (400 or 100 mg/kg). Reductions to 20 mg/kg or 10 mg/kg (depending upon the constituent) would be achieved if initial concentrations were less than the threshold. For lead, the concentration in the extract (TCLP) will be reduced to below 3 mg/kg.

ESTIMATED COST

The estimated present cost of the alternatives ranges from $0 for No Action, $18 million for Alternative 4, and up to $89 million for Alternative 6.

The No Action Alternative has no cost but would provide no protection of human health and the environment. Alternative 2 has the least capital cost of the alternatives that propose remedial action, and would provide protection of human health and the environment. This alternative, however, is estimated to incur the highest operation and maintenance cost, since very long-term management of groundwater could be required. The potential for contaminant migration from the buried sediments and the need for long-term groundwater management would be significantly reduced or eliminated under Alternatives 3A and 3B for a moderate increase in capital cost. Alternatives 4 and 5 are estimated to have costs similar to Alternatives 3A and 3B but would not provide as much protection to human health and environment. Alternative 6 provides marginal improvement in protection of human health and the environment for significantly greater cost.

REFERENCES

U.S. Environmental Protection Agency. *Interim Final Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA.* OSWER Directive 9355.3-01. Washington, DC. 1988.

GLT595/076.51

Table 4-3
TREATMENT LEVELS TO BE OBTAINED
TO COMPLY WITH LDR TREATBILITY VARIANCE

Contaminant	Reference Concentration (mg/Kg)	1x10-4 Excess Lifetime Cancer Risk Target (mg/Kg)	Observed Concentration Range (mg/Kg)	Threshold Concentration (mg/Kg)	Concentration Range To Be Achieved (mg/Kg)
LDR CONSTITUENTS FOR K001					
Pentachlorophenol	2250	NA	BDL	400 (TWA)	95 percent reduction
Napthalene	30000	"	0.019 - 2600	400 (TWA)	or 20 mg/Kg (TWA)
Phenanthrene	--	"	0.06 - 4600	400 (TWA)	"
Pyrene	225	"	0.016 - 2000	400 (TWA)	"
Toluene	22500	"	0.002 - 2.0	100 (TWA)	90 precent reduction
Xylene	150000	"	0.002 - 17	100 (TWA)	or 10 mg/Kg
Lead	--	"	2.3 - 519 (TWA)	300 (TCLP)	3 mg/Kg (TCLP)
CONTAMINANTS OF CONCERN					
2,4-dinitrophenol			620	NA	NA
Cadmium	37.5		1.6 - 76	"	NA
Chrysene	NA	6.1	0.038 - 510	"	90 percent reduction
Benzo(a)anthracene	"	6.1	0.069 - 420	"	or sum of carcinogenic
Benzo(a)pyrene	"	6.1	0.040 - 230	"	PAHS < 6.1 mg/Kg
Benzo(b)fluoranthene	"	6.1	0.010 - 270	"	"
Benzo(k)fluoranthene	"	6.1	0.014- 250	"	"
Benzo(ghi)perlyene	"	6.1	0.044 - 77	"	"
Dibenz(ah)anthracene	"	6.1	0.051 - 24	"	"
Ideno(123cd)pyrene	"	6.1	0.029 - 78	"	"
Sum of carcinogenic PAHs		6.1	<0.33 - 1900		"

NOTES
1. Concentration ranges defined in "Superfund LDR Guidance, #6A"; OWSER 9347,3-06FS.
2. Only the concentration range for LDR constituents for K001 need to be attained to comply with LDRs.
3. Contaminants of concern include only the primary contaminants of concern identified in the baseline risk assessment.
4. Observed concentration range for soil and sediment.
5. No threshold concentrations developed for toluene and xylene. Ranges based on "Other Polar Organics" category.
6. Treatability Variance applies to Alternatives 3A, 3B, 4, and 5.

Appendix A
EVALUATION OF ARARS

Appendix A
EVALUATION OF ARARs

Remedial actions must attain the applicable or relevant and appropriate requirements (ARARs) established by the U.S. EPA and the Wisconsin DNR for the site. Remedial actions must also take into account the "to be considered" criteria or guidelines if the ARARs do not address a particular situation. This appendix lists ARARs for the site and evaluates whether each of the alternatives proposed in Chapter 3 achieves the ARARs. The identification of ARARs in this FS is based upon an evaluation conducted by the U.S. EPA and the Wisconsin DNR following their review of detailed descriptions of each alternative in the draft FS report.

Contributors to the ARARs evaluation include:

- Wisconsin DNR—Bureau of Solid and Hazardous Waste Management
- Wisconsin DNR—Bureau of Water Supply
- Wisconsin DNR—Bureau of Water Resource Management
- Wisconsin DNR—Bureau of Water Regulation and Zoning
- Wisconsin DNR—Bureau of Endangered Resources
- U.S. EPA—Office of RCRA
- U.S. EPA—Air and Radiation Division

DEFINITIONS OF ARARS

Applicable requirements are standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that address a specific hazardous substance, pollutant, contaminant, remedial action, or other circumstance.

For a requirement to be applicable, the remedial action or the circumstances at the site must satisfy all of the jurisdictional prerequisites of that requirement. For example, the minimum technology requirements for landfills under RCRA would be applicable only if a new hazardous waste landfill (or an expansion of an existing landfill) were to be built on a CERCLA site.

Relevant and appropriate requirements are standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not applicable to a hazardous substance, pollutant, contaminant, remedial action, or other circumstances at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. For example, while RCRA regulations are not applicable to closing in-place hazardous waste that was disposed of before 1980, RCRA regulations for closure of waste in place may be deemed relevant and appropriate. In some circumstances, a requirement may be relevant to the particular site-specific situation but will not be appropriate because of differences in the purpose of the requirement, the duration of the regulated activity, or the physical size or characteristic of the situation it is intended to address. For example, maximum contaminant levels (MCLs) under the Safe Drinking Water Act

(SDWA) may not be appropriate to use for groundwater that has no potential as drinking water.

A requirement that is judged to be relevant and appropriate must be complied with to the same degree as if it were applicable. Relevant and appropriate requirements that are more stringent than applicable requirements take precedence. There is more discretion in the determination of relevant and appropriate requirements than in the determination of applicable requirements.

Another factor in determining which requirements must be complied with is whether the requirement is substantive or administrative. Onsite CERCLA response actions that pertain directly to actions or conditions in the environment must comply with substantive requirements. Administrative requirements, such as prescribing methods and procedures and paying fees, facilitate the implementation of the substantive requirements of a statute or regulation. Onsite CERCLA response action must meet the intent of the law (substantive requirements), but need not conform with all the applicable administrative requirements. This distinction applies only to onsite actions; offsite response actions are subject to the full administrative requirements of applicable standards or regulations, including administrative requirements such as permits.

Section 121(d)(4) of CERCLA identifies six circumstances under which ARARs may be waived:

- The remedial action selected is only a part of a total remedial action (interim remedy) and the final remedy will attain the ARAR upon completion.
- Compliance with the ARAR will result in a greater risk to human health and the environment than alternative options.
- Compliance with the ARAR is technically impracticable from an engineering perspective.
- An alternative remedial action will attain an equivalent standard of performance through the use of another method.
- The ARAR is a state requirement that the state has not consistently applied (or demonstrated the intent to apply consistently) in similar circumstances.
- For Section 104, Superfund-financed remedial actions, compliance with the ARAR will not provide a balance between protecting human health and the environment and the availability of Superfund money for response at other facilities.

OTHER CRITERIA OR GUIDELINES TO BE CONSIDERED

In addition to the legally binding requirements established as ARARs, many federal and state programs have developed criteria, advisories, guidelines, or proposed standards that may provide useful information or recommend procedures if no ARARs address a particular situation or if existing ARARs do not provide protection. In such situations, these "to be considered" criteria or guidelines should be used to define the remedial action. Examples of criteria to be considered are reference doses (RfDs) and potency factors for ingestion of noncarcinogenic and carcinogenic compounds used in risk assessment.

CLASSIFICATION OF ARARS

The EPA, in OSWER Directive No. 9234.1-.01, defines three types of ARARs:

- Chemical specific
- Location specific
- Action specific

Chemical-specific ARARs regulate the release of materials having certain chemical or physical characteristics, or materials containing specified chemical compounds to the environment. These requirements generally set health- or risk-based concentration limits or discharge limits for specific hazardous substances. If, in a specific situation, a chemical is subject to more than one discharge or exposure limit, the more stringent of the requirements should be applied.

Location-specific ARARs pertain to the geographical or physical position of the site, rather than to the nature of the contaminants or the proposed site remedial actions. These requirements may impose additional constraints on the remedial action or limit the type of remedial actions that can be implemented. Flood plain restrictions and protection of endangered species are among the potential location-specific ARARs.

Action-specific ARARs define acceptable treatment and disposal procedures for hazardous substances. These ARARs generally set performance, design, or other similar action-specific requirements for activities related to management of hazardous substances or pollutants. Since there are usually several alternative actions for any remedial site, different requirements can come into play. The action-specific requirements do not in themselves determine the remedial alternative; they indicate how or to what level treatment or cleanup will be achieved.

DETERMINATION OF ARARS

CHEMICAL-SPECIFIC ARARS

Chemical-specific ARARs regulate the release to the environment of specific substances having certain chemical or physical characteristics. They are important in determining the extent of soil, sediment, and groundwater remediation as well as determining the residual levels of contaminants allowable after treatment.

Groundwater

Groundwater Quality Standards. State of Wisconsin chemical-specific standards for groundwater are listed in NR 140 of the Wisconsin Administration Code. Table A-1 presents the enforcement standards and preventive action limits. Chapter NR 140 requires that corrective action be taken if enforcement standards or preventive action limits are exceeded at a point of standards application.

The point of standards application is one of the following locations:

- Any point of present groundwater use
- Any point beyond the boundary of the property on which the facility, practice, or activity is located
- Any point within the property boundaries beyond the three-dimensional design management zone if one is established by the department at each facility, practice, or activity

The Wisconsin DNR must designate a design management zone for the site before the point of standards application can be determined. For groundwater samples taken during the RI, only one well (MW-07S) exceeded the levels listed in Table A-1 (for benzene). This excludes wells and samples where pure phase was observed.

Wisconsin administers the implementation of two major federal laws within the state, the Clean Water Act (CWA) and the Safe Drinking Water Act (SDWA), that contain chemical-specific standards and criteria that are often ARARs for groundwater remediation. Table A-2 presents the standards and criteria pertinent to groundwater (and surface water) used as a drinking water supply.

Because state groundwater standards are exceeded beneath the site, corrective actions would be required by the state. Selection of the No Action Alternative in both operable units would not meet this state ARAR. All remaining alternatives would achieve state ARARs for groundwater.

According to CERCLA Section 121(d)(2)(B)(ii), corrective actions are not required if three conditions occur at a site:

- There are known and projected points of entry of groundwater into surface water.
- There is or will be no statistically significant increase in contaminant concentrations measurable or predicted to be measurable in the receiving surface water.
- The remedial action includes measures that preclude human exposure.

Because these conditions cannot be verified with sufficient certainty, except for Alternative 6, corrective actions for groundwater are included in Alternatives 2 through 5.

Surface Water Quality Standards. Chemical-specific ARARs are relevant to the Moss-American site because the Little Menomonee River receives natural groundwater discharge from the site. In addition, Alternatives 2 through 5 would discharge treated groundwater to the river. Wisconsin surface water quality criteria and standards are dependent on the water use designation of the river. The Little Menomonee River is classified for warm water sport fish communities (NR 104). Table A-3 lists the Wisconsin Water Quality Criteria (NR 105) for this classification.

ARARs which protect aquatic life are listed in Tables A-4 and A-5. These standards are expressed according to acute and chronic toxicity levels. Table A-4 lists Wisconsin water quality criteria applicable to the river classification designated for the Little Menomonee River. Table A-5 lists the CWA FWQC for aquatic life protection.

Discharges to Surface Water. Discharges of treated groundwater to the Little Menomonee River are regulated by Chapter 147, Wisconsin Statutes. These regulations state that no discharge shall contain quantities of listed pollutants greater than those that would remain after the discharge had been treated by the best available technology economically achievable (BATEA) or greater than any lesser quantity necessary to provide an ample margin of safety. For this FS, treatment with an oil-water separator followed by granular activated carbon is considered to meet BATEA. The treatment processes for alternatives discharging treated groundwater to the river (Alternatives 2 through 5) would be designed to meet the WPDES discharge limits. Discharge limits have been developed for this site and are presented in Appendix F.

LOCATION-SPECIFIC ARARS

Location-specific ARARs are those requirements that relate to the geographical position of the site. The location-specific requirements currently identified as potential ARARs for CERCLA remedial actions are listed in Table A-6.

There are several location-specific ARARs applicable to the Moss-American site. About one-quarter of the site (excluding flood plain downstream from the original property) is within the 100-year flood plain. Therefore the requirements of RCRA—40 CFR 264.18(b) and Executive Order 11988, Protection of Flood Plains—may be applicable or relevant and appropriate to actions on the site. These regulations would affect the siting of the treatment systems of Alternatives 2 through 6. In each case the treatment system would be located above the 100-year flood elevation (about 718 M.S.L. onsite) and be protected from erosion damage. Containment actions on soil assume that contaminated soil in the 100-year flood plain would be moved out of the flood plain and consolidated with the other contaminated soil before covering.

All alternatives (except no action) include significant excavation affecting wetlands adjacent to or downstream of the site. Potential ARARs regarding these wetlands include Executive Order 11990, which requires that actions at the site be conducted in a manner minimizing the destruction, loss, or degradation of wetlands; and NR 116 Wisconsin DNR Guidance on Department Regulation of Stream Channelization Projects, which require environmental assessments be made and submitted to Wisconsin DNR for review. These ARARs would be met by use of mitigative actions such as reconstruction of affected channels to replace lost wetlands. Alternatives including groundwater collection are expected to have minimal effects on water elevations in the surrounding wetlands.

In summary, it is expected that all of the remedial action alternatives except no-action will comply with the identified location-specific ARARs. Some of these ARARs require that special considerations be included in the development, and later the design, of the remedial actions.

ACTION-SPECIFIC ARARS

Action-specific ARARs are requirements that define acceptable treatment and disposal procedures for hazardous substances. The potential federal action-specific ARARs are listed in Table A-7. The potential Wisconsin ARARs are listed in Table A-8. Important action-specific ARAR evaluations for the alternatives are discussed below.

Identification of Hazardous Waste

The definition of the waste disposal at the landfill is important in determining the status of RCRA requirements. Since the hazardous substances found at the Moss-American site were generated and managed before the effective date of RCRA, RCRA is not applicable to the site unless wastes are moved outside the area of contamination or placed in an intervening unit, such as an incinerator. RCRA requirements may be relevant and appropriate if wastes disposed before November 1980 are defined as RCRA hazardous waste or are sufficiently similar to RCRA hazardous wastes. Nonaqueous wastes generated from creosote facility discharges are classified as a RCRA hazardous waste (K001). The Wisconsin DNR and U.S. EPA have determined that soils and sediment contaminated by this waste should be managed as a RCRA hazardous waste as a result of the mixture rule (40 CFR 26.3(c)(2)(i)).

RCRA Requirements for Treatment of Hazardous Waste

Alternatives 3A through 6 include excavation and treatment of contaminated sediment and soil. Since the treatment activities would be conducted within the area of contamination (except for the case of the Northeast Landfill) RCRA would not be applicable except for the cases of slurry bioreactors or onsite incinerators, since these would be considered intervening units. RCRA would be applicable for treatment of the Northeast Landfill. Alternatives 3A, 3B, 4, and 5 would comply with LDRs through a Treatability Variance. Alternative 6 would treat to the standards established for K001 wastes in the LDRs.

Landfill Closure Cover Requirements

As discussed above, RCRA requirements are not applicable but may be considered relevant and appropriate to remedial alternatives not involving excavation of sediment or soil. The U.S. EPA and Wisconsin DNR has indicated that RCRA closure requirements will not be ARARs.

The Wisconsin Administrative Code NR 504 lists requirements for closure of sanitary landfills. Some of these requirements include a 2-foot clay layer with a 1.5- to

2.5-foot cover layer and 0.5-foot of topsoil on the surface. The Wisconsin DNR has indicated this cover is relevant and appropriate for instances where contaminants are covered in place. The soil covers proposed for Alternatives 2 through 6 would not meet these NR 504 requirements.

This FS presumes that an ARARs waiver would be obtained to permit the use of a soil cover to contain untreated and treated soil and sediment onsite. The waiver would be based upon the "equivalent standard of performance" waiver, because neither type of cap (impermeable or permeable) prevents groundwater contamination (which has already occurred as a result of the high water table and migration of contaminants into subsurface soils.) Both caps should provide an "equivalent standard of performance" in limiting direct contact with contaminated soils, which has been identified as the principal risk to public health from site contaminants. In the case of Alternatives 3A through 5, a soil cover is an "alternative landfill" type of hybrid closure, where the removal of contaminated soil that results potentially poses a direct contact threat but does not pose a threat to groundwater (i.e., residual leachate contamination does not exceed health-based levels).

Groundwater Treatment Requirements

WPDES permit requirements and discharge limits must be met before discharge of treated groundwater to the Little Menomonee River (Alternatives 2 through 5). At a minimum, NR 220 requires best available control technology for treatment before discharge. Specific discharge limits have been established by the Wisconsin DNR and are presented in Appendix F. Potential pretreatment requirements for discharge to the POTW are presented in Appendix F. All groundwater treatment processes would be designed to meet the WPDES discharge limits.

Air Emission Treatment Requirements

Alternatives including sediment and soil treatment (Alternatives 2 through 6) will result in discharge of contaminants to the air. The need for air emission treatment such as vapor phase activated carbon treatment was evaluated based on requirements of NR 445 and an evaluation of public health risks. Based on the relative amounts of VOCs in the sediment and soil (only a few samples had VOC concentrations greater than a few mg/kg), emission treatment would probably not be necessary. Emissions would be reevaluated during predesign and air emission treatment would be included in the remedial alternative if necessary.

Land Disposal Restrictions

The RCRA Land Disposal Restrictions (LDRs) apply to Superfund cleanups when wastes found at the site are considered (RCRA) restricted wastes, and when the removal action will involve the "placement" of the waste. The LDRs prohibit, with certain exceptions, the land disposal (placement) of specific hazardous wastes (including K001 waste) unless they are first treated to standards established under the LDRs (RCRA Section 3004). The U.S. EPA has identified the contaminated soil and sediment at the Moss-American site as a K001 waste, and thus the LDRs have been established as ARARs for the Moss-American site.

For most restricted wastes (including K001), incineration is the basis for establishing the treatment standard. Exceptions to these standards may be available within RCRA rules if the wastes are disposed of in units satisfying the statutory no-migration criteria, or if a capacity extension has been granted for the wastes.

Under the RCRA no-migration petition, land disposal of restricted wastes may be performed if it can be demonstrated that there will be no migration of hazardous constituents above health-based levels from the disposal unit for as long as the wastes remain hazardous. Details of the petition are specified in RCRA Section 268.

Under the RCRA capacity extension, the LDR treatment standards do not have to be met for 2 years from the date the standards go into effect, and wastes can be landfilled if the landfill is in compliance with the EPA's RCRA minimum technology requirements. The national RCRA landfill capacity extension for K001 wastes will expire in August of 1990.

For the LDRs to be applicable to a CERCLA response, the action must constitute a placement of a restricted hazardous waste. The EPA currently uses the concept of areas of contamination (AOC) to define whether placement occurs for CERCLA actions involving onsite disposal of wastes. An AOC is defined as the areal extent of contiguous contamination. Thus, a given site could have several AOCs. The contaminated areas may contain varying types and concentrations of hazardous substances. Based upon this definition, it appears that the Moss-American site consists of two AOCs:

1. One large area that includes approximately 20 acres west of the river on the original property, and the river itself. Although contaminated sediments may not be continuous throughout the river, this was not indicated during the remedial investigation, and therefore all of the river is included in this area.

2. The Northeast Landfill, where settling pond dredgings are believed to have been landfilled.

Under current EPA interpretation, placement (per OSWER Directive 9347.3-O5FS; July 1989) would occur when:

- Wastes are consolidated from different AOCs into a single AOC
- Wastes are moved outside an AOC and returned to the same or different AOC
- Wastes are excavated from an AOC, treated using a device located within that AOC, and redeposited on the same AOC

Placement would not occur, however, when the wastes are:

- Consolidated within the AOC
- Processed within the AOC, but not in a separate unit such as a tank

The interpretation also indicates that contaminated soil west of the river, the sediment downstream of the original property, and the contaminated sediment from the river bank could be moved around within the 20-acre area of contamination and covered or capped or landfilled without triggering LDRs. If the materials were treated onsite in an "intervening unit," such as a bioreactor tank or incinerator, then LDRs would be applicable. According to current interpretation, the contaminated soil east of the river could not be moved without triggering the LDRs.

When promulgating the LDR treatment standards, the U.S. EPA recognized that treatment of wastes to the LDR treatment standard would not always be possible or appropriate and in fact are generally inappropriate for contaminated soil and debris (55 FR 8762). A treatability variance process (40 CFR 268.4) is available to comply with LDRs. A treatability variance does not remove the requirement to treat restricted soil and debris. Rather, under a treatability variance, alternate treatment levels based on data from actual treatment of soil, or best management practices for debris, become the treatment standard that must be met, as described in the preamble to the revised NCP.

Table A-9 summarizes the LDR treatment standards and alternative treatability variance levels for specific K001 waste constituents. The LDR treatment standards identify concentrations of restricted wastes and their associated constituents which may not be exceeded. The treatment standards are based on BDAT and are specific for individual constituents as expressed concentration in the waste (40 CFR 269.43) or as the specific constituents concentration in the treated waste extract (40 CFR 268.41).

OSWER Directive 9347.3-06FS (second edition), Superfund LDR Guide #6A: *Obtaining A Soil and Debris Treatability Variance for Remedial Actions,* outlines the process for obtaining and complying with a treatability variance for onsite soil and debris contaminated with RCRA wastes in accordance with 40 CFR 268.44. In accordance with this directive, Table A-9 presents the targeted treatability variance concentration ranges for those restricted K001 constituents detailed in soils at the Moss-American site. For those constituents less than the threshold concentration range, the waste should be treated to reduce the concentration of the constituent to within the specified target concentration range. If the waste concentration is above the threshold concentration range, the waste should be treated to reduce the concentration of the constituent to within the specified percent reduction range.

The Wisconsin DNR has proposed sediment quality criteria for the Little Menomonee River based upon the surface water quality standards listed in Table A-3. These proposed criteria, presented in Table A-10, were derived using a partitioning approach currently being developed by the U.S. EPA. The proposed criteria require the removal of sediment having carcinogenic PAH levels greater than about 3 mg/kg. Because these criteria are not promulgated, they are addressed in this FS as "to-be-considered" criteria.

SUMMARY

A summary of how each alternative achieves the ARARs identified for it is presented in Table A-11.

GLT595/081.51

Appendix B
RIVER HYDRAULICS MANAGEMENT FOR REMEDIAL ACTION ALTERNATIVES

Appendix B
RIVER HYDRAULICS MANAGEMENT FOR REMEDIAL ACTION ALTERNATIVES

INTRODUCTION

This appendix discusses the management of Little Menomonee River hydraulics for the detailed remedial action alternatives presented in Chapter 4. Management of hydraulics is important to all alternatives (except the No Action alternative) because each involves some remedial action on the Little Menomonee River. This appendix summarizes the existing hydraulics of the river, and then discusses hydraulic implications of a temporary river diversion and a permanent river relocation. Potential methods for temporary diversion and permanent river relocation are described in this appendix for the purposes of evaluating alternatives and estimating costs. The actual design and location of each diversion would be determined following a more detailed hydraulic analysis and may depend upon additional guidance from appropriate agencies.

EXISTING HYDRAULICS

Estimated runoff rates in the Little Menomonee River watershed are needed to design hydraulic components of remedial action alternatives for removing contaminated sediment from the river. The Little Menomonee River comprises a low flow channel and a wide overbank flood plain. Culverts and bridges constrict flood discharges at several locations along the river.

LOW-FLOW CHANNEL HYDRAULICS

The proposed remedial action alternatives require modifying the Little Menomonee River low-flow channel, either through a permanent relocation of the low-flow channel or temporary flow diversions from the channel. The cross-sectional geometry of the flood plain varies somewhat along the study limit (from Brown Deer Road to the confluence with the Menomonee River). The cross-sectional area of the low flow channel (as measured during the RI), however, does not vary significantly. The low-flow channel capacity of the river is estimated from Manning's Equation to be about 330 cfs based on typical surveyed channel cross sections at 300-foot intervals along the study reach. Cross sections were obtained during the remedial investigation.

The calculation assumed a channel roughness coefficient of 0.035 as was assumed in the Federal Emergency Management Agency's 1987 Flood Insurance Study (FIS) for the City of Milwaukee. The average bottom slope along the study reach is about 3.5 feet per mile (0.0007 ft/ft). The average channel velocity at bank-full capacity would be about 2.7 feet per second.

Stream flow gaging records are not available for the Little Menomonee River. Therefore, records from three gaged streams nearby (11 to 27 years of data) were used to estimate flow characteristics for the Little Menomonee River. The records were used to estimate an average annual stream flow per watershed area, as summarized in Table B-1.

Table B-1
AVERAGE ANNUAL STREAMFLOW ESTIMATE

OSGS Gage Number	Location	Average Annual Streamflow (cfs)	Watershed Area (mi^2)	Unit Discharge (cfs/mi^2)
4087030	Menomonee River at Menomonee Falls	31	35	0.9
4087088	Underwood Creek at Wauwatosa	14	18	0.8
4087120	Menomonee River at Wauwatosa	98	123	0.8

These records indicate that a unit discharge of about 0.8 cfs/mi^2 is typical for the area. Based on the area of the Little Menomonee River watershed and the assumed unit discharges, the average annual stream flow in the Little Menomonee River would be about 10 cfs at Brown Deer Road and about 17 cfs at the confluence with the Menomonee River (based on 0.8 cfs/mi^2). These results assume that average annual stream flows are directly proportional to watershed area. This assumption is reasonable for relatively low flows that are more a function of runoff volume than watershed characteristics such as land surface and basin shape.

The FIS provides regulated discharges for 10-, 50-, 100-, and 500-year recurrence interval floods. These discharges were plotted on log-probability paper to estimate a 2-year discharge of about 170 cfs at Brown Deer Road and about 375 cfs at the confluence with the Menomonee River. The 2-year discharge approaches the low-flow channel capacity and might, therefore, overtop the banks of the existing low-flow channel in areas where the cross-sectional area is less than the average.

100-YEAR FLOOD PLAIN HYDRAULICS

The regulated 100-year flood discharge along the study reach varies from 770 cfs at Brown Deer Road to 2,100 cfs at the confluence with the Menomonee River. The discharges would overtop the channel banks and inundate the flood plain along the study reach at an average width of about 600 feet and mean velocity of about 1.1 feet per second.

Eighteen culverts cross the river along the study reach. Some of these culverts would raise 100-year flood elevations behind roadway embankments and constrict the flood lain where the river crosses the roadways. However, these culverts are assumed to have an insignificant hydraulic effect for the low-magnitude discharges used for the hydraulic analysis of remedial action alternatives.

PREVIOUS CHANNELIZATION ACTIVITIES

The earliest available references regarding the location of the Little Menomonee River in the study area are U.S. Geological Survey (USGS) topographic maps. These maps from the University of Wisconsin map library are based on land surveys done in 1890 and 1899 and show the river prior to channelization. These 1890 and 1899 maps were compared with USGS topographic maps drawn from 1976 survey data. Some minor channel modifications including alignment changes and channel straightening were made between 1890 and 1976. (Milwaukee County obtained the corridor along the river during the late 1950s and early 1960s.) The Milwaukee County Park system has no record of channelizing this portion of the river. Any alteration to the river was done prior to this time (Personal communication. P. Hathaway, March 21, 1990).

PERMANENT RIVER RELOCATION

If the river is permanently relocated, then contaminated sediment could be contained in place as described in Alternative 2.

PERMANENT HYDRAULIC STRUCTURES

The permanently relocated river could be constructed as shown in Figure B-1. The location minimizes skew angles and transition lengths at culverts and bridges, but ties back into existing invert elevations. The location of the relocated channel would be adjusted to minimize destruction of existing vegetation.

At locations where the old and new riverbeds intersect, a vertical hydraulic barrier would be constructed between the old and new channels to minimize the potential for migration of contaminants from the buried sediments to the new bed. The reuse of some existing culverts may be necessary for the proposed river alignment, but the possibility of replacing some culverts should be explored during design. Existing culverts could be replaced with culverts with larger capacity, and the new culverts could be more preferentially located.

Figure B-2 illustrates a conceptual cross section of the proposed channel. The figure illustrates the recommended relationship between existing and proposed channels intended to reduce riparian habitat losses. Because the existing channel does not always follow the historic river alignment and the proposed channel would be designed to follow the historic river alignment, the distance between the existing and proposed channels would vary.

The new channel capacity could be designed to have a capacity higher than the existing channel to reduce potential flood hazards and damages within the flood plain. The proposed channel conceived for this FS does not provide this additional capacity. The final channel geometry will depend on the results of a hydraulic backwater analysis conducted during design phases.

A hydraulic sediment transport analysis will also be required as part of the design. The results of this analysis will affect final channel hydraulics and alignment. The relocated river should have a sediment transport capacity similar to upstream and downstream channels.

Figure B-3 illustrates a pilot channel with a capacity of the average annual stream flow. This pilot channel would be built to concentrate low flows and would be constructed within a larger channel. The pilot channel would be constructed with a meandering alignment, while maintaining the existing average longitudinal slope. The meanders would replicate natural stream characteristics by causing deeper water to flow along the outside of each curve and shallower water along the inside of each curve.

Pools and riffles within the pilot channel would be designed to provide an environment suitable for aquatic wildlife. The pools and riffles would require alternating steeper and more level areas along the length of the pilot channel. Riffle and pool depths should average 0.5 and 2.5 feet, respectively, although these depths will depend on base flow conditions in the channel.

The outer channel and side slopes should be graded to the same longitudinal slope as the pilot channel. The outer channel should be graded to encourage development of wetlands or sloughs by varying the channel width and side slopes.

The design and construction of areas where tributaries join the relocated Little Menomonee River would differ depending on the positions of the tributary, the existing (old) channel, and the new channel. If the tributary joins the river at a point where the old channel lies between the tributary and the new channel, the tributary would be extended to the main channel with a closed conduit. This would reduce the chance of contaminating tributary water with buried sediment. However, if the old channel does not lie between the new channel and the tributary, the tributary could be extended to the new channel in an open channel. Typical tributary channel transitions are shown in Figure B-4.

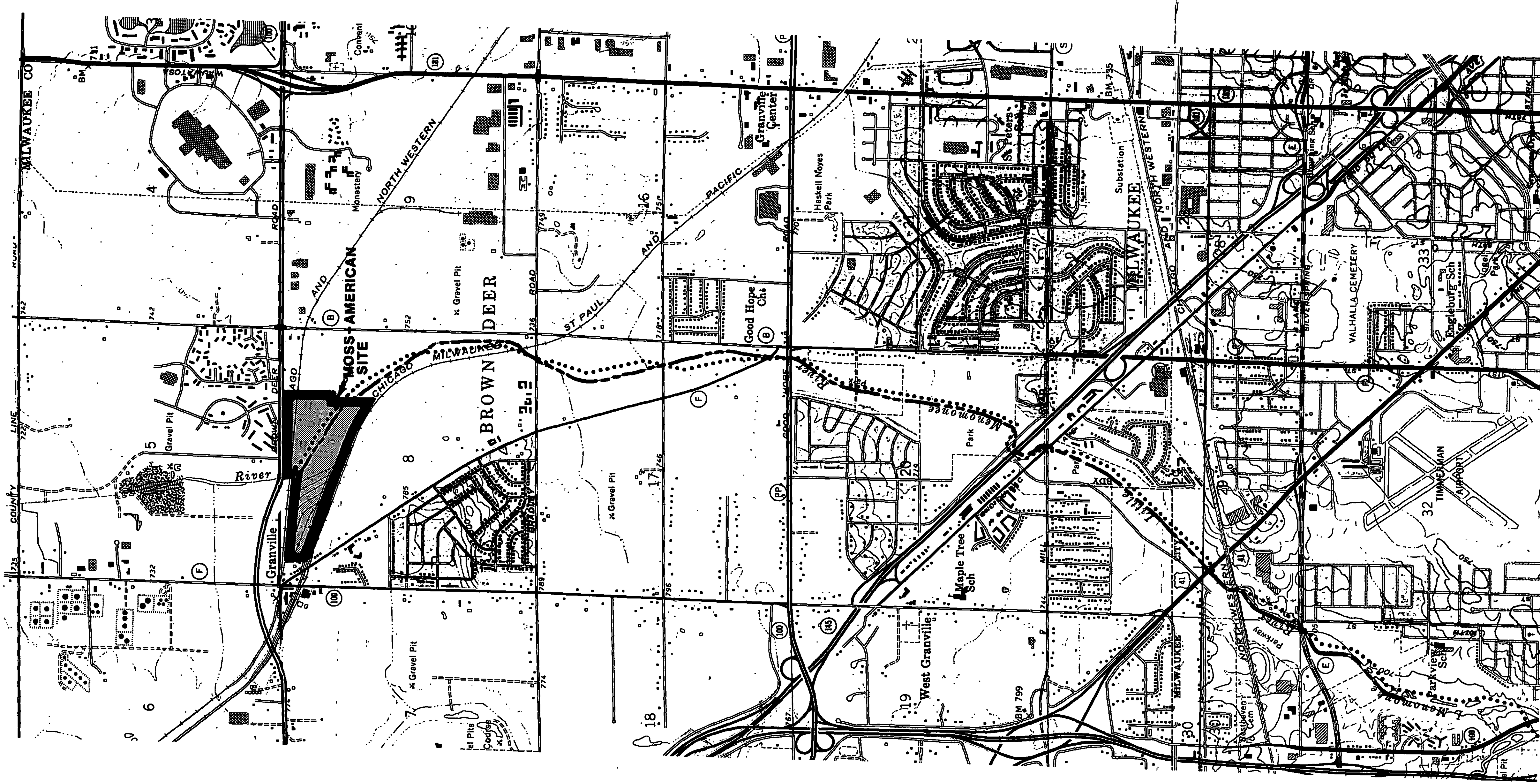
Flood plain hydraulics would be temporarily affected during construction activities. Construction activities would be limited to the area immediately adjacent to the low-flow channel in order to maintain existing overbank flood-carrying capacity.

CONSTRUCTION PHASING

A permanent river relocation would be built in the following phases:

- Construct all channel reaches with exception of transitions into and out of roadway crossings.

- Construct transitions at each roadway crossing starting upstream and progressing downstream. (Each subsequent transition would divert runoff from the relocated channel back into the existing channel, until the next downstream transition is constructed. The steps needed to build a typical transition are shown in Figure B-5.)



N

0 1000 2000

SCALE IN FEET

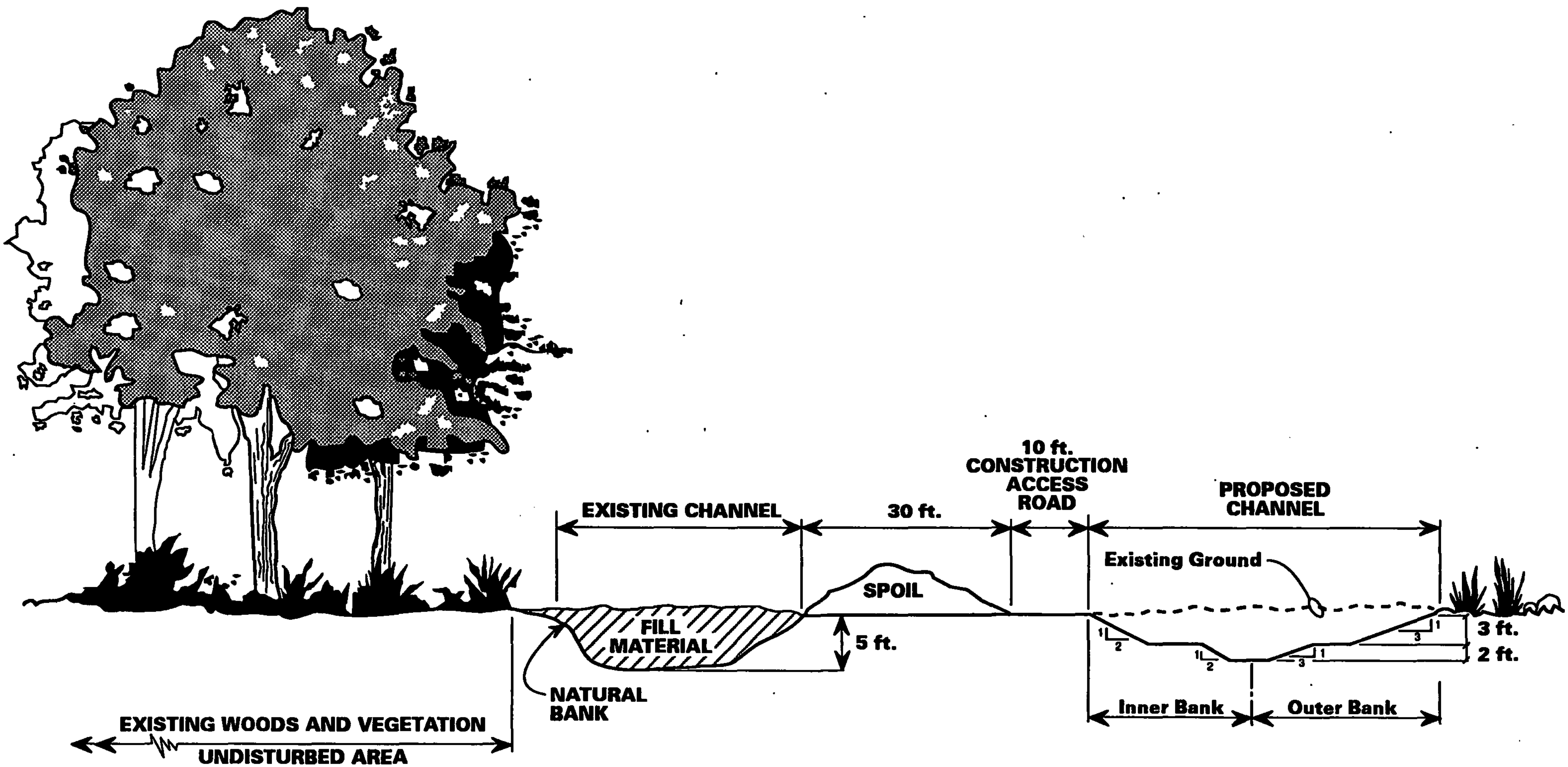
LEGEND

EXISTING RIVER ALIGNMENT

PROPOSED RIVER ALIGNMENT

FIGURE B-1
PERMANENT RIVER RELOCATION
MOSS-AMERICAN FS

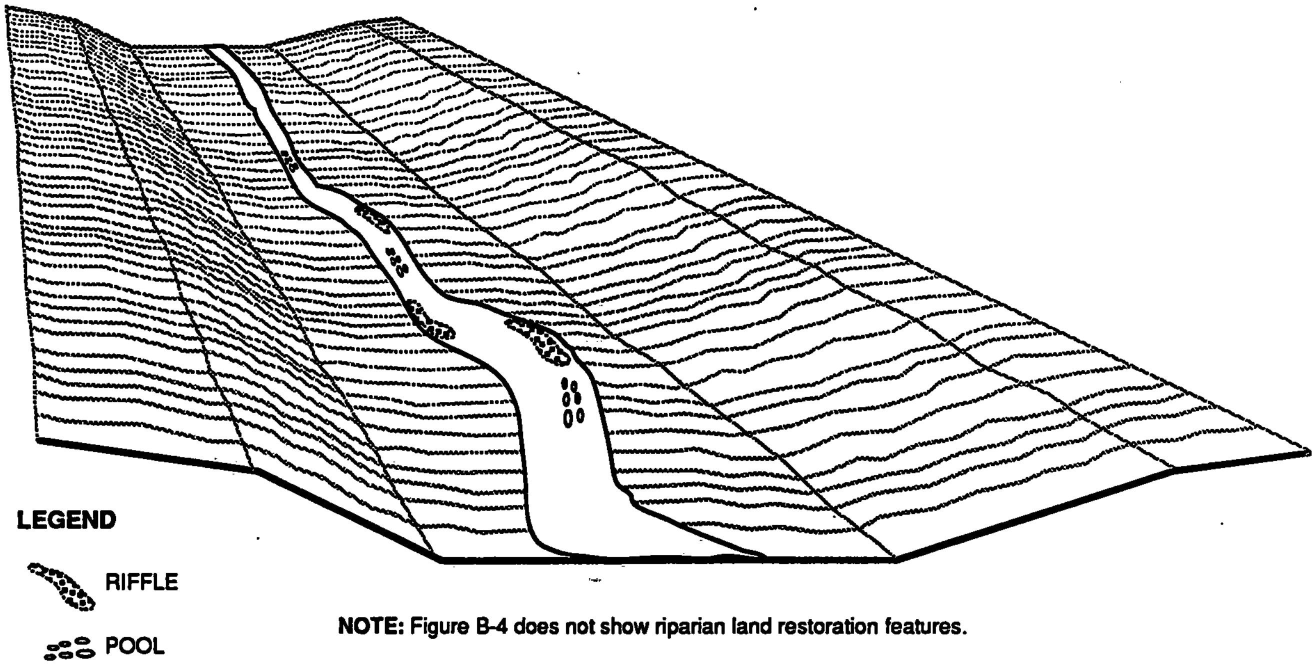
GLO65564.FS FIG B-4 3-30-90 mms



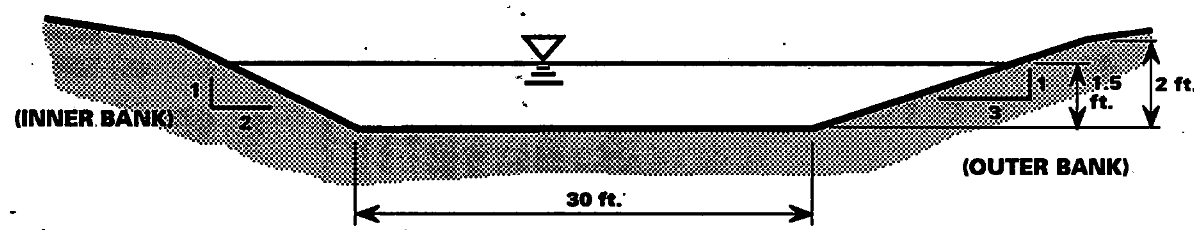
NOT TO SCALE

NOTE: Figure B-3 does not show riparian land restoration features.

FIGURE B-2
TYPICAL PROPOSED CHANNEL CROSS SECTION
MOSS-AMERICAN FS



NOTE: Figure B-4 does not show riparian land restoration features.



NOT TO SCALE

Manning's "n" = 0.035

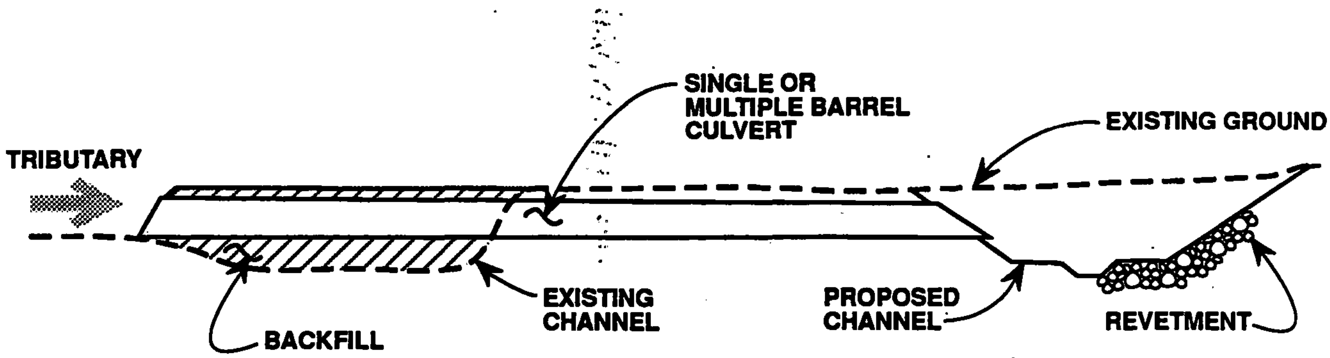
S_0 = 0.0007 ft / ft

Q = 10 cfs

V = 1.1 fps

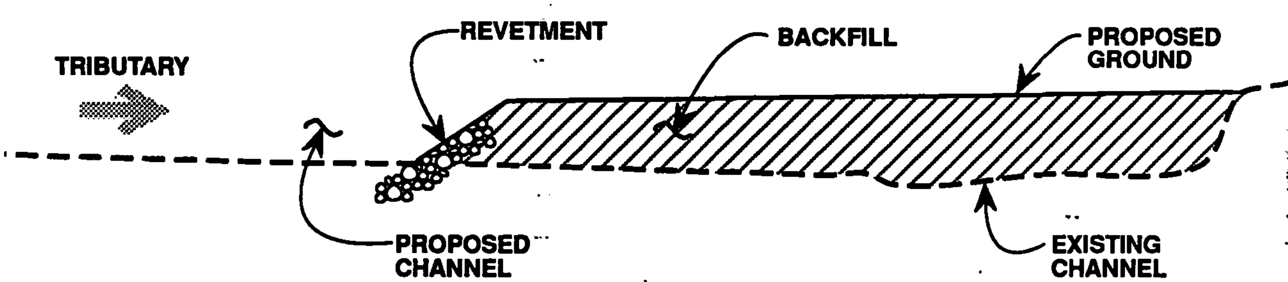
GLO65564.FS TYP CHAN CROSS 3-26-90mms

FIGURE B-3
TYPICAL PROPOSED PILOT CHANNEL CROSS SECTION
MOSS-AMERICAN FS



TRIBUTARY ON OPPOSITE SIDE OF PROPOSED CHANNEL

Not to Scale

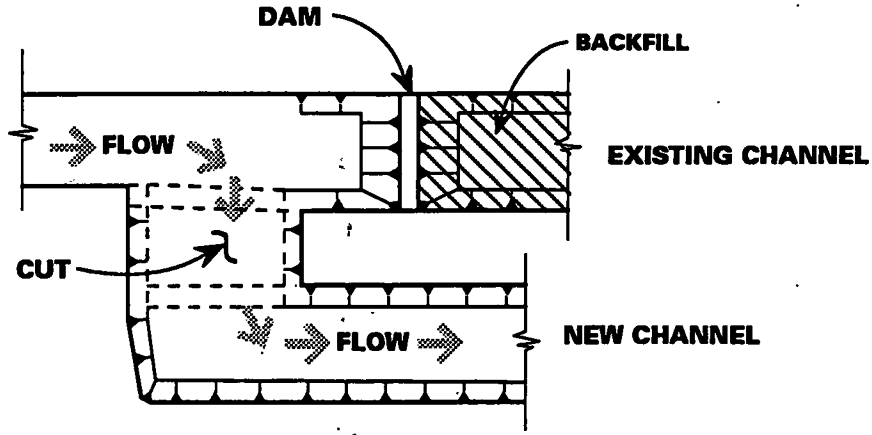


TRIBUTARY ON SAME SIDE AS PROPOSED CHANNEL

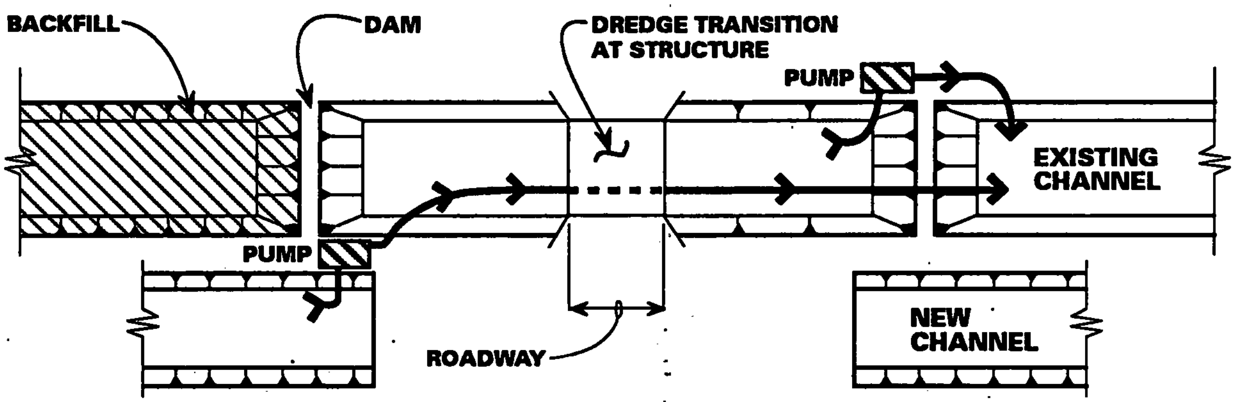
Not to Scale

GLO65564.FS FIG B-5 3-26-90 mms

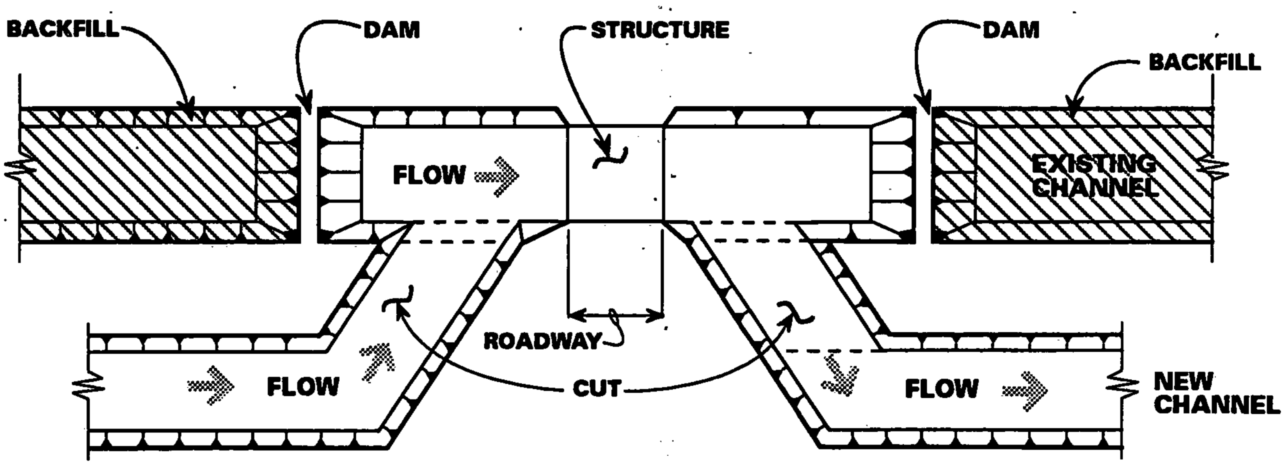
FIGURE B-4
TYPICAL PROPOSED LOW FLOW CHANNEL RECONSTRUCTION OF TRIBUTARIES
MOSS-AMERICAN FS



PHASE 1 - DIVERSION TO NEW CHANNEL AT UPSTREAM END OF STUDY AREA



PHASE 2 - DREDGE TRANSITION AT STRUCTURE



PHASE 3 - REROUTE FLOW THROUGH CLEANED STRUCTURE

GLO65564.FS FIG B-6 1-11-90 mms

FIGURE B-5
CONSTRUCTION PHASES AT TYPICAL ROADWAY CROSSING
MOSS-AMERICAN FS

These construction phases would require two soil moving operations. The first would excavate soil for the new channel and deposit the material between the new and existing channels. The second would fill the old channel with the stockpiled soil excavated from the new channel.

Vegetation would be removed between the new and existing channels to provide an area for stockpiling excavated earth and for construction access. A mitigation plan would be prepared for reducing potential soil erosion following construction. The mitigation plan would include regrading overbank areas and replacing removed vegetation.

CONSTRUCTION ACCESS

Construction access routes to the site would be from existing public roads. Generally, access would be needed between all points where public roads intersect the river because of inadequate vehicular clearance through culverts. The number of access points could be reduced if a temporary construction road were built along the channel.

REGULATORY ISSUES

Federal, state, and local regulatory issues are summarized in Appendix A with the discussion of site-specified ARARs.

The potential impact of construction activities in the river and floodplain on wetlands must be addressed. The following is a cursory analysis of the types of wetlands that might be adversely impacted by remedial actions for contaminated sediment. A more detailed evaluation would be required as part of predesign activities.

The vegetation along the Little Menomonee River between Brown Deer Road and the confluence with the Menomonee River is primarily wooded wetland with some grassy and shrubby upland areas. According to the Wisconsin Wetland Inventory classification system, the wooded wetlands (T3K) consist primarily of broad-leaved deciduous trees in areas of wet soil. The shrubby areas in wet soil (S3K) also are characterized by broad-leaved deciduous species. Woody species that may be found in these areas include willow ash, elm, and silver maple. An area of emergent vegetation (Elk) with cattails, sedges, grasses, or asters growing in wet soil is also present. Fields and shrubby areas makeup the upland portions of the study area.

The Southeastern Wisconsin Regional Planning Commission (SEWRPC) has designated the Little Menomonee River and the land adjacent to it as a primary environmental corridor. Primary environmental corridors generally include a variety of natural environments and related elements such as rivers, shorelands, floodplains, wetlands, woodlands, wildlife habitats, parks and open spaces. The entire study area is part of a primary environmental corridor.

SEWRPC has identified a wildlife habitat in the study area. A wildlife habitat is an area devoted to natural open uses. The vegetative cover in a wildlife habitat is capable of supporting a high and balanced diversity of wildlife by providing nesting areas, travel routes, concealment, and shelter for a variety of wildlife species. High-value wildlife habitat areas contain a wide diversity of wildlife and are adequate in size to meet all the habitat requirements of the species concerned, including territorial and vegetative composition requirements. These areas are generally located in proximity to other wildlife habitat areas. Medium-value wildlife habitat areas generally lack one of the criteria for a high-value wildlife habitat, however, these areas have a good plant and animal diversity. Low-value wildlife habitat areas generally lack two or more of the criteria for a high-value wildlife habitat, however they may be important because they are located close to medium or high-value habitats. They also may provide corridors linking higher-value wildlife habitat areas, or may be the only available range in the area.

Table B-2 lists the existing vegetation types located along the Little Menomonee River, for each type the presence of a primary environmental corridor, the class of wildlife habitat, and the acreage are indicated. For the acreage calculations, it was assumed that the construction corridor for the new alignment would be 100-feet-wide. The types cleared were assumed to be the same as those adjacent to the river. Alignment deviations in excess of 100 feet from the existing river channel may alter the acreage affected.

Table B-2
POTENTIALLY DISTURBED WETLANDS

Vegetation Type	Acres Along Current Alignment	Estimated Number of Acres Disturbed by New Alignment	Primary Environmental Corridor	Habitat Class
Wetland				
T3k	69	22	Yes	low
T3/S3k	42	18	Yes	medium and low
S3k	13	3	Yes	low
S3/Elk	11	3	Yes	low
Field/Shrub	a	2	Yes	high and low
Upland				
Field/Shrub	b	17	Yes	high and medium
Field	b	2	Yes	high and medium

a WI wetland classification not available. Less than 2 acres.
b Vegetation type includes most of nonwetland portion of environmental corridor

The banks of a new channel would need to be stabilized. Seed mixtures appropriate for wet areas, such as those described in the Wisconsin Department of Transportation specifications (Section 630.2), could be used along with shrub plantings. Red osier dogwood and willow are shrubs tolerant to changing water levels and could be planted along the banks. In areas of current wetlands, existing vegetation would be allowed to recolonize the area. A new channel could cross some areas of upland vegetation. These areas would be seeded and planted with species characteristic of wet areas, resulting in a net increase in wetland/riparian vegetation (Reference: SEWRPC. March 1981. Technical Record. Volume 4, No. 2).

The design of a new river channel should incorporate the following instream and riparian habitat mitigation guidelines:

- Maintain sediment transport capacity similar to upstream and downstream channels. A hydraulic sediment transport analysis will be required to ensure a stable design.

- Where appropriate, the channel should include a pilot channel to concentrate low to mean annual flows, and an outer channel to convey higher flows. Where appropriate, the modified or relocated inner channel shall have meandering alignments. Pool and riffle areas should be incorporated in the inner channel design to improve channel stability and increase habitat diversity.

- The inner and outer channel bank slopes shall be one vertical to two horizontal for the inside curve of meanders and one vertical to three horizontal for the outside curve of meanders.

- Minimize construction activities in existing wetlands.

- Cut vegetation at ground level, leaving existing root systems intact.

- Use erosion and sediment-control measures during construction.

- Restore topsoil to original horizon.

- Revegetate disturbed areas by seeding and/or planting. Allow reestablishment of riparian vegetation from surrounding area.

- Maintain the wetlands hydrology.

- Construct on-channel wetlands or sloughs by widening the outer channel and constructing the grade of the wetland or slough equal to the inner channel grade.

- Final grading and vegetation of stream banks should take place in early spring or summer, one growing season prior to the reestablishment of flow.

Construction of a new channel will provide features needed to restore and enhance aquatic and terrestrial habitats. These features would include river meanders which are similar to the meanders present before channelization, wetlands or sloughs on the channel, and alternating deep and shallow areas in the river. Establishment of vegetation along the banks would provide habitat for terrestrial species, shading and shelter for aquatic species, and bank stabilization.

Preparation of design plans shall be coordinated with the Wisconsin DNR's Department of Fish Management, Department of Water Resource Management, and Department of Water Regulation and Zoning. Analysis of the potential for localized flooding shall be performed for proposed temporary detention facilities.

The enhancement of environmental quality and aesthetics will be required as a condition of the Chapter 30 permit review approval process.

COST EVALUATION

Cost opinions for the temporary river relocation are discussed in Appendix I.

TEMPORARY RIVER DIVERSION

A temporary river diversion would allow for mechanical excavation of contaminated sediment as described for Alternatives 4, 5, and 6.

CONSTRUCTION PHASING

A temporary river diversion would require construction phasing. Construction would proceed by isolating and cleaning reaches of the river from upstream to downstream. Construction in the downstream direction would reduce the chance of recontaminating reaches that had been cleaned.

Construction phasing would require temporary diversion of the existing river into a conduit that would bypass the particular reach of the river undergoing remediation (removal of sediment). The diversion would allow for removal of water in the reach, and expose the existing river bed to permit dry excavation of contaminated sediment.

TEMPORARY HYDRAULIC FACILITIES

Figure B-6 illustrates an example of one approach to divert runoff around a typical isolated river reach. The purpose of the hydraulic structures on the figure is explained in the following subsections.

Temporary hydraulic facilities would be designed for low, nonflood discharges. Discharges caused by storm events could exceed the capacities of these facilities and temporarily disrupt construction activities. In this appendix the facilities are described in concept only. The actual approach to temporary diversion, as well as size and location of these facilities would be determined by detailed hydraulic analysis during the preliminary design.

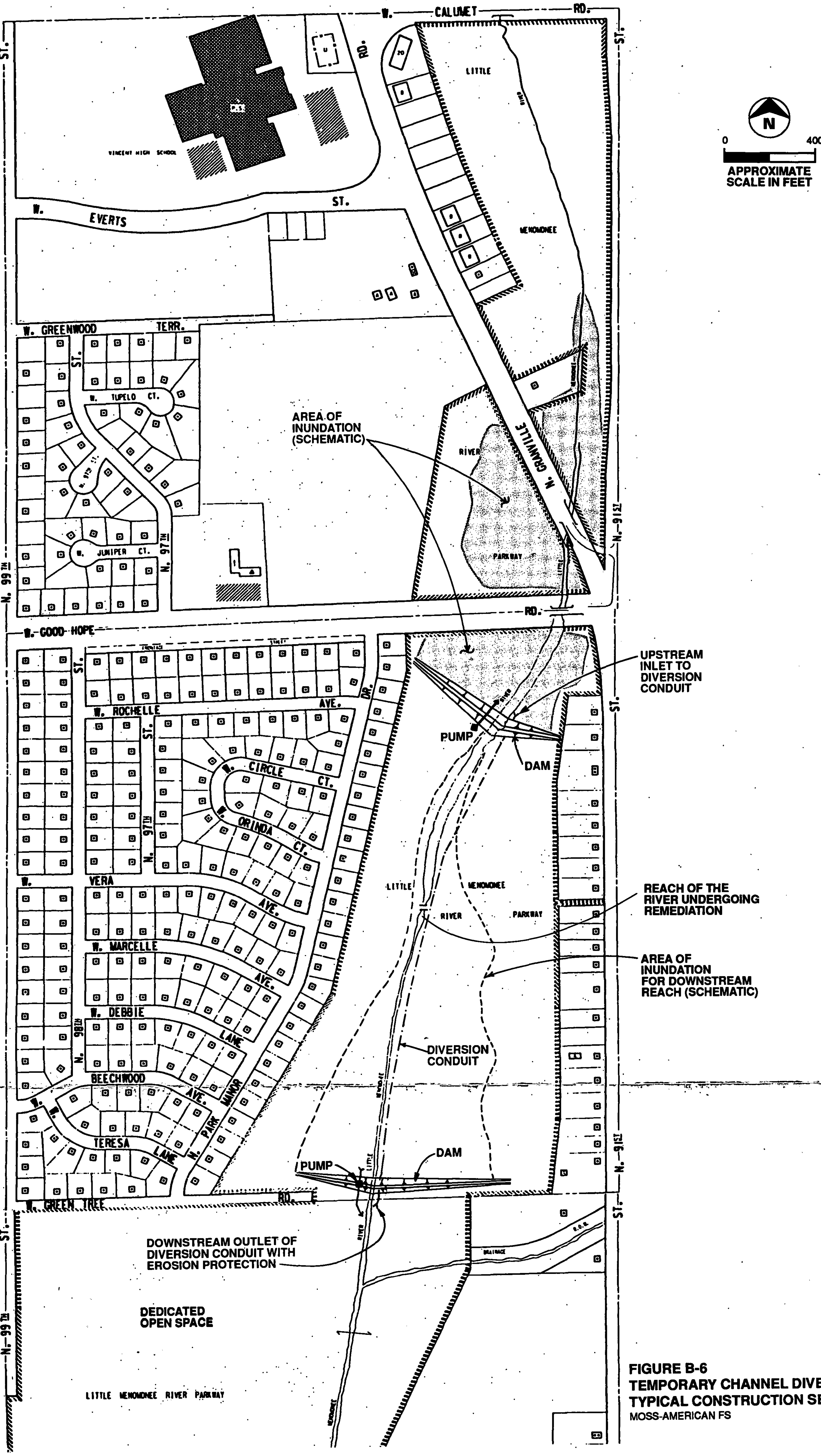


FIGURE B-6
TEMPORARY CHANNEL DIVERSION
TYPICAL CONSTRUCTION SEQUENCE
MOSS-AMERICAN FS

Detention Facilities

Detention of runoff at each point of diversion would reduce the size of conduit needed to convey runoff around a particular channel reach. The conduit would be placed on the ground rather than laid in a trench to reduce the loss of vegetation and excavation costs. The conduit is discussed in the next subsection.

A low-head dam with an ungated outlet would be placed across the river at each required point of temporary detention. The outflow from each site would be automatically regulated according to the volume of stored runoff. The required storage volume behind each dam would be the volumetric difference between the base inflow rate and the design outflow rate over the time needed to excavate a particular channel reach. The determination of the height of each embankment would require an analysis of upstream property flooding potential.

The placement of the dams would depend on the available storage capacity at various dam sites and the rate that construction (sediment removal) could proceed between adjacent dams. Potential dam sites are behind existing roadway embankments. At these locations, short earthen embankments or cofferdams could be used to restrict the outflow through the culvert. Earthen embankments or cofferdams would also be used at intermediate locations between roadway crossings. A dam would also be needed at the downstream end of each river reach to prevent flooding back into the reach.

A drainage system would be needed at the downstream side of each dam embankment to collect groundwater seepage into the area being dewatered for excavation. The system could consist of a toe drain system or a system of well points. The purpose of these systems would be to reduce erosion of embankment material and dewater the isolated river reach. Water seeping through the embankment would be collected and pumped back into the flood pool upstream of the dam.

A number of alternative approaches to diverting runoff could be used in lieu of the approach presented above. Use of sheet piling to isolate small sections and pumping the river flow around the isolated area, for example, might be demonstrated to be an acceptable approach. As stated earlier, the methods presented in this appendix are conceptual and the methods that will be used will be determined in the design phase.

Diversion Facilities

Detained runoff would be diverted into an open drainageway (ditch or trench) or into a closed conduit (PVC or other type of flexible conduit) from each temporary impoundment along the channel. The conduit would be laid across the channel overbank opposite to the side of construction access. The water surface elevation behind each dam would provide the potential energy needed to convey the diverted flow into the existing river downstream of the isolated reach. The conduit size would depend upon storage characteristics of each pond, type and length of pipe material, and ground surface slope between the pond and the point of discharge. The conduit length would also have to span the length of channel to be treated. A flexible conduit could be used to avoid mature vegetation and constructed to follow the natural course of the channel bank.

Pumping Facilities

Two pumps would be needed for each reach to be excavated. A pump at the downstream end of the isolated reach would discharge any pooled water into the downstream channel. It is assumed that the trapped water would not contain appreciable amounts of contaminated suspended sediments. Sampling and testing could verify that this water is uncontaminated. A second pump at a sump, located along the downstream embankment of the upstream dams, would collect seepage through the dam and discharge it back into the flood pool upstream of the dam. These two pumping facilities are proposed for removing water between the two adjacent dams.

Erosion Control Facilities

Runoff collected in each detention pond would be diverted back into the existing channel downstream from each isolated reach. Erosion control techniques would be used to reduce soil erosion at these locations. Erosion would be controlled by riprap aprons, preformed scour holes with revetment, or other appropriate methods. Erosion control design would vary according to the discharge characteristics at the diversion conduit outlet and the existing hydraulics of the river.

CONSTRUCTION ACCESS

Potential construction access routes to the site would be from existing public roads. Generally, access would be needed between all points where the river intersects public roads because of inadequate vehicular clearance through culverts. The number of access points could be reduced if a temporary construction road were built along the channel.

RESTORED RIVER AND FLOOD PLAIN HYDRAULICS

The original river would be restored in its existing channel and according to its original size and capacity. Tributary channel transitions to the river would also be restored. Embankment material used for the detention ponds could be evenly graded across the restored channel bottom to original elevations. Additional material, suitable for the channel bottom, would be chosen to replace the excavated channel bottom material.

Flood plain hydraulics would be temporarily affected during construction activities. Construction activities, however, would be limited to dam sites and diversion conduit locations. These construction activities would not significantly disrupt overbank flood-carrying capacity. The restored channel capacity could be increased to reduce potential flood hazards or damages within the flood plain. Vegetation along the channel banks would also be replaced.

REGULATORY ISSUES

Federal, state, and local regulatory issues are summarized in Appendix A with the discussion of site-specific ARARs.

Mitigation measures to minimize the impacts to wetlands would include the measures addressed under the regulatory issues section for permanent river relocation.

COST EVALUATION

Cost opinions for the temporary river relocation are discussed in Appendix I.

GLT595/082.51

Appendix C
VOLUMES OF CONTAMINATED MEDIA

Appendix C
VOLUME OF CONTAMINATED MEDIA

This appendix describes the methodology and presents the results of volume calculations for contaminated media. Volumes of material having levels of contamination exceeding target concentrations for remedial action goals identified in Chapter 2 were estimated for each medium. The volumes are used in the development and evaluation of remedial alternatives for the site.

In this FS report, "contaminated" means that concentrations of contaminants in the media are above background levels. The extent of contamination in any media group does not necessarily define the extent of removal or volume of media to be managed. Potential criteria determined from the remedial action goals (i.e., "action levels" or "removal criteria") are discussed in Chapter 2.

SOIL

The volume of contaminated soil onsite was estimated using four different criteria:

- Soil exceeding risk-based risk target concentrations
- Soil above the water table exceeding risk-based target concentrations risk and soil below the water table with pure phase (oil)
- Visibly contaminated soils
- Soils containing pure phase

SOIL EXCEEDING RISK-BASED TARGET CONCENTRATIONS

Carcinogenic PAHs are the principal contributors to risk posed by the soil. (The RI found that other contaminants are relatively insignificant in terms of risk to human health.) Target concentrations for carcinogenic PAHs that correspond to various risk levels in soil are listed on Table C-1. The estimated excess lifetime cancer risk is based on the residential exposure setting described in the RI report (Chapter 4). The carcinogenic PAH concentration is the sum for the following chemicals: benzo[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, benzo[g,h,i]perylene, chrysene, dibenzo[a,h]anthracene, and indeno[1,2,3-cd]pyrene.

The extent of soil contamination based on carcinogenic PAH concentrations for the area within the former property boundaries at the Moss-American site is shown in Figures C-1 and C-2 (reproduced from the RI report). The extent of soil contamination outside the former property boundaries, particularly for the flood plain deposits along the Little Menomonee River, could not be determined based upon existing data.

Table C-1
RISK-BASED TARGET CONCENTRATIONS FOR SOIL

Excess Lifetime Cancer Risk	Total Carcinogenic PAH Concentration (mg/kg)[a]
10^{-6}	0.061
10^{-5}	0.61
10^{-4}	6.1

[a]A summation of carcinogenic PAH concentrations assumes all carcinogenic PAHs have the same potency.

Detection levels for individual PAHs ranged between 0.33 and several hundred mg/kg. Thus, the lowest possible quantitation limit for the sum of the eight carcinogenic PAH compound is about 1 mg/kg. This is roughly equivalent to a risk level between 10^{-5} and 10^{-4}. Laboratory results, however, often included estimated concentrations when compounds were positively identified but present below the quantification level. Therefore, to estimate the volume of soil having concentrations exceeding the 10^{-6} targets, it was necessary to make some qualitative judgments based upon measured values of extractable organics and from field observations. To use the 1×10^{-6} concentrations as targets for cleanup levels, it will be necessary to review whether these levels can be measured accurately in the field during the remedial action.

Contaminated soil volumes were calculated based on the areal extent of contamination, the thickness of contamination, and the carcinogenic PAH concentration. The methods used to estimate each parameter and the results are described below.

Extent of Soil Contamination

On the basis of the field screening results and the analytical data, the RI report (Chapter 3) identified the processing area and vicinity, the settling ponds, treated storage areas, the fill area, the northeast landfill, and the southeast landfill as contaminated. The presence of contaminants in these areas was confirmed with compound-specific analyses. The boundaries of these areas were originally defined based on historical use at the facility. Because it was not possible to measure 10^{-6} risk-based PAH concentrations, the area of contamination considered in this FS was expanded somewhat beyond the limits shown in Figure C-1.

Specifically, the area of contamination was expanded to include part of the drip tracks, the entire process area, and the entire treated storage area. The expanded area of contamination is shown in Figure C-2. The drip track area is included

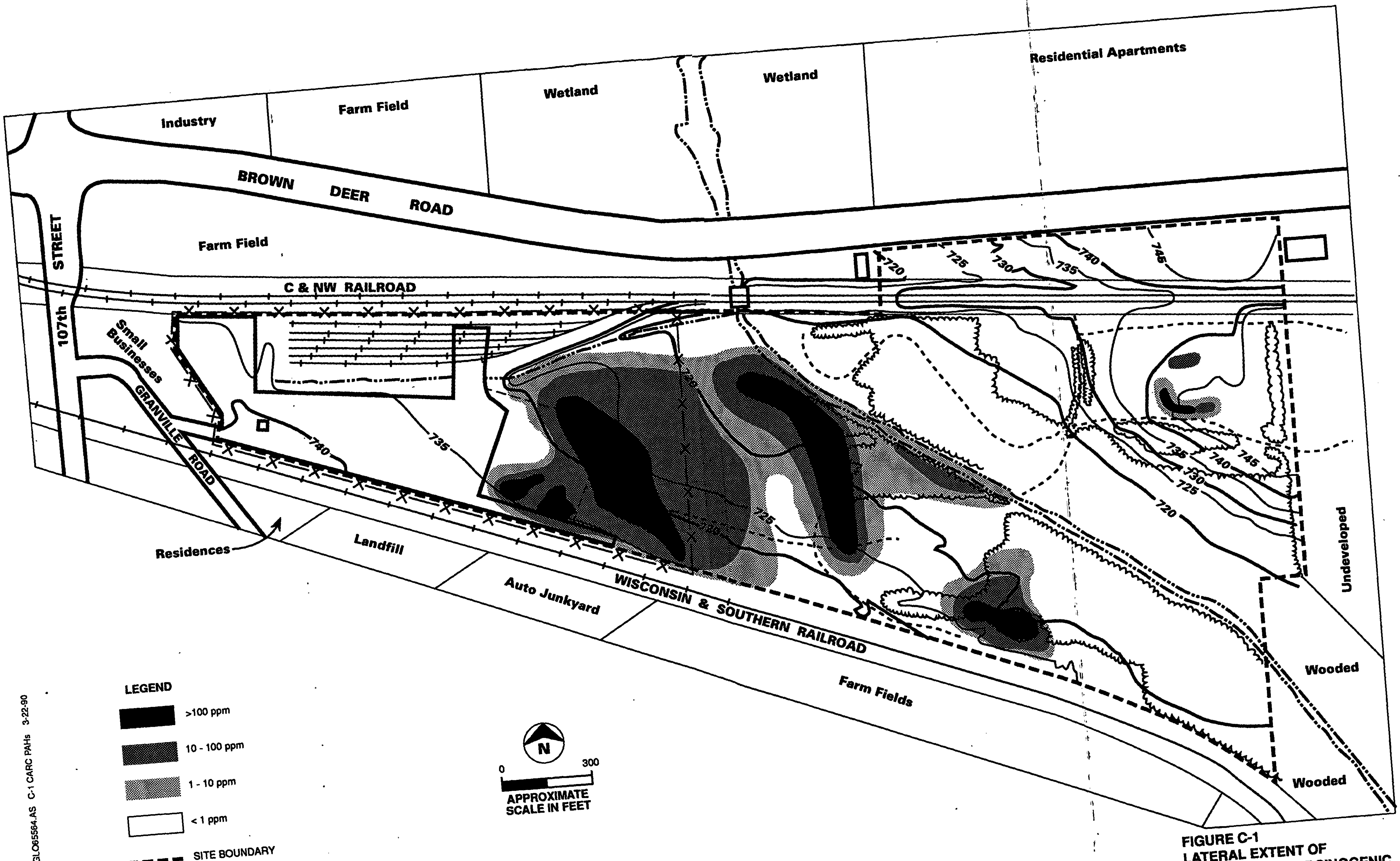
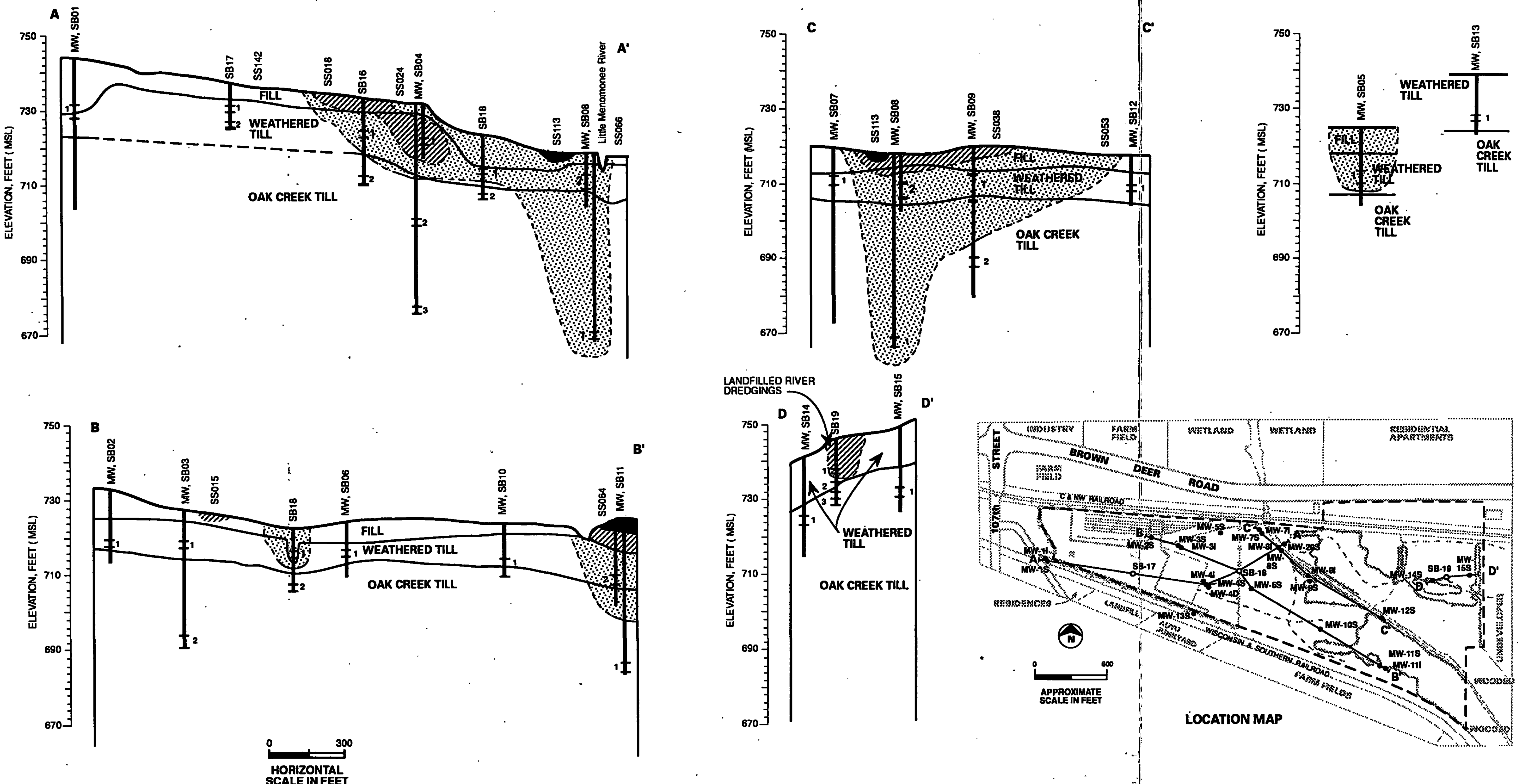


FIGURE C-1
LATERAL EXTENT OF MEASURABLE CARCINOGENIC PAH CONTAMINATION
MOSS-AMERICAN FS



LEGEND

(blank)	< 0.1 ppm
(stippled)	0.1 - 30 ppm
(hatched)	30 - 1000 ppm
(solid)	> 1000 ppm

SB = SOIL BORING SAMPLE
SS = SURFACE SOIL SAMPLE
MW = MONITORING WELL LOCATION

FOR MORE INFORMATION ON THE CROSS-SECTIONS PLEASE REFER TO THE TECH MEMO FOR TASKS FI & FS

GLO65564.FS C-2 VERT EXT PAH 3-22-90

FIGURE C-2
VERTICAL EXTENT OF MEASURABLE PAH CONTAMINATION
MOSS-AMERICAN FS

[illegible]

because of slightly elevated extractable organic concentrations in one sample and a thin seam of visible contamination in the area. The process area and storage areas are included because of visible contamination.

The site was divided according to past land use and each of the historical use areas was considered separately in estimating the volume of contaminated soil. The site was divided according to past land use because the soils and contaminant distribution within each area exhibit physical similarities. For example, the sludge disposal area consists of a layer of coarse gravel over a dark brown silty-clay with no visible evidence of contamination throughout. The treated storage area, however, has a silty, sandy, and gravelly fill, over a layer of wood chips that lies above a black silty clay. The gravel fill often includes cinders, and the black silty clay grades into apparently uncontaminated sediments (based on visual observations). The fill area, solid waste pile, and southeast landfill each had bricks, old rail ties, wood, metal scraps, and other rubbish in a black silty soil matrix.

The contaminant distribution in the processing area and vicinity is variable. The variability is evident from the carcinogenic PAH concentrations, which range from zero to 1,900 ppm, and from visual observations, which range from apparently clean soil to oil-saturated soil. From the observed variability, it is clear that the actual volume of contaminated soil (determined during predesign or construction phase) could differ significantly from the estimated volume.

Thickness of Contaminated Soil

The thickness of contaminated soil was estimated for each sample point based on:

- Detectable carcinogenic PAH concentrations from specific soil horizons
- Presence of visibly contaminated soil
- High extractable organic concentrations from specific soil horizons (high levels of extractable organics [EO] were presumed to represent high levels of PAHs)

An average contaminated thickness for each land use area was then estimated by arithmetically averaging the estimated thicknesses for all the sample locations within each area.

Visual contamination was defined by the presence of tarry or oily soil. Visual observations were supplemented with a distinct creosote odor. The visual detection level correlated with an EO of about 1,000 mg/kg. Therefore, soil with an EO level of over 1,000 mg/kg was assumed to exceed 10^{-6} targets. Field observations were verified with results from a limited number of analytical samples.

The thickness of contaminated soil in the sludge disposal area, dredgings area, and solid waste pile was estimated based on the thickness of the soil type in which contamination was detected.

In most areas, the thickness of the contaminated soil was equivalent to the depth of contamination, since the soil contamination resulted from deposition and subsequent percolation of contaminants from the land surface. In a few areas, however, the contamination appears to be below clean fill on the surface. The sludge disposal area in particular consists of visibly clean coarse gravel over finer soils with measurable PAH concentrations. This also occurs in the process and localized areas in parts of the treated storage area. The estimated thickness does not include overlying material where it does not appear to be contaminated.

(NOTE: Soil boring logs are in Appendix F, Attachment F-1 of the RI report. Test pit logs are summarized in Appendix E, Table C-1, and C-2 of the RI report; however, the thickness of contamination and stratigraphy is not included on the summary tables. This information was obtained from the original logs.)

Average Carcinogenic PAH Concentration

The carcinogenic PAH concentration used to represent each of the land-use areas is shown in Table C-2. The concentrations listed are the arithmetic average of all the samples from within each area. Individual carcinogenic PAH concentrations are shown on Figure C-3. For samples with no detectable carcinogenic PAHs, a value of zero was assigned.

Data are limited for the dredgings area along the river, the sludge disposal area, and the solid waste pile. Because of the physical similarities of the soil and apparent contaminant distribution within these three areas, it is reasonable to assume comparable contaminant levels throughout each area.

Soil Volume

The estimated volume of contaminated soil for each area is shown in Table C-2. According to the estimate, approximately 210,000 cubic yards of soil on the site are contaminated. Because the 10^{-6} target of 0.061 mg/kg is below the detection limit of the samples analyzed, it is not possible to distinguish between the volume of soil that is "contaminated" (i.e., detectable levels of carcinogenic PAHs), and soil that exceeds the 10^{-6} target. However, average carcinogenic PAH concentration exceeded the 10^{-4} risk value for all contaminated areas except the sludge disposal area.

Figure C-4 illustrates the relationship between average carcinogenic PAHs and volume of soil. Each successive data point in the figure represents an area with the average carcinogenic PAH concentration and associated volume indicated. The figure provides a general indication of the volume of soil requiring management for a given set of cleanup level.

Spatial variability in carcinogenic PAH concentration across the site affects the level of confidence in volume estimates that are based on the calculated average concentration. The difference between estimated and actual volumes for each area may be significant, especially for the three areas that were classified on the basis of a single sample.

Spatial variability was most evident in the processing area and vicinity and along the buried settling pond trench. The soils in both of these areas have been reworked since the facility was dismantled. The most contaminated soils from the process area were excavated, shipped to a hazardous waste landfill, and sludge from the settling

Table C-2
ESTIMATED VOLUME OF CONTAMINATED SOIL

Location/Area	Approximate Surface Area (ft^2)	Average Thickness (ft)[a]	Carcinogenic PAH Conc[b] (mg/kg)	Soil Exceeding 10^{-6} Risk (yd^3)[c]	Unsaturated Soils and Saturated Soil with >10 ppm or free product (yd^3)[c]	Visibly Contaminated Soils (yd^3)[c]
Processing Area	120,000	10	400	45,000	45,000	55,000
Processing Vicinity	280,000	2	40	20,000	20,000	included above
Settling Ponds[d]	40,000	10	500	15,000	15,000	included above
Treated Storage	400,000	2	40	30,000	30,000	included above
Fill	60,000	3	1,000	7,000	7,000	9,000
Dredgings	30,000	0.5	60[e]	600	600	0
Sludge Disposal	140,000	0.5	1[e]	3,000	3,000	0
Solid Waste Pile	20,000	3	8	2,000	2,000	2,000
Southeast Landfill	60,000	4	700	9,000	9,000	11,000
Northeast Landfill	10,000	4	600	1,500	1,500	1,000
Deep Soils				75,000	0	0
TOTAL				210,000[e]	130,000	80,000

[a]Based on data from test pit logs and soil borings.
[b]Arithmetic average of measurements from within the area.
[c]Volume of contaminated soil in bank cubic yards. Add 0 to 20% for loose cubic yards.
[d]Data is questionable due to variability within the area.
[e]Rounded to two significant figures.

GLT938/110.51

ponds was excavated and buried in the northeast landfill. Clean fill was then added to both areas. The process area soils were again reworked when the automobile transfer station was established.

The sample collection procedure biased measured PAH concentrations. Although test pit locations were selected to obtain representative coverage of contaminated areas, samples within each test pit were collected from areas that appeared to be the most contaminated soil (based on visual screening). This would suggest that the estimate for the volume of contaminated soil is a conservative one. The actual volume removed, however, could be increased by the inability to effectively separate clean from contaminated soil. If contaminated soils are excavated, the total volume of soil requiring treatment may be more than estimated because of mixing with less contaminated soil.

UNSATURATED SOILS GREATER THAN 10^{-6} RISK AND SATURATED SOILS GREATER THAN 10 PPM CARCINOGENIC PAHS OR CONTAINING PURE PHASE

Contaminated soils based on this criteria were determined because:

- It is unlikely that residential development would occur below the water table; therefore, the 10^{-6} risk criteria may not apply below the water table.

- Surface water criteria would probably be met when carcinogenic PAH concentrations in saturated soil are less than 10 ppm. (The presence of free product would clearly indicate greater than 10 ppm carcinogenic PAHs.)

This volume is the same as the 10^{-6} risk volume with the exception of the deep contamination detected at 50 to 60 feet below the source area and settling ponds which is estimated to be about 80,000 cubic yards. Therefore, the volume of contaminated soil that meets these criteria is estimated to be 130,000 cubic yards.

VISIBLY CONTAMINATED SOILS

The volume of contaminated soil based on visible contamination was estimated in an effort to use available data to estimate highly contaminated areas. The extent of visible contamination was determined during the remedial investigation and is shown in the RI report in Figure E-7. The estimated volume of visibly contaminated soil is 80,000 cubic yards.

VISIBLE PURE PHASE IN SOIL

The volume of visible pure phase in soil was estimated to determine the volume of soil that would need to be removed to remove pure phase from the groundwater. Removing pure phase (and associated heavily contaminated soils) may reduce the time required for groundwater collection and treatment.

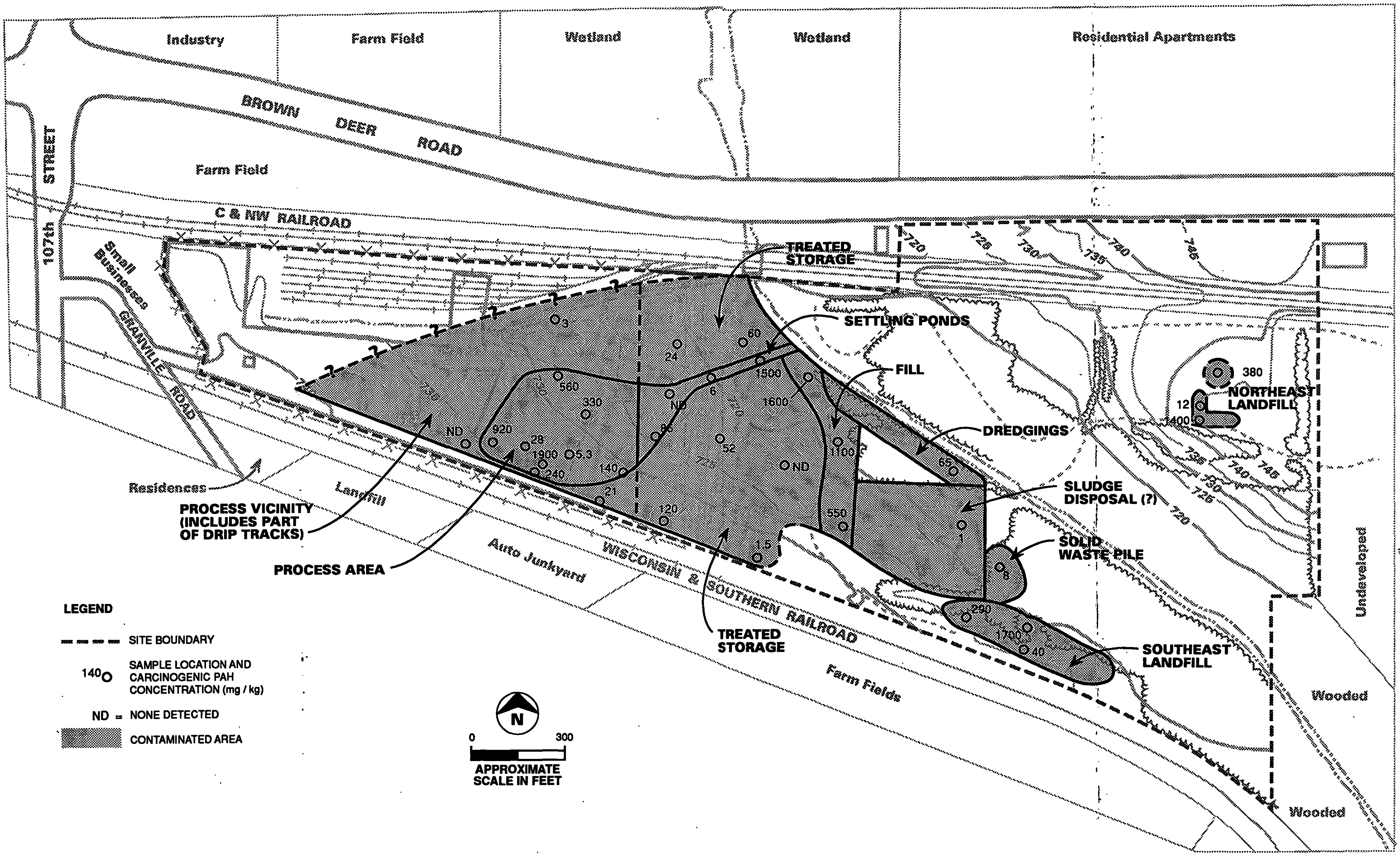
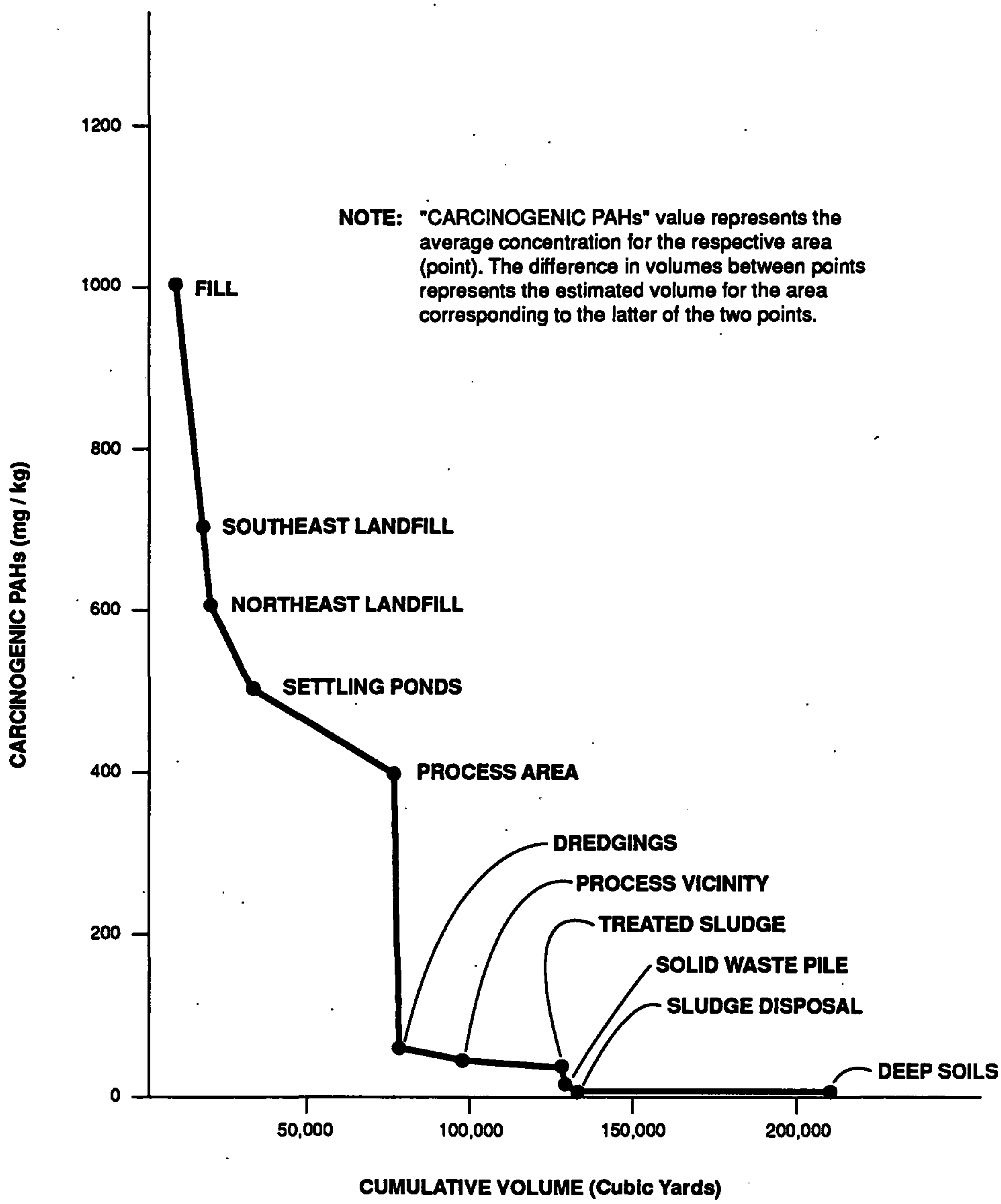


FIGURE C-3
SOIL EXCEEDING REMEDIAL ACTION GOALS
MOSS-AMERICAN FS

GLO65564.AS FIG C-3 3-23-90mms



GLO6564.AS C-2 VOL SOIL CARC PAH 3-26-90

FIGURE C-4
VOLUME OF SOIL EXCEEDING CARCINOGENIC PAH CONCENTRATIONS
MOSS-AMERICAN FS

Pure phase was observed in the processing area, settling pond area, southeast landfill and northeast landfill. The estimated total volume of soil containing visible pure phase is 50,000 cubic yards.

OVERSIZE MATERIAL

Areas of the treated storage area and southeast landfill were observed to contain substantial amounts of large debris, such as railroad ties, boulders, and construction rubble. The quantity of this "oversize" material is unknown, and no effort was made in the RI to collect information to quantify it. For the purposes of this FS, the volume of oversize is assumed to be about 3,000 cubic yards.

FLOOD PLAIN SOILS

Soils in the flood plain and dredgings along the Little Menomonee River downstream from the facility may be contaminated with creosote. Creosote contaminated sediments could have been deposited on flood plains during floods.

Thirty locations were sampled for concentration of extractable organic compounds and checked for an oily appearance. Eleven of those areas are within the boundary of the former facility. No visible contamination or elevated extractable organic concentrations were noted in samples from dredgings piles, the river bank (where river was channelized), and most of the flood plain areas. Two flood plain samples—SS1007 and SS1011—contained visible oil, but the samples were not analyzed for TCL/TAL. SS1007 was collected from a swampy area north of Leon Terrace and SS1011 was from a low area on the west bank 1,500 feet south of Good Hope Road.

The data available are insufficient to estimate the volume of contaminated soil in the Little Menomonee River flood plain. The issue of flood plain soil contamination should be addressed in a subsequent phase of the RI/FS/RD/RA process. The results are not expected to influence the selection of an appropriate remedy for the original site and river.

GROUNDWATER

This section addresses the estimated extent and volume of contaminated groundwater. The estimate is based on information presented in the RI report in Chapter 3, Appendix E, Appendix F, and the analytical data in Appendix O.

The federal Ambient Water Quality Criteria Document for PAHs (U.S. EPA 1980), Wisconsin Water Quality Criteria (NR-105), and Wisconsin Groundwater Quality Standards (NR-140) were the basis for defining the contaminated groundwater. The standards are summarized in Appendix A. These criteria, which include "to-be-considered" (TBC) criteria, were used because the goal for the groundwater operable unit is to prevent migration of contaminants into the river.

EXISTING GROUNDWATER DATA

Lateral Extent

The estimated lateral extent of groundwater contamination is shown in Figure C-5. The analytical data in the boxes include organic compounds detected in the groundwater samples, including estimated values (J-qualified data). No inorganic contamination was detected in the filtered groundwater samples. The groundwater was sampled from a 5-foot interval at the base of the weathered till or alluvium. An oil sheen was present on the sample from MW-4. The data from MW-8 were unusable because the sample contained approximately 25 percent creosote oil.

The lateral extent of contamination extends from the processing area to the river in a band that could be up to 400 feet wide. The shaded area on the map shows the maximum expected width of the band. The contaminated plume follows the groundwater gradient at the site, which is northeasterly toward the river (Appendixes I and J in the RI report address the groundwater flow system and contaminant velocity calculations). Groundwater contamination was not detected in the upgradient wells (MW-1S, MW-1D, MW-13).

Based on the PAHs detected in MW-2, there is an apparent migration of contamination to the north. This may occur because a storm drain crosses beneath the parking lot from south to north (it empties into the ditch near MW-2). During periods of high groundwater levels, the drain could cause a localized groundwater gradient to the north. This would cause contaminant migration from the source area in the direction of MW-2. Contaminants observed in MW-2 might also be the result in drainage from the west end of the parking lot and from the rail unloading area that passes through the ditch near MW-2. This runoff could contribute, or be responsible for the contamination at MW-2. (The parking lot and unloading area are part of the existing business at the site and are not related to past site operations.)

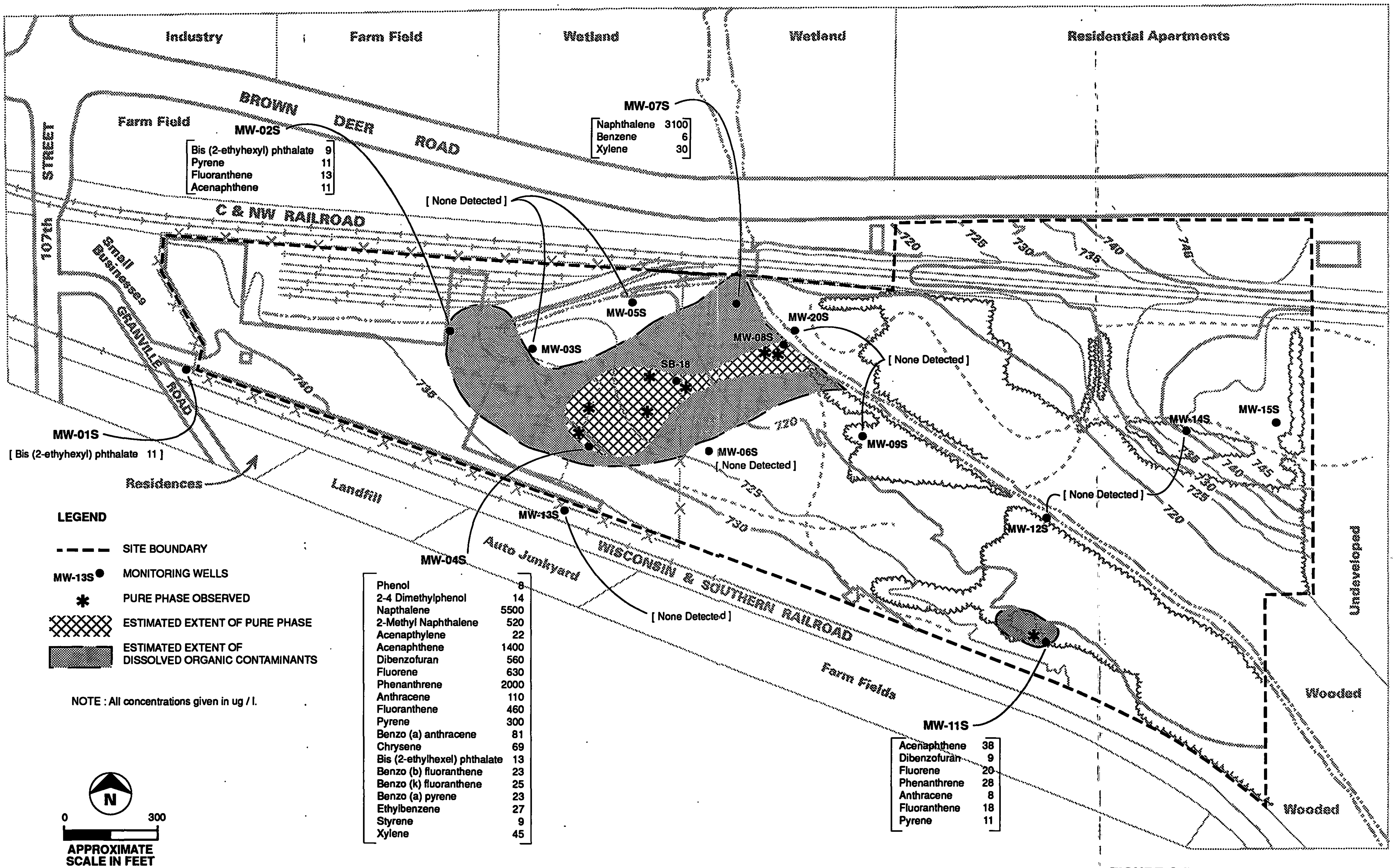
Groundwater was also found to be contaminated in a localized area near the southeast landfill around MW-11. The extent of this area is assumed to be equal to the extent of soil contamination.

Vertical Extent

The observed vertical extent of groundwater contamination was limited to the shallow zone of the alluvium and weathered till at the site. This zone is 10 to 20 feet thick. While groundwater contaminants were not observed at depths greater than 20 feet, oil stains at a depth of 27 feet were observed on soil surfaces within the unweathered Oak Creek till at MW-4. The Oak Creek Formation is a hard and thick silty-clay till that appears to form a continuous confining layer beneath the site. The vertical extent of contamination is depicted in Figure C-6.

Volume of Contaminated Groundwater

The volume of contaminated groundwater was estimated by dividing the contaminated area into four separate areas (based on the estimated saturated thickness of each area). Within each area, surface area and the saturated thickness of groundwater above the unweathered till was computed from the map and information in the RI



GLO65564.AS C-5 (FIG 3-15) 5-16-90

FIGURE C-5
ESTIMATED EXTENT OF CONTAMINATION IN SHALLOW GROUNDWATER
MOSS-AMERICAN FS

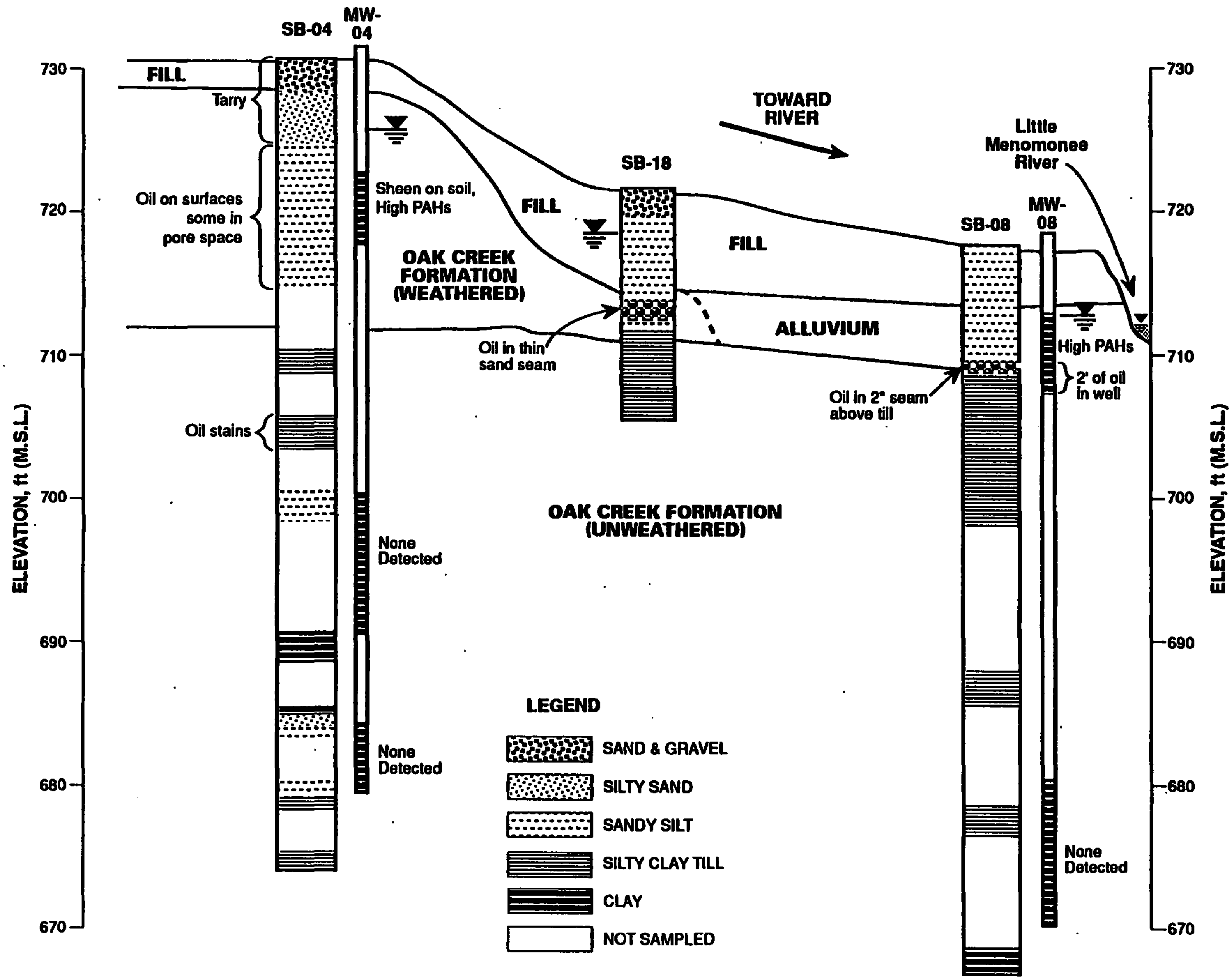


FIGURE C-6
VERTICAL DISTRIBUTION OF CONTAMINANTS IN SOIL BORINGS AND WELLS
MOSS-AMERICAN FS

report. The porosity of the soil was assumed to be 0.3. The volume of contaminated groundwater within each area was calculated as follows:

$$\text{area} \times \text{saturated thickness} \times \text{porosity} = \text{volume}$$

The total estimated volume of contaminated groundwater on the site is 1.8 million ft^3. The values used in the calculation and other hydraulic data are shown in Figure C-7.

Extent of Pure Phase Contamination

Pure phase observed with the groundwater in shallow test pits and soil borings is marked with a star in Figure C-8, and the estimated extent of the pure phase is indicated by the cross-hatched area. The three borings shown in Figure C-6 illustrate the vertical distribution and migration of pure phase at the site.

Pure phase in SB-4, near the original source area (processing area), extends from depths of approximately 8 to 18 feet as stringers in pore spaces or coatings on soil surfaces. Pure phase appears to migrate downslope along the axis of the old settling ponds from the processing area toward the river. Migration appears to be along the sand seams as noted in SB-18 and SB-8. Migration may also occur through the trench of the old settling ponds. During the RI, a culvert containing oil stringers was discovered between two of the backfilled ponds (just west of SB-18). It is not known if the oil is migrating or was simply trapped there when the ponds were backfilled.

The migration of creosote was observed at MW-8. During drilling, a 2-inch sand seam was noted at a depth of 8 feet. The screen for MW-8 straddles this seam and extends about 2 feet into the till. Two feet of creosote migrated into the well between the time the well was constructed and the time it was sampled, which was approximately 1 month. Apparently the portion of the well that extends into the till acted as a sump to collect the creosote.

SEDIMENT

This section presents the rationale used to estimate volumes of contaminated sediment that are to be removed or otherwise managed in the proposed remedial action alternatives. In this FS, volume estimates were calculated based on three methodologies. One methodology estimates volumes based upon risk-based "target concentrations" that quantitatively define sediment having concentrations of contaminants exceeding acceptable limits, for example, concentrations that would pose a 1×10^{-6} excess lifetime cancer risk to an exposed population. Removal of this sediment would result in a residual risk less than 1×10^{-6}. A second estimate is based upon removing sediment having concentrations that exceed maximum probable background levels. The third approach to estimating volume uses qualitative information to estimate sediment volumes that appear to be grossly contaminated and contain pure phase. Removal of this volume of sediment would likely eliminate much of the contamination. If an acute risk (skin irritation) is currently present, this would likely be eliminated by removing the first and second methods, and significantly reduced by removing the volume estimated using the third method.

The excess lifetime cancer risk concept is discussed briefly in a preceding section on the volume of contaminated soil and in detail in the RI report. The risk-based target concentrations for sediment are given in Table C-3. These targets for protection of human health are based upon a recreational exposure setting. Also presented in Table C-3 are sediment quality criteria for protection of aquatic life. These sediment quality criteria, recently developed by the Wisconsin DNR, are derived from state water quality criteria and are based upon an equilibrium partitioning approach consistent with proposed methodology being developed by the U.S. EPA.

CONTAMINANT DISTRIBUTION

The distribution of carcinogenic PAHs in the river are shown in Figure C-9. The depth of the soft sediment is illustrated by the sample results shown on the cross-sections in Attachment B-2 to Appendix B in the RI report. Visual observations of sediment samples are given in Attachment B-4, also in the RI report. Pertinent data from the RI report are summarized in Table C-4 and are arranged such that each row represents information obtained from a particular location along the length of the river. Major road crossings are given in Table C-4 to indicate the general location of each sample. Exact locations are given on the map series attached to Appendix B in the RI report.

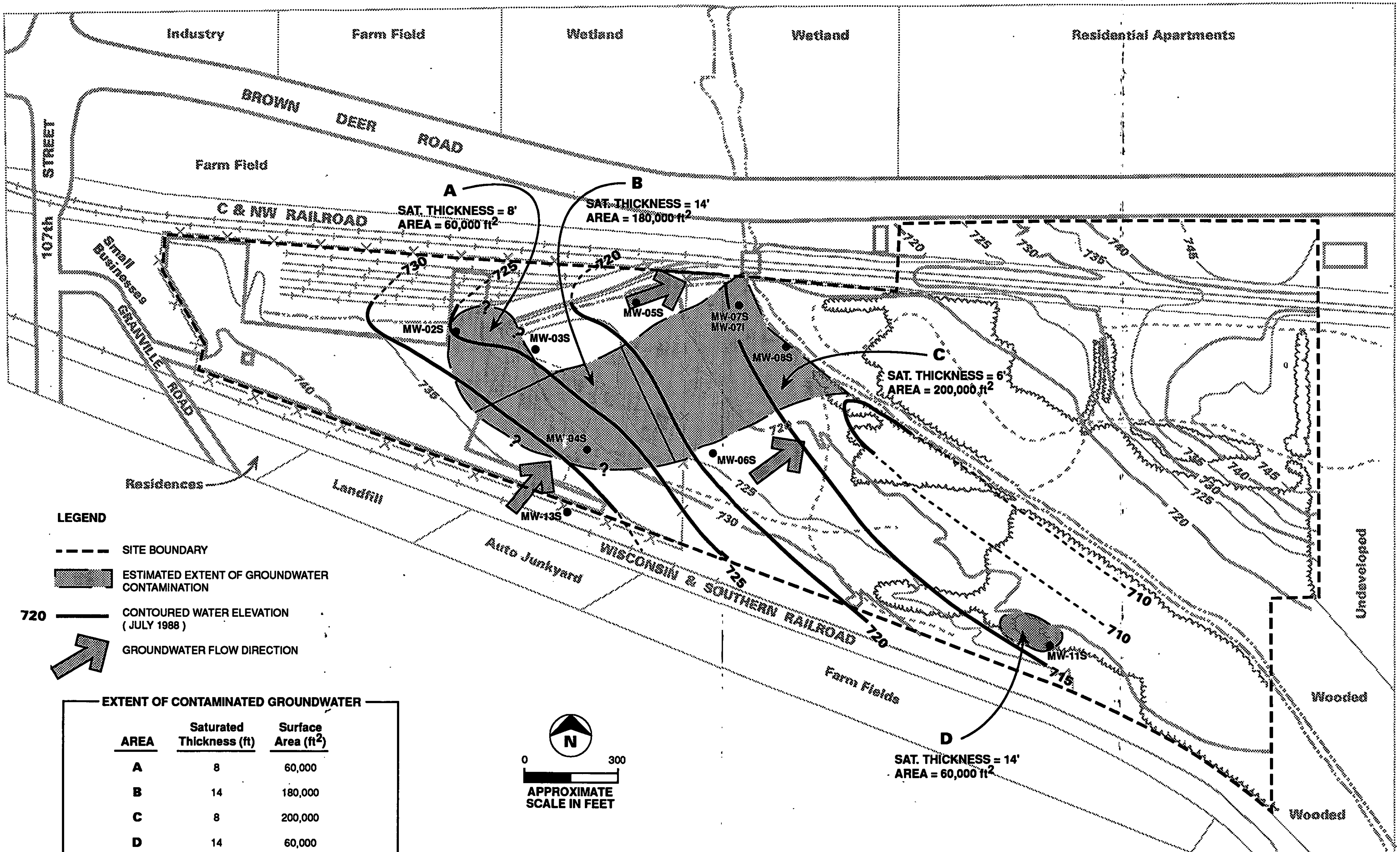
Visual observations are summarized by the histogram on the left side of Table C-4. Visual criteria for classifying contaminant levels in soils were: (1) no visual contamination; (2) a sheen was produced on the water when the sample was collected; (3) a sheen was visible on the soil; and, (4) the soil contained visible oil (pure phase).

For comparison, carcinogenic PAH concentrations are also shown. Carcinogenic PAHs ranged from none detected to 570 mg/kg. Total PAHs ranged up to almost 10,000 mg/kg, or 1 percent of the total sediment/water/oil mixture.

Table C-4 also shows the estimated cross-sectional area of soft sediment for several sections of the river. This information is used to calculate the total volume of soft sediment in the river.

Figure C-3 and the visual observations summarized in Table C-4 indicate a slight decrease in contaminant levels downstream from the site. The most contaminated sediments occur between the site and Mill Road where 33 of 63 samples contained visibly contaminated sediments. Only 3 of the 42 samples downstream of Mill Road contained visibly contaminated sediments. Carcinogenic PAH data show a similar distribution.

The RI concluded that elevated PAH concentrations are present in varying amounts over the entire length of the 5-mile reach of the Little Menomonee River downstream from the site. It is important to note that the RI did not intend to precisely map the extent of contamination. Based on the information in the RI report, it is not possible to identify the exact distribution of oily sediment throughout the river. The contaminant distribution and the volumes calculated in this section are based on a statistical interpretation of the data.

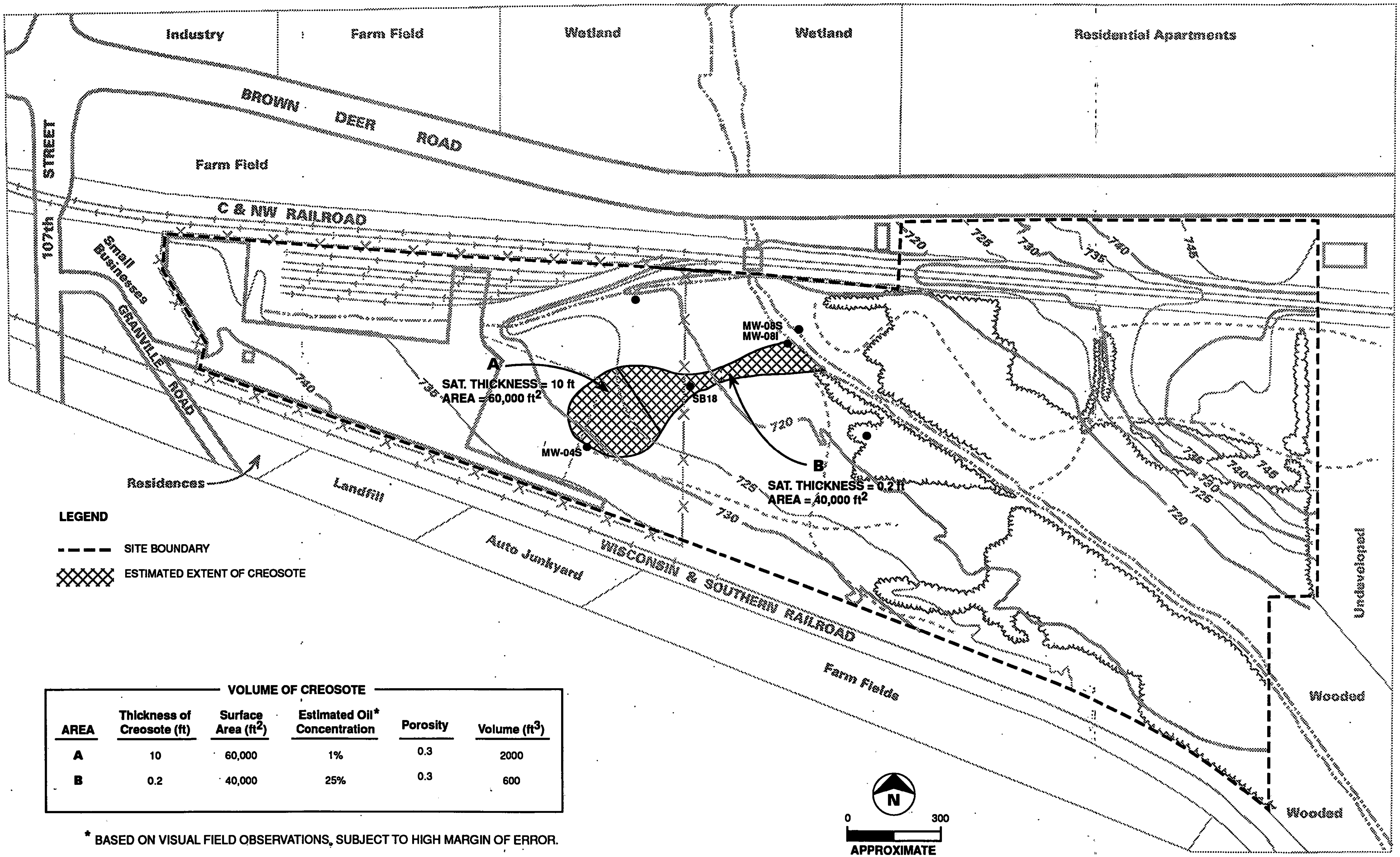


EXTENT OF CONTAMINATED GROUNDWATER

AREA	Saturated Thickness (ft)	Surface Area (ft^2)
A	8	60,000
B	14	180,000
C	8	200,000
D	14	60,000

GLO65564.AS FIG C-7 Est Vol Contam Grdwtr 3-22-90

FIGURE C-7
ESTIMATED EXTENT OF CONTAMINATED GROUNDWATER
MOSS-AMERICAN FS



LEGEND

- - - - SITE BOUNDARY

XXXXX ESTIMATED EXTENT OF CREOSOTE

VOLUME OF CREOSOTE

AREA	Thickness of Creosote (ft)	Surface Area (ft^2)	Estimated Oil* Concentration	Porosity	Volume (ft^3)
A	10	60,000	1%	0.3	2000
B	0.2	40,000	25%	0.3	600

* BASED ON VISUAL FIELD OBSERVATIONS, SUBJECT TO HIGH MARGIN OF ERROR.

GL065564.AS Est Vol of CREOSOTE 3-23-90

FIGURE C-8
ESTIMATED VOLUME OF CREOSOTE
MOSS-AMERICAN FS

MOSS AMERICAN SEDIMENT RISK — Table C-3

(ref compounds listed in RI table M-27 & WDNR SQCs)

RISK BASED TARGET CONCENTRATIONS FOR CARCINOGENS IN SEDIMENTS

Chemical	U.S.EPA Carcinogen Classification	Cancer Potency Factor (kg-day/mg)	Source[a]	Risk-specific concentrations at cancer risk levels: 1E-04 mg/kg	1E-05 mg/kg	1E-06 mg/kg	DNR SQC mg/kg
Arsenic	A	2	b	2230	223	22	
Benzo[a]anthracene	B2	11.5	c	388	39	4	
Benzo[b]fluoranthene	B2	11.5	c	388	39	4	
Benzo[k]fluoranthene	B2	11.5	c		39	4	
Benzo[a]pyrene	B2	11.5	c	388	39	4	3
Benzo[g,h,i]perlyene	B2	11.5	c	388	39	4	
Chloroform	B2	0.0061	IRIS	730984	73098	7310	87
Chyrsene	C	11.5	c	388	39	4	
Dibenz[a,h]anthracene	B2	11.5	c	388	39	4	
Indeno[1,2,3-cd]pyrene	B2	11.5	c	388	39	4	
Methylene chloride	B2	0.0075	IRIS	594533	59453	5945	4
PAHs (carcinogenic)	B2/C	11.5	c	388	39	4	3
2,3,7,8-TCDD (Dioxin)	B2	156000	HEAST	0	0	0	0

EXPOSURE ASSUMPTIONS:

Exposure setting:	Recreational Based on Sediment Ingestion
Soil intake (g/day)	0.1
Body weight (kg)	70
Number of days/week exposed	2
Number of weeks/year exposed	20
Number of years exposed	10
Years in lifetime	70
Lifetime average soil intake (g/kg body weight per day)	0.0000

a. Sources of Cancer Potency Factors:
  IRIS - Integrated Risk Information System. U.S. EPA 1988.
  HEAST - Health Effects Assessment Summary Tables. U.S. EPA 1989
  HEAST(v) - Health Effects Assessment Summary Tables. U.S. EPA 1989. Verified values awaiting entry into IRIS.

b. Based on Risk Assessment Council unit risk of 5x10-5(ug/l)-1. U.S. EPA 1988.

c. Carcinogenic PAHs based on benzo[a]pyrene potency from Ambient Water Quality Criteria Document. U.S.EPA 1980.

d. WDNR SQC (average % organic carbon in sediment) derived from NR 105.09 WAC: Human Cancer Criterion.

NOTE: The risk-specific concentrations presented in this table do NOT represent a determination of "safe" soil concentrations by CH2M HILL. They are estimated using procedures established by U.S. EPA. They are based on specific exposure assumptions and cancer potency factors and are calculated for specific cancer risk levels. Because cancer potency factors are subject to change, the reference concentrations are also subject to change. The risk-specific concentrations are provided for information purposes only. They can serve as only the first cut at developing clean up goals based on public health protection. The risk-specific concentrations are for individual chemicals. They do not account for exposure to multiple chemicals and by other routes of exposure.

VOLUME OF CONTAMINATED SEDIMENT

Methods

The total volume of soft sediment in the river was calculated by multiplying the estimated cross-sectional area of soft sediment for each of 22 river cross sections by a representative river length. The cross-sectional area of soft sediment was determined from the sample depths shown on the cross sections in Appendix B of the RI report. The maximum sample depth represents the vertical extent of soft sediment. Each cross-sectional area was assumed to be representative of the river length extending halfway in each direction to adjacent cross sections.

Contaminated sediment volumes were calculated for four conditions:

- Volume exceeding the 1×10^{-4} excess lifetime cancer risk target concentrations (see Table C-3)
- Volume exceeding the 1×10^{-6} excess lifetime cancer risk target concentrations
- Volume that exceeds background carcinogenic PAH concentrations
- Volume that has an oily appearance

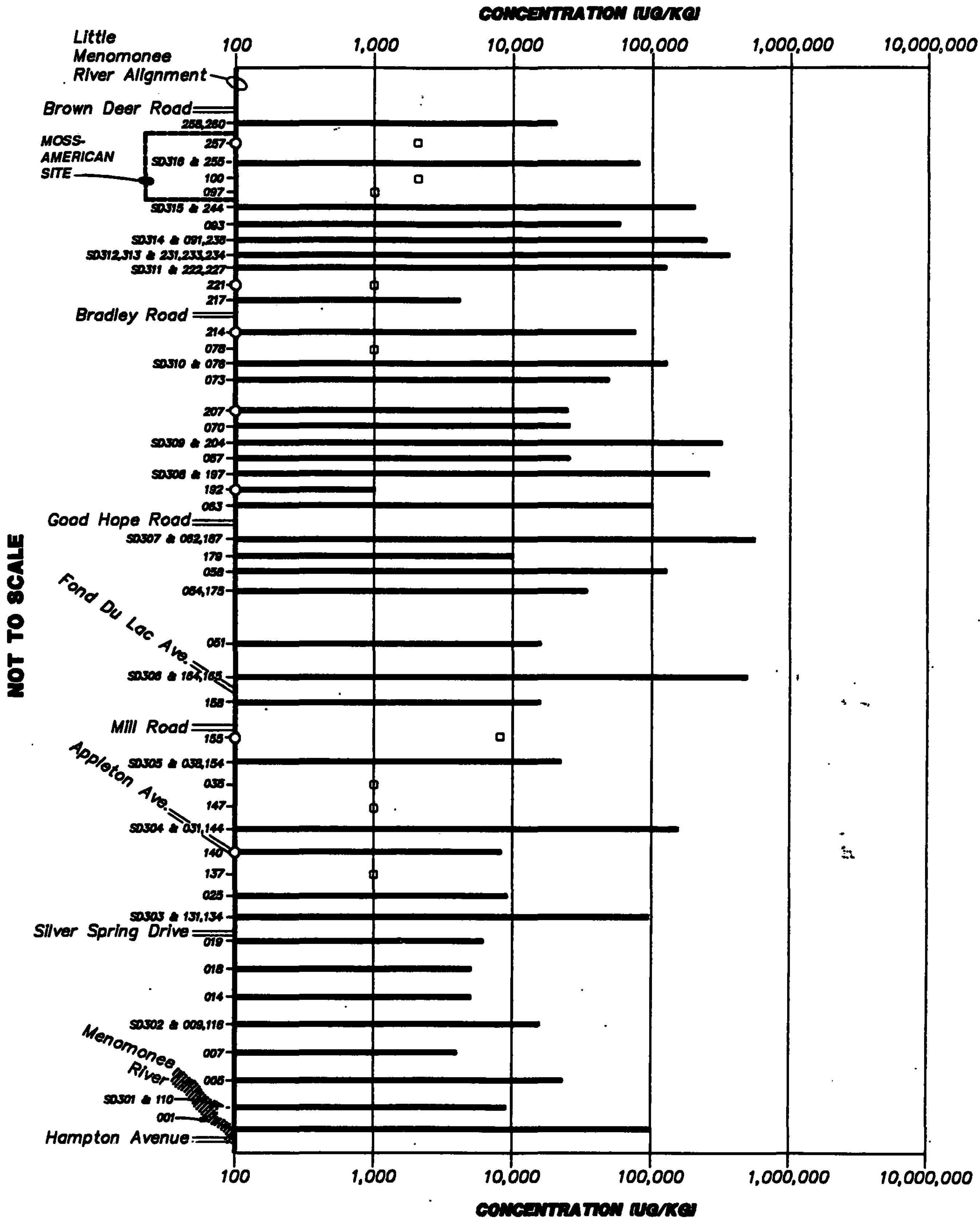
Volumes exceeding the cancer risk target concentrations were estimated by multiplying the percentage of samples exceeding the target concentrations within a given reach by the estimated volume of sediment within that reach.

Results

The total volume of soft sediment in the Little Menomonee River south of Brown Deer Road to the confluence with the Menomonee River is estimated to be about 44,000 cubic yards. The total volume is the sum of the soft sediment area times the river length for each of the 22 sections.

The estimated total volume of sediment exceeding the calculated 10^{-6} and 10^{-4} excess lifetime cancer risk levels is given in Table C-5, and are about 37,000 and 3,500 cubic yards, respectively. The volume of sediment with carcinogenic PAHs exceeding background levels (18 mg/kg) is estimated to be 26,000 cubic yards. The estimated total volume of visibly contaminated sediment is 5,200 cubic yards. This is based on the visual evidence of oil on sediment samples.

Potential difficulties exist with implementing a cleanup action based on a qualitative criterion such as "visibly contaminated." The volume observed to have an oily sheen, for example, was estimated to be about 15,000 cubic yards, versus 5,200 cubic yards for the volume observed to contain pure phase (oil). Should an alternative be pursued that considers this criterion, the development of a more quantitative criterion should be reinvestigated during the preliminary design, keeping in mind that the intent of a partial removal is twofold:



LEGEND

SEDIMENT SAMPLE NO. AND LOCATION (If more than one sample was taken at a sample location, concentration is the highest of the two.

257-O INLET SAMPLE NO. AND LOCATION

□ NOT DETECTED AT DETECTION LIMIT INDICATED

L5564.PP\FIGA 8/18/89

FIGURE C-9
SUM OF CARCINOGENIC PAHs IN SEDIMENTS
MOSS-AMERICAN FS

Table C-4
OBSERVATIONS OF OIL AND CONTAMINANTS IN RIVER SEDIMENT

Sample Number	Visual Classification: No Sheens	Sheen on Water	Sheen on Soil	Free Oil	(1) CPAH PPM	(2) CPAH PPM	Sample Number	(3) CPAH PPM	Sample Number	Section Descriptions: No.	Length (feet)	Area (sq ft)
HAMPTON ROAD												
SD 1	—	—			96	0	SD110	9	SD301	1	1,100	54.6
SD 2	—	—										
SD 3	—	—										
SD 4	—	—										
SD 5	—	—			21							
SD 6	—											
SD 7	—	—			4							
SD 8	—	—										
SD 9	—	—			8	0	SD116	15	SD302	2	2,400	34.4
SD 10	—											
SD 11	—	—										
SD 12	—	—										
SD 13	—											
SD 14	—	—			5							
SD 15	—	—										
SD 16	—	—										
SD 17	—	—										
SD 18	—	—			5							
SD 19	—	—	—		6					3	2,000	34.8
SD 20	—											
SD 21	—	—										
SILVER SPRING ROAD												

Table C-4
OBSERVATIONS OF OIL AND CONTAMINANTS IN RIVER SEDIMENT

Sample Number	Visual Classification: No Sheens	Sheen on Water	Sheen on Soil	Free Oil	(1) CPAH PPM	(2) CPAH PPM	Sample Number	(3) CPAH PPM	Sample Number	Section Descriptions: No.	Length (feet)	Area (sq ft)
SILVER SPRING ROAD												
SD 22	—	—				103	SD131	12	SD303	4	1,300	81.8
SD 23	—											
SD 24	—											
SD 25	—				9							
SD 26	—											
SD 27	—	—				0	SD137			5	1,900	18.4
SD 28	—											
SD 29	—	—										
SD 30	—	—										
SD 31	—	—	—	—	141	53	SD144	68	SD304	6	1,800	32.4
SD 32	—											
SD 33	—											
SD 34	—											
SD 35	—				0							
SD 36	—	—										
SD 37	—	—										
SD 38	—	—	—	—	22	0	SD154	2	SD305	7	1,800	36.0
SD 39	—	—										
SD 40	—	—										
SD 41	—	—										
SD 42	—											
MILL ROAD												

Table C-4
OBSERVATIONS OF OIL AND CONTAMINANTS IN RIVER SEDIMENT

Sample Number	Visual Classification: No Sheens	Sheen on Water	Sheen on Soil	Free Oil	(1) CPAH PPM	(2) CPAH PPM	Sample Number	(3) CPAH PPM	Sample Number	Section Descriptions: No.	Length (feet)	Area (sq ft)
MILL ROAD												
SD 43	—	—	—									
SD 44	—	—	—									
SD 45	—	—	—	—		19	SD158			8	2,300	43.6
SD 46	—	—	—									
SD 47	—	—	—	—		313	SD164	136	SD306	9	1,900	35.5
SD 48	—	—	—									
SD 49	—	—										
SD 50	—											
SD 51	—	—			16							
SD 52	—	—	—									
SD 53	—											
SD 54	—	—	—		34	10	SD175			10	1,900	45.5
SD 55	—	—	—									
SD 56	—	—	—									
SD 57	—	—										
SD 58	—	—	—		136							
SD 59	—	—	—	—		7	SD179			11	1,400	26.2
SD 60	—	—										
SD 61	—	—	—									
SD 62	—	—	—	—	504	31	SD187	323	SD307	12	1,400	17.6
GOOD HOPE ROAD												

Table C–4
OBSERVATIONS OF OIL AND CONTAMINANTS IN RIVER SEDIMENT

Sample Number	Visual Classification: No Sheens	Visual Classification: Sheen on Water	Visual Classification: Sheen on Soil	Visual Classification: Free Oil	(1) CPAH PPM	(2) CPAH PPM	Sample Number	(3) CPAH PPM	Sample Number	Section Descriptions: No.	Section Descriptions: Length (feet)	Section Descriptions: Area (sq ft)
GOOD HOPE ROAD												
SD 63	———	———	———		100							
SD 64	———	———	———									
SD 65	———	———	———									
SD 66	———	———	———	———		236	SD197	204	SD308	13	1,300	41.9
SD 67	———	———			26							
SD 68	———	———										
SD 69	———	———	———	———		570	SD204	155	SD309	14	1,600	36.5
SD 70	———	———			43							
SD 71	———	———										
SD 72	———	———										
SD 73	———	———			46							
SD 74	———	———										
SD 75	———	———	———									
SD 76	———	———	———	———	144			75	SD310	15	1,700	16.0
SD 77	———	———	———									
SD 78	———				0							
SD 79	———											
SD 80	———	———										
SD 81	———	———	———	———		4	SD217			16	1,400	14.0
BRADLEY ROAD												

Table C-4
OBSERVATIONS OF OIL AND CONTAMINANTS IN RIVER SEDIMENT

Sample Number	Visual Classification: No Sheens	Sheen on Water	Sheen on Soil	Free Oil	(1) CPAH PPM	(2) CPAH PPM	Sample Number	(3) CPAH PPM	Sample Number	Section Descriptions: No.	Length (feet)	Area (sq ft)
BRADLEY ROAD												
SD 82	—	—										
SD 83	—	—	—									
SD 84	—	—										
SD 85	—	—	—	—		8	SD227	132	SD311	17	1,300	53.5
SD 86	—	—	—									
SD 87	—	—	—									
SD 88	—	—	—	—		277	SD231	448	SD312	18	1,400	23.3
	—	—	—	—		238	SD234	270	SD313			
SD 89	—	—	—	—								
SD 90	—											
SD 91	—	—	—	—	212	230	SD236	162	SD314	19	1,600	33.2
SD 92	—											
SD 93	—				51							
SD 94	—											
SD 95	—	—										
SD 96	—	—	—	—		452	SD244	20	SD315	20	1,300	21.2
SD 97	—	—			0							
SD 98	—	—										
SD 99	—	—										
SD 100	—	—			0							
SD 101	—	—	—	—		29	SD255	83	SD316	21	900	25.0
SD 102	—	—										
SD 103	—					20	SD260			22	800	28.7
SD 104	—											
BROWN DEER ROAD												

NOTES:
1. Results from initial samples collected at 300-foot intervals
2. Results from samples taken from cross-sectional sampling
3. Results from confirmatory sample round

Table C-5
VOLUME OF SEDIMENT
EXCEEDING TARGET LEVELS

Stream Reach	Estimated Volume of Sediment (yd^3)	Range of Carcinogenic PAH Concentrations	Estimated Volume of Contaminated Sediment (yd^3)				
			$>10^{-4}$	$>10^{-6}$	Volume Exceeding Background Levels for Carcinogenic PAHs	Volume With Visible Traces of Oil	Volume w/>100 ppm Carcinogenic PAHs
Brown Deer Rd. to Bradley Rd.	8,500	DL-452	1,000	7,500	7,500	2,200	4,500
Bradley Rd. to Good Hope Rd.	5,900	DL-570	500	5,400	4,900	1,200	3,000
Good Hope Rd. to Mill Rd.	11,700	7-504	1,100	10,700	8,500	1,800	5,300
Mill Rd. to Silver Spring Dr.	9,800	DL-313	900	6,200	4,500	0	1,800
Silver Spring Dr. to Hampton Rd.	7,900	4-103	0	6,500	700	0	0
	43,800		3,500	36,300	26,100	5,200	14,600

Notes: 1. See Table C-4 for samples and corresponding concentrations for each reach.
2. Background level of total carcinogenic PAHs based on maximum probable concentration. See Appendix J.
3. DL = detection limit.

GLT938/108.51

- To remove contaminants present in phases that are more mobile than the dissolved phase

- To remove a significant fraction of the mass of contaminants

DISCUSSION

The estimated volume of soil, groundwater, or sediment requiring removal, treatment or some other form of management will depend on several factors. In particular, it will depend on the remedy that is selected. The selection of a particular remedy, however, will depend, in part, on the volume requiring management. This appendix attempted to address this interdependence by presenting a range of volumes for each media by using different criteria to estimate the volume requiring management.

Several problems were identified during this process. The problems and recommended solutions are discussed below.

FLOOD PLAIN SOILS

The volume of soil requiring remediation in the flood plain of the Little Menomonee River, if any, has not been determined. An extensive sampling program will be required to identify the nature, extent, and volume of contaminated flood plain soil.

IDENTIFYING AND MEASURING REMEDIAL ACTION LEVELS

The identification of "contaminated" soil and sediment focused on the target concentration associated with the 10^{-6} excess cancer risk for PAHs. However, the analytical data obtained for onsite soils did not measure concentrations in that range. In addition, much of the interpreted extent of contamination (per the RI Work Plan and QAPP) was based on the extractable organic data generated in the field which also did not identify appropriate contaminant levels. Therefore, the outer extent of contamination used to calculate the volume of soil exceeding the 10^{-6} target concentration was estimated based on past site operations and visual observations.

Differentiation between higher risk target concentrations, for example contouring between 10^{-5}, 10^{-4}, and 10^{-3} target concentrations, was not possible because of the limited number of data points for PAH analysis and for the reasons discussed above regarding detection levels. (The detection level for PAHs was comparable to the 10^{-4} target concentration.) Therefore, volumes were estimated by grouping areas according to past land use. This appears to be an appropriate method, except in the process area where contaminant levels were variable. If a treatment process is selected, it may be appropriate to investigate additional studies to further define soils, and possibly sediments, to be treated.

An attempt was made to differentiate soils based on visual screening criteria. While visual criteria appear to have some merit, especially for identifying gross contamination and free product, a more quantitative criterion could benefit decisionmaking during the RA.

GLT938/001.51

Appendix D
SEDIMENT REMOVAL

Appendix D
SEDIMENT REMOVAL

INTRODUCTION

Sediment removal technologies that survived screening included hydraulic dredging and dry excavation. This appendix presents a more detailed evaluation of the implementability, effectiveness, and relative cost of these technologies. It also presents rationale supporting selection of the representative process option for removal of contaminated sediment in the detailed alternatives.

HYDRAULIC DREDGING

Hydraulic dredging removes sediment from river bottoms. A cutter head attached to a hose is lowered to the bottom of the river, and a vacuum is applied to the hose to suction the sediment up to the surface. The cutter head loosens the sediment and breaks up oversize objects that would otherwise be too large to pass through the hose. The dredgings, which have the appearance of muddy water, are pumped through a series of water treatment processes to separate the sediment solids from the water, which is returned to the river. The principal advantage of dredging is that it can limit the amount of vegetation clearing and soil erosion on property immediately adjacent to the river. A hydraulic dredge mounted on a floating raft could pump the dredged sediment through hundreds of feet of forested riverbanks to the water treatment area, whereas excavation would necessitate clearing of some forested riverbank areas.

A potential advantage of dredging is that the dewatering stage can be used to separate sediment into coarse and fine fractions. This could reduce the quantity of sediment requiring treatment if the distribution of contaminants in sediment is such that most contaminants are associated with the fine fraction. Another advantage is that the dredge could operate in areas that might otherwise require a significant amount of clearing to provide access to heavy equipment.

Potential disadvantages of hydraulic dredging are that it could suspend significant quantities of sediment resuspended by but not captured by the dredge, and that the condition or appearance of the riverbed cannot be observed during the removal process. Resuspension of sediments to uncontaminated areas downstream would be an undesirable consequence.

In 1973 the Rexnord Company performed a demonstration test for the U.S. EPA to evaluate the effectiveness of hydraulic dredging methods on removing contaminated sediment in the Little Menomonee River. A schematic of the Rexnord system is shown in Figure D-1. The hydraulic dredge consisted of a suction line mounted on a pontoon platform. The suction head was equipped with hydraulically operated cutting knives to reduce clogging of the suction line with debris. Sediment was pumped from the river to a water treatment facility as far as 1,000 feet from the pontoon platform. The water treatment facility consisted of a preclarifier to remove heavy solids, a reactor clarifier where coagulants were added to improve settleability of finer solids, pressure filters, and carbon filters to polish the clarifier effluent. Sediment solids from the clarifiers were pumped to a tanker truck and hauled offsite for disposal at a sanitary landfill.

Approximately 3,500 feet of river bottom was dredged over a period of 3.5 months. Approximately 1.5 million gallons of river mud was pumped out by the dredge, and approximately 180,000 gallons of sludge at 35 percent solids were decanted from the clarifiers. In general, the system was considered to be successful in reducing the quantity of contaminated sediment, although no cleanup goals had been established. The sediment removed by the dredge was considered by Rexnord to be limited to the readily accessible, soft sediment near the surface of the river bed.

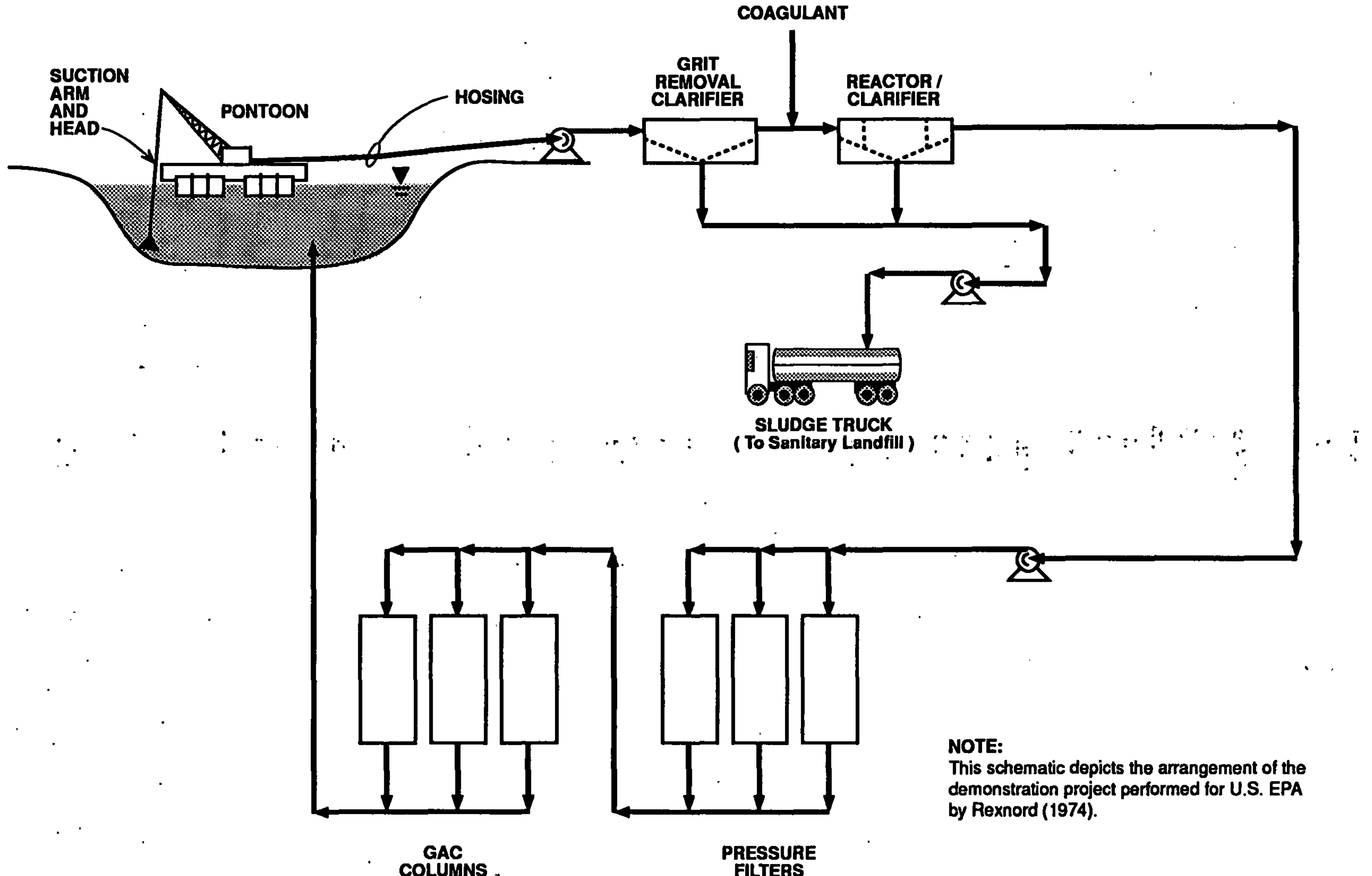
The Rexnord report concluded that the hydraulic dredge was appropriate only when the sediment to be removed was within the upper 6 inches of the river bed, and that front end loaders might be more appropriate for removing sediments at greater depth. The report noted that in cases where the muds were contaminated to depths greater than 6 inches, the frequency of line clogs and equipment breakdowns greatly impeded progress. The amount of sediment resuspension and its impact on downstream environment was not evaluated.

DRY EXCAVATION

Dry excavation would be performed by temporarily diverting river flow around a section of the river, then removing the contaminated sediment in that reach using a front-end loader, backhoe, or clamshell. Temporary diversion could be accomplished by constructing a dam at the upstream end of the section to be removed, then piping the backwater to the downstream end of the section. Because the water table is typically above the top of the sediment, some dewatering in the section to be excavated (e.g., using well points) may be necessary before excavation. Excavated sediment would be placed in a lined, open top truck for hauling to the treatment area. This approach would require construction of an access road along side of the river for the sediment hauling trucks. Construction of the road would require that a significant amount of trees be cleared.

The advantages of dry excavation are that:

- There is no resuspension of sediments requiring control.
- If removal is performed during the dry season and the river reach is losing water, some in situ dewatering might be achieved by simply diverting the river, lessening the amount of subsequent dewatering required.
- The effectiveness of the cleanup operation is easier to verify compared to hydraulic dredging.
- Deeper removal than hydraulic dredging can be achieved.



NOTE:
This schematic depicts the arrangement of the demonstration project performed for U.S. EPA by Rexnord (1974).

FIGURE D-1
HYDRAULIC DREDGING ARRANGEMENT
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The disadvantages are that:

- There would be a greater amount of clearing and construction.
- Some slurrying of the sediment would be required for slurry bioreactor treatment.
- Greater material handling operations are required.

CONCLUSIONS

While the demonstration test concluded that dry excavation would be a superior method for sediment removal, it is believed that advances in technology since that time would make it possible to overcome one of the major deficiencies of the earlier system—the inability to remove sediments thicker than 6 inches. It is likely that current hydraulic dredging technology would be more effective in removing soft sediment than was achieved during the demonstration test, which is believed to contain the bulk of contaminants present in river sediments. Resuspension remains a potentially difficult problem, but it could be mitigated by operating in hydraulically isolated segments of the river, using a sequence of dams to isolate the working reach. Because the effectiveness of hydraulic dredging is uncertain and because verification would be difficult, it is retained only for alternatives where partial removal of the more grossly contaminated sediment is to be performed. In instances where more thorough removal is required (e.g., contaminated sediment exceeding background levels), then dry excavation is considered a more reliable method that can be field verified during the remedial action.

GLT938/002.51

Appendix E
GROUNDWATER CONTAINMENT AND REMOVAL

Appendix E
GROUNDWATER CONTAINMENT AND REMOVAL

INTRODUCTION

This appendix discusses groundwater containment and removal technologies and presents a conceptual model for the recommended groundwater remedial measure at the Moss-American site. Pertinent background information is cross-referenced as follows: the nature and extent of groundwater contamination on the site is presented in Chapter 3 and Appendix O of the RI report; site hydrogeology is described in Chapter 2 and Appendixes E, F, G, I, and J of the RI report; and pertinent ARARs are described in Appendix A of this FS; the estimated volume of contaminated groundwater is presented in Appendix C of this FS report.

REMEDIAL ACTION OBJECTIVES

The objectives of remediation of groundwater at the site are to prevent the discharge of creosote and dissolved PAHs to the Little Menomonee River and to attain the ARARs for groundwater quality. Prevention of migration of contaminated groundwater to drinking water wells is not a goal since contaminated groundwater is believed to be present only in the shallow aquifer, which discharges to the Little Menomonee River. The RI concluded that vertical migration of contaminants was not occurring at a significant rate.

The concentration goals adopted for groundwater contamination are the Wisconsin Groundwater Quality Standards. Federal Ambient Water Quality Criteria and Wisconsin Water Quality Criteria for surface waters were also considered. Only one well exceeded Wisconsin's groundwater quality enforcement standards listed in NR 140 (MW-7S, for benzene). NR 140 does not list standards for individual PAHs or for oil and grease, which are the predominant contaminants at the site. While NR 105 does define standards for PAHs in surface water, the effects of dilution tend to reduce the relevancy of this standard. The potential impact of NR 105 on the discharge of collected groundwater to the Little Menomonee River is addressed in Appendix F.

AREAS REQUIRING CONTROL MEASURES

All groundwater containing contaminants associated with creosote was considered to be contaminated. The estimated extent of groundwater contamination is shown in Figure E-1 with the flow characteristics for the shallow groundwater. Contamination extends from the processing area to the river in a band that could be up to 400 feet wide. The contaminated plume generally follows the groundwater gradient at the site, which is northeast toward the river. The apparent migration of part of the plume to the north (the northwesternmost leg of the plume in Figure E-1) may have resulted from preferential flow along the bedding of a storm drain beneath the parking area or from contaminated runoff from the existing facility at the site. The maximum depth of contamination extends as deep as 20 feet and appears to be inhibited by the unweathered Oak Creek Formation, a hard, dense, silty-clay till.

Control measures will be necessary west of the river to satisfy the remedial action objective of minimizing contaminant migration to the river and achieving Wisconsin DNR groundwater quality standards. Areas where pure phase was observed and groundwater near MW-7 exceeded the groundwater quality standards. Although no groundwater contamination was detected east of the river, the investigations performed to date have not been of sufficient detail to determine that groundwater contamination does not exist.

AVAILABLE REMEDIAL TECHNOLOGIES

Remedial technologies for groundwater extraction and containment typically consist of extraction wells for gradient control or groundwater removal, interceptor drains or trenches, slurry walls or other vertical barriers, and low-permeability caps. Another option is complete aquifer removal.

EXTRACTION WELLS

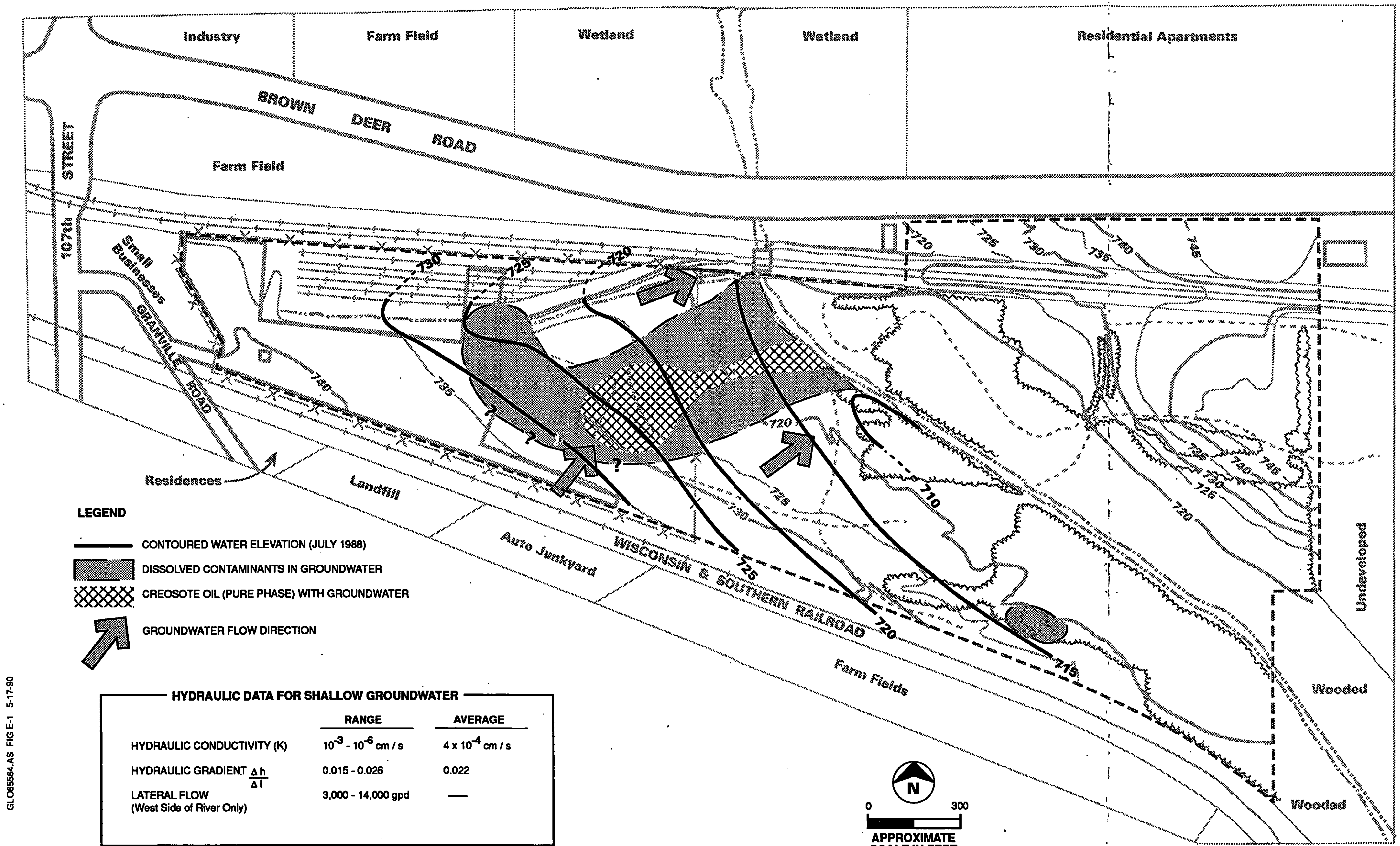
Groundwater extraction wells were considered for removing free product and contaminated groundwater immediately downgradient of the source area. Based on the hydraulic characteristics of the shallow groundwater near MW-04, pumping rates of up to 1 gallon per minute should be possible with wells penetrating to the bottom of the unweathered till. The width of the capture zone could be as much as 200 feet. However, pumping tests would be required to verify the actual capture zone.

Groundwater extraction from the source area would reduce overall cleanup time by removing contaminants near the source. However, because dissolved PAHs have a tendency to adsorb strongly to the surface of the aquifer matrix, and because some of the PAHs are present in groundwater as immiscible liquids, estimating the cleanup time is extremely difficult. Based upon what is known at the site and experience with similar waste at other sites, it is certain that the time frame to remove contaminants that are sorbed will be more than a lifetime. The time to remove the immiscible fraction would be less, but also difficult to quantify.

To satisfy the remedial objective for groundwater (preventing groundwater contaminants from migrating to the river), a series of extraction wells would have to capture the contaminated groundwater along the west bank of the river. Pumping from the source area, without additional groundwater controls along the river, would not satisfy the objective because contaminants have already migrated to the river.

Using extraction wells is possible along the river, but this technology is not recommended. The following conditions which affect design and performance make it difficult to ensure that using a system of extraction wells will prevent migration of contaminants towards the river:

- Heterogeneities in the soil such as thinly bedded silts and sands will unpredictably affect drawdown between well-points.



HYDRAULIC DATA FOR SHALLOW GROUNDWATER

	RANGE	AVERAGE
HYDRAULIC CONDUCTIVITY (K)	10^{-3} - 10^{-6} cm / s	4×10^{-4} cm / s
HYDRAULIC GRADIENT $\frac{\Delta h}{\Delta l}$	0.015 - 0.026	0.022
LATERAL FLOW (West Side of River Only)	3,000 - 14,000 gpd	—

FIGURE E-1
EXTENT OF CONTAMINATION AND HYDRAULIC CHARACTERISTICS OF THE SHALLOW GROUNDWATER
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- Heterogeneities in the soil will affect uniform migration of pure phase.
- Seasonal groundwater fluctuations and their effect on well-hydraulics are not understood.

INTERCEPTOR DRAINS OR TRENCHES

The use of drains along the river is a simple and effective way to intercept migrating contaminants. Horizontal gradients predominate onsite, and continuous drains installed between the river and contaminated areas would capture groundwater migrating from the contaminated areas. A groundwater gradient toward the drain would be established along the entire path of the drain, thus shortening the travel time required for contaminants to reach the collection system. Heterogeneities in the soil and their effect on drawdown and free product migration would be negated by backfilling a trench with homogeneous permeable gravel.

Expanding the drainage network into the source area would help to reduce the time necessary to achieve cleanup standards.

SLURRY WALLS AND OTHER VERTICAL BARRIERS

The use of a barrier technology alone would not satisfy the remedial objective for groundwater because vertical barriers would inhibit but not prevent contaminant migration to the river. Vertical barriers can be effectively used in conjunction with a drain system. Installing a vertical barrier parallel to the river between a drain system and the river would inhibit recharge from the river to the drain, thus reducing the volume of water collected in the drain.

LOW-PERMEABILITY CAPS

Capping contaminated soil with nearly impermeable material would reduce infiltration and reduce groundwater discharge. However, because less than one-half of the groundwater flow onsite is attributable to infiltration, and because a large fraction of contaminant mass is below the high water table, lateral migration would continue to transport contaminants to the river. Therefore, low-permeability caps are not recommended for meeting the remedial objective for groundwater.

AQUIFER REMOVAL

Excavation and treatment of contaminated soil from source areas onsite could effectively remove the contaminated aquifer matrix, reducing the need for groundwater remediation in those areas. This approach is potentially applicable to the contaminated aquifer at the southeast corner of the site and to the areas of pure phase identified in Figure E-2. The approach could also be applied to mitigate potential migration from the northeast landfill. Contaminant migration from that area was not found during the RI.

RECOMMENDED GROUNDWATER REMEDIAL ACTION

MAIN FEATURES

The recommended action for preventing contaminated groundwater from discharging to the Little Menomonee River is illustrated in Figures E-2 and E-3. The main features of the conceptual plan are the drain line and collection sump between the river and contaminated plumes, and the excavation of the contaminated soil in the southeast landfill. These two features alone would satisfy the remedial objectives for groundwater. It is assumed that the drain will collect all the contaminated groundwater discharged from the site west of the river, a total average flow of approximately 10 gpm.

The time required to reduce the concentration of benzene to NR 140 Enforcement Standards cannot be predicted because the extent and source of benzene at MW-7 is not known. The time required to lower the PAH concentrations to a level that will not cause the surface water to exceed PAH standards cannot be predicted because the movement of the pure phase and immiscible fractions is not well understood.

SUPPLEMENTAL FEATURES

In addition to the main features, several supplemental features are included in the conceptual plan. These are a vertical barrier between the river and main drain, supplemental drains, and removal of the northeast landfill.

Vertical Barrier

A synthetic geomembrane liner placed along the east wall of the main drain trench would reduce the volume of water collected in the drain system by preventing recharge from the river to the drain.

Supplemental Drains

Two supplemental drains are recommended. An extension south of the main drain would collect water that percolates through the heavily contaminated soil in this area. Installation of the drain would be unnecessary if the narrow strip of visibly contaminated soil were removed. The second drain would collect groundwater and free product directly from the source area and along the path of the old settling ponds. The purpose of this drain is to reduce the path length (through the soil) and travel times for contaminants.

Northeast Landfill

Remedial action considerations for the northeast landfill are recommended even though no groundwater problem was observed there during the RI. The sediment buried in the landfill contains appreciable amounts of creosote that will eventually migrate. If some form of soil or sediment treatment is selected as part of the overall remedial action for the site, then excavation and treatment of the relatively small volume of sediment in the northeast landfill is recommended to eliminate the risk of future groundwater problems.

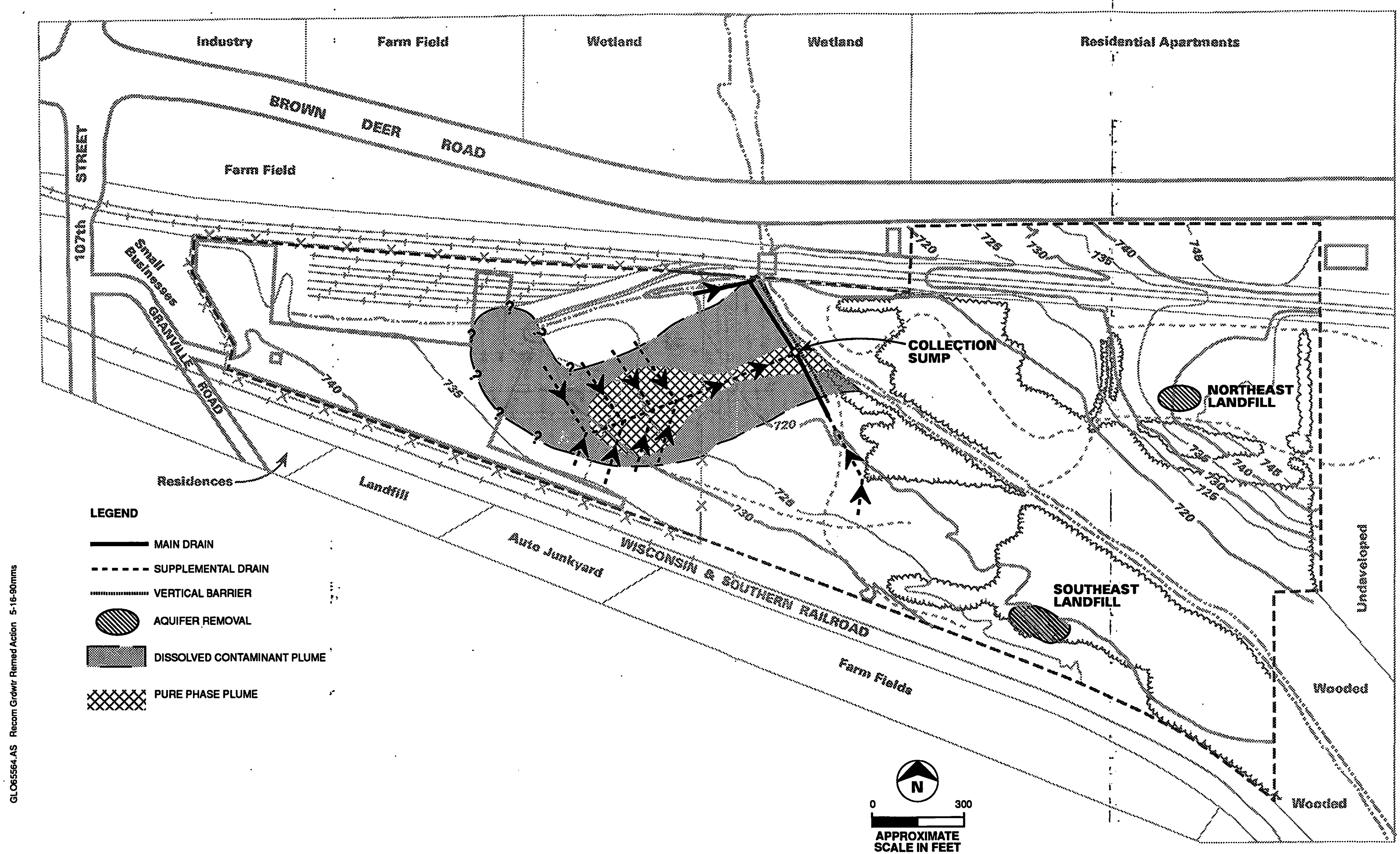

FIGURE E-2
RECOMMENDED GROUNDWATER REMEDIAL ACTION
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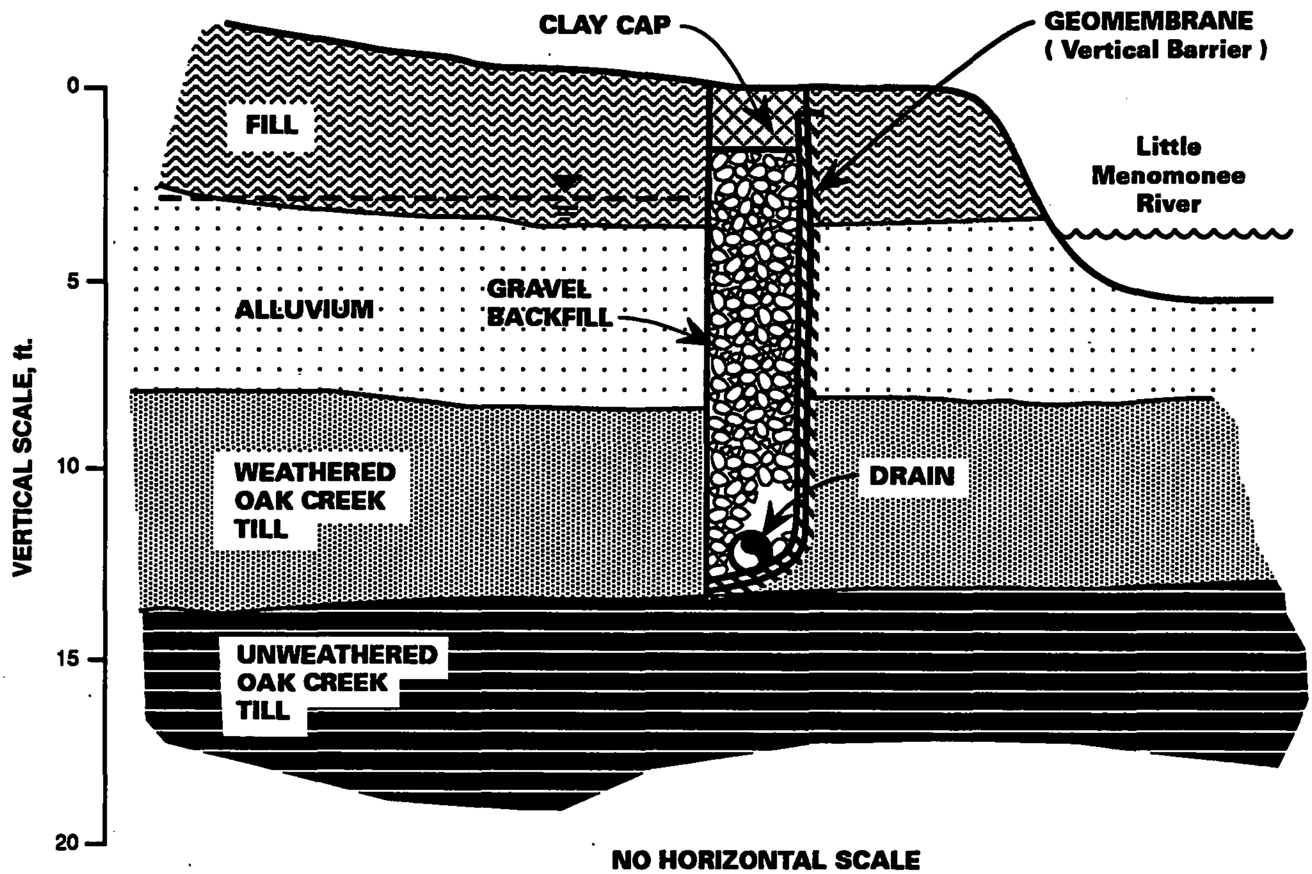

NOTE: The stratigraphy for this cross section is based on the geologic condition at MW-08, which is near the collection sump shown in FIG E-2.

FIGURE E-3
CONCEPTUAL CROSS SECTION OF THE PROPOSED DRAIN AND VERTICAL BARRIER
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REFERENCES

Lohman, S. W. *Groundwater Hydraulics*. Geological Survey Professional Paper Washington, DC: U.S. Government Printing Office. 1979.

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Appendix F
GROUNDWATER TREATMENT AND DISPOSAL

Appendix F
GROUNDWATER TREATMENT AND DISPOSAL

INTRODUCTION

This appendix evaluates potentially applicable groundwater treatment technologies. Potentially applicable groundwater treatment alternatives identified in Chapter 3 were evaluated on the bases of treatment effectiveness, relative cost, and implementability for incorporation into remedial alternatives. This appendix includes an evaluation of discharge to the Little Menomonee River and to the Milwaukee Metropolitan Sewerage District (MMSD) publicly owned treatment works (POTW).

ONSITE GROUNDWATER TREATMENT

EFFLUENT REQUIREMENTS

The extent to which groundwater must be treated will depend upon the effluent limitations established for the point of discharge and the concentration of contaminants present in the extracted groundwater. For discharge to the Little Menomonee River, these requirements have been established by the Wisconsin DNR. For discharge to the POTW, the pretreatment standards will be set by the MMSD. In either case a discharge permit will be required.

Surface Water Discharge

Discharges to surface water bodies may not contain pollutants in concentrations that exceed applicable surface water quality criteria. Furthermore, Wisconsin Statutes Chapter 147 states that discharges must be treated by the best available technology economically achievable (BATEA). Thus, even though a discharge does not cause applicable water quality criteria to be exceeded, some effluent treatment could still be required. BATEA includes those technologies commonly used in water and wastewater treatment (Wisconsin Surface Water Quality Criteria (NR 105) for protection of human health are listed in Appendix A (Tables A-3 and A-4). Water quality criteria for protection of aquatic life are also presented in Appendix A (Table A-5). The Wisconsin DNR has also established chemical specific effluent limits for four compounds present in groundwater at the site that could be discharged to the river during site remediation. (These mass-type limits are presented in Table F-3 later in this appendix.)

Discharge to POTW

Discharge to the POTW is regulated by Administrative Code NR 211, which determines pretreatment standards. The Clean Water Act prohibits discharges that interfere with the operation of the POTW, pass through the POTW without sufficient treatment, or impair the use or disposal of POTW sludge. Because established pretreatment guidelines do not include the organic compounds present at the site, no separate set of potential effluent guidelines has been developed for this discharge alternative.

Preliminary discussions with a representative from the POTW did not yield any specific volume limits for discharging to the sewer (located onsite, just east of the river). However, the discharge may not have a total VOCs concentration greater than 5 ppm.

ESTIMATION OF FLOW AND CONCENTRATIONS OF CONTAMINANTS IN EXTRACTED GROUNDWATER

Appendix I of the Moss-American RI report contains the data and calculations for estimating groundwater flow along the flowpaths illustrated in Figure F-1. Because these calculations were based on data collected during an extremely dry period (Summer 1988), expected average conditions were estimated. Average saturated thicknesses and log-average hydraulic conductivities were used to estimate expected average groundwater flow. The minimum and maximum estimates presented in Table F-1 and are considered representative of seasonal variations in the groundwater flow. The dry period and normal flow estimates presented in Table F-1 represent the groundwater flows associated with the three flowpaths (described in Appendix E) contained within the boundary of the proposed collection trench shown in Figure F-1.

Table F-1
ESTIMATED GROUNDWATER FLOW

	Flow Rate (gpd)		
Flowpath	Summer 1988	Estimate Min.	Normal Max.
1	110	360	1,900
2	260	450	2,300
3	1,000	710	3,700
Total	1,370	1,520	7,900

ESTIMATED CONCENTRATIONS OF POLLUTANTS IN EXTRACTED GROUNDWATER

To estimate contaminate concentrations in discharge to the river, data were grouped according to one of three groundwater flowpaths associated with the extent of the vertical barrier (see Figure F-1). If a volatile or semivolatile analyte was not detected within a flowpath, then that analyte was not considered to exist within that flowpath. A detected volatile or semivolatile analyte was considered representative of the entire flowpath if it occurred in the shallow well nearest the river. If an analyte was not detected in the well nearest the river but detected in another well within the flowpath, then an assigned concentration equal to the detection limit for that analyte was used to represent the flowpath. This calculation was repeated for each potential pollutant, the results of which are shown in Table F-2.

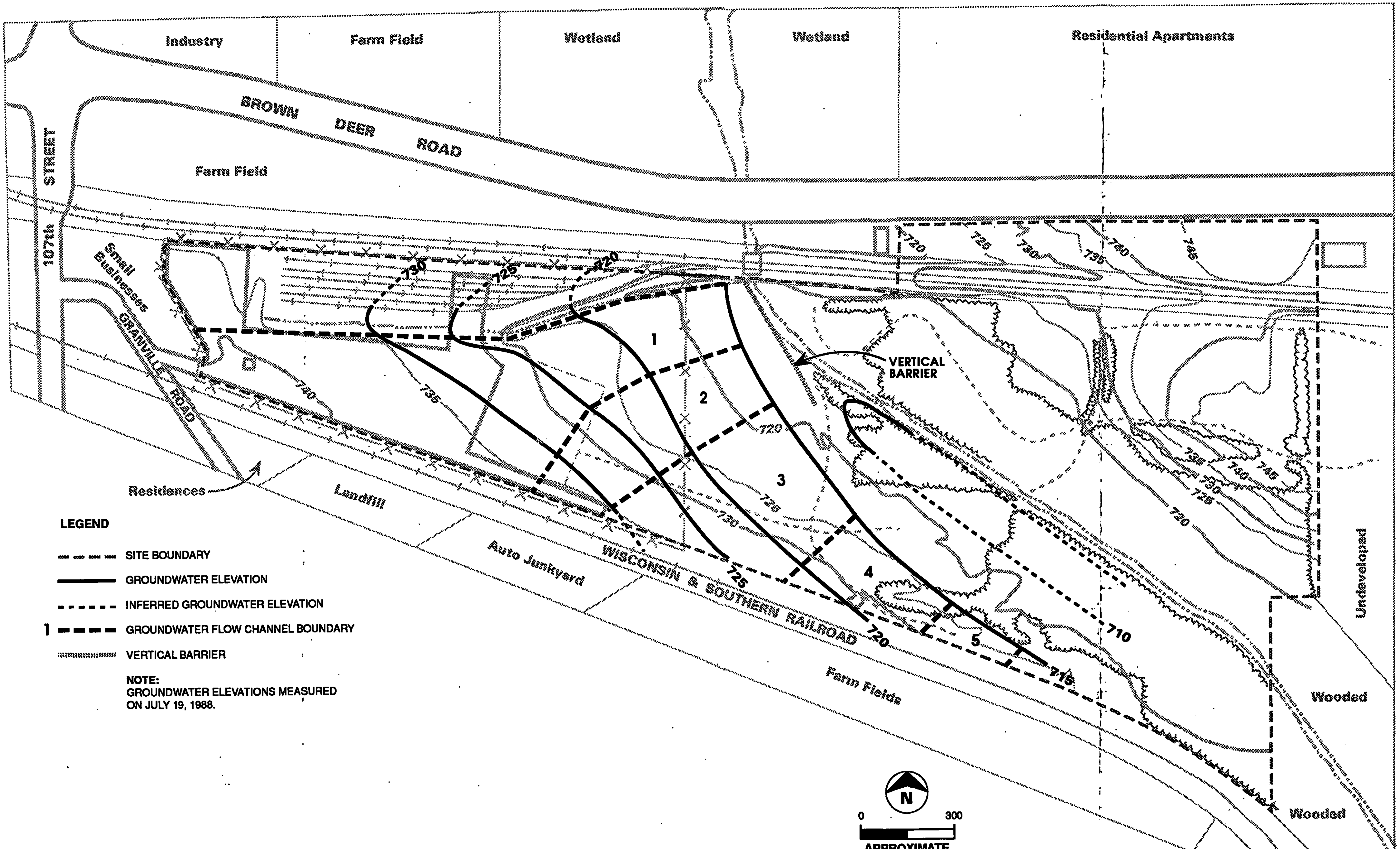

FIGURE F-1
GROUNDWATER ELEVATIONS AND FLOW CHANNELS
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Table F-2
POTENTIAL GROUNDWATER POLLUTANTS
(ug/l)

Compound	Flowpath 1	Flowpath 2	Flowpath 3	Combined Concentration 1988	Combined Concentration Min. Est.	Combined Concentration Max. Est.	Max. Mass Discharge (lb/day)	Effluent Guidelines Max. Mass Discharge (lb/day)	Effluent Guidelines Daily Max. Concentration
VOLATILE ORGANICS									
Benzene	7	Total BTX	--	Total BTX	Total BTX	Total BTX			
Xylene	30	> 2	--	14	30	30			
CARCINOGENIC PAHs									
Benzo(a)anthracene	--	81	--	15	24	24			
Benzo(a)pyrene	--	23	--	4	7	7			
Benzo(b)fluoranthene	--	23	--	4	7	7			
Benzo(k)fluoranthene	--	25	--	5	7	7			
Chrysene	--	69	--	13	20	20			
Total Carcinogenic PAHs	--	--	--	41	65	65	0.004	0.0019	
NONCARCINOGENIC PAHs									
Acenaphthene	--	1,400	--	266	415	408			
Acenaphthylene	--	22	--	4	7	6			
Anthracene	--	110	--	21	33	32			
Fluoranthene	--	460	--	87	136	134			
Fluorene	--	630	--	120	187	183			
2-Methylnaphthalene	--	520	--	99	154	151			
Naphthalene	3,100	5,500	--	1,293	2,363	2,347			
Phenanthrene	--	2,200	--	418	651	641			
Pyrene	--	300	--	57	89	87			
Total Noncarcinogenic PAHs	--	2,698	--	513	798	786			
OTHER ORGANICS									
Phenol	--	8	--	2	2	2			
bis(2-Ethylhexyl)phthalate	8	13	--	3	6	6			
Dibenzofuran	--	560	--	106	166	163			
2,4-Dimethylphenol	--	14	--	3	4	4			
Ethylbenzene	--	27	--			8	0.0005	200	45
INORGANICS									
Cadmium	--	--	--	--	--	--			
Copper	161	--	--	13	38	39			
Lead	56	--	--	5	13	13			
Nickel	164	--	--	13	39	39			
Zinc	670	--	109	133	210	212			

The maximum concentrations of contaminants in water discharged to a treatment system were estimated by assuming that pure phase migrates to the oil/water separator and concentrations of contaminants come into equilibrium with the water; i.e., their dissolved concentration in the water is given by its solubility.

Table F-3 identifies effluent requirements for discharges to the Little Menomonee River. These effluent requirements were developed by the Wisconsin DNR for discharges from the site and are based on applicable state water quality criteria presented in Appendix A.

Table F-3
WATER QUALITY-BASED EFFLUENT LIMITS
FOR THE MOSS-AMERICAN SITE

Chemical	Daily Maximum (mg/l)	Monthly Average Limit (lb/day)	Annual Average Limit (lb/year)
Ethylbenzene	45	200	--
2,3,7,8-TCDD	--	1.9×10^{-9}	6.9×10^{-7}
Chloroform	29	1.6	--
Total Carcinogenic PAH Compounds	--	1.9×10^{-3}	0.68

Note: Devleoped by the Wisconsin DNR, Surface Water Standards Unit, January 8, 1990.

As shown in Table F-2, total PAHs could potentially exceed the effluent guidelines. No other criteria would be exceeded without treatment. Therefore, discussion of potential methods for removal of organic chemicals are limited to those listed in the technology screening table for PAHs.

REMOVAL OF ORGANIC CONTAMINANTS

Table F-4 identifies and describes the physical properties of the contaminants in the groundwater that exceed the groundwater standards and effluent guidelines. The following subsections address how effectively the potentially applicable technologies could bring the discharge into compliance.

Coagulation/Flocculation

Although data on the removal of these organic chemicals by coagulation and flocculation is not extensive, 80 to 100 percent of these compounds might be removed by use of polymeric materials (U.S. EPA 1980). A pilot study would be necessary to substantiate the degree of removal and provide design data.

Table F-4
GROUNDWATER CONTAMINANT DATA

Compound	Influent Concentration (ug/l)	Molecular Weight	Specific Gravity @ (C)	Solubility (ug/l) @ (C)	Absorptability (mg/g @ ug/l X 10-3)	Henry's Constant (atm-m3/mol)	Biodegradability	Comments
VOLATILE ORGANICS								
Benzene	Total BTX	78.0	0.88	1,780,000 (25)	80 (400)	5.55E-03	Yes	Rapid volatization followed by photolysis of vapor. No aqueous oxidation. Also removed by GAC and activated sludge.
Xylene	30	106.0	0.88	546,000 (25)	70 (500)	1.64E-03	Yes	
CARCINOGENIC PAHS								
Benzo(a)anthracene	24	228.3	--	14 (25)	--	--	Slowly	Four-ring compound. Slowly biodegraded. Due to low solubility, removed by GAC, coagulation, sedimentation, but not stripped.
Benzo(a)pyrene	7	252.3	--	3.8 (25)	1 (270,000)	--	Slowly	Five-ring, not quickly biodegraded. Adsorption is dominant removal pathway.
Benzo(b)fluoranthene	7	252.3	--	--	--	--	Slowly	Four-ring compound. Slowly biodegraded. Due to low solubility, removed by GAC, coagulation, sedimentation, but not stripped.
Benzo(k)fluoranthene	7	252.3	--	--	1 (50,000)	--	Slowly	Four-ring compound. Slowly biodegraded. Due to low solubility, removed by GAC, coagulation, sedimentation, but not stripped.
Chrysene	20	228.3	--	2 (25)	--	--	Slowly	Four-ring compound. Slowly biodegraded. Due to low solubility, removed by GAC, coagulation, sedimentation, but not stripped.
NONCARCINOGENIC PAHS								
Acenaphthene	408	154.2	1.07 (95)•	3,420 (25)	100 (50,000)	2.41E-04	Yes	Three-ring compound. Possibly removed in activated sludge. Adsorption principle transport process. Possible photolysis and oxidation with chlorine and ozone. Near complete removal with activated sludge and GAC.
Acenaphthylene	6	152.2	--	3,930 (25)	80 (78,000)	1.14E-04	Yes	Three-ring compound. Possibly removed with activated sludge. Strongly adsorbed. Possible photolysis or oxidation by chlorine or ozone.

Table F-4
GROUNDWATER CONTAMINANT DATA

Compound	Influent Concentration (ug/l)	Molecular Weight	Specific Gravity @ (C)	Solubility (ug/l) @ (C)	Absorptability (mg/g @ ug/l x 10-3)	Henry's Constant (atm-m3/mol)	Biodegradability	Comments
Anthracene	32	178.2	1.25 (27)•	73 (25)	5 (24.000)	--	Yes	Three-ring compound. Possibly biodegraded. Principle removal by adsorption. Possible photolysis or oxidation with chlorine or ozone. Large removals reported for GAC. activated sludge. sedimentation. and filtration.
Fluoranthene	134	202.3	--	260 (25)	50 (14.000)	--	Yes	Four-ring compound. Strong adsorption. Possibly biodegraded or oxidized with chlorine or ozone.
Fluorene	183	166.2	1.2 (0)•	1.980 (25)	10 (27.000)	1.17E-04	Yes	Three-ring compound. Strongly adsorbed. Possibly biodegraded or oxidized with chlorene or ozone. High removals reported from sedimentation and activated sludge.
2-Methylnaphthalene	151	--	1.025 (14)•	--	--	--	--	No information contained in Treatability Manual.
Naphthalene	2.347	128.2	1.145 (20)•	34.400 (25)	100 (68.000)	--	Yes	Two-ring compound. Rapidly biodegraded. strongly adsorbed. possible volatilization. oxidation and photolysis. High removal reported for sedimentation. activated sludge and adsorption.
Phenanthrene	641	178.2	1.179 (25)•	1.290 (25)	50 (42.000)	--	Slowly	Three-ring compound. Adsorption probable. Possibly biodegraded or oxidized with chlorene or ozone. High removal reported for sedimentation. ozonation. activated sludge. and GAC.
Pyrene	87	202.0	1.277 (0)•	140 (25)	--	--	Slowly	Four-ring compound. Slowly biodegraded. Due to low solubility. Removed by GAC. coagulation. sedimentation. but not stripped.
Total PAHs as defined in Table F-1. note l	786	--	--	--	--	--	--	--

Table F-4
GROUNDWATER CONTAMINANT DATA

Compound	Influent Concentration (ug/l)	Molecular Weight	Specific Gravity @ (C)	Solubility (ug/l) @ (C)	Absorptability (mg/g @ ug/l x 10-3)	Henry's Constant (atm-m3/mol)	Biodegradability	Comments
OTHER ORGANICS								
Phenol	2	94.1	1.071 (25)*	6.70E+07 (25)	80 (430,000)	1.30E-06	Yes	Single ring compound. Quickly biodegraded. Nearly completely removed in activated sludge. Also removed by GAC.
bis(2-Ethylhexl)phthalate	6	391.0	--	400 (25)	Approx. 1	--	Yes	Single ring compound. Adsorption strongest mechanism. Biodegradation important. High removals reported for sedimentation, activated sludge and GAC.
Dibenzofuran	163	168.2	--	--	--	--	--	No information contained in the Treatability Manual.
2,4-Dimethylphenol	4	122.2	--	1.7E+07 (25)	100 (130,000)	--	Yes	Single ring compound. Biodegradeable and adsorbed with GAC.
INORGANICS								
Cadmium	--	112.4		Variable				Precipitation is probable method of removal for all of these metals, although some removal by adsorption is possible. Degree of removal is dependent both upon pH and conjugate base used to form the precipitate molecule.
Copper	39	63.6		Variable				
Lead	13	207.2		Variable				
Nickel	39	58.7		Variable				
Zinc	212	65.4		Variable				

NOTE: All physical data in this table, except that denoted by "*" were taken from Treatability Manual, Vol. 1. The excepted information was taken from Perry's Handbook of Chemical Engineering, 6th Edition.

Coagulation and flocculation do not constitute the ultimate disposal of these compounds. The compounds would be removed from the groundwater but remain in the residual sludge. The sludge would be a hazardous waste requiring dewatering and removal to an offsite facility for landfilling or incineration. Dewatering could be accomplished by conventional means, such as filter pressing or vacuum filtration.

Oil-Water Separation

Oil-water separation is a unit operation in which the pure phase product is removed from the extracted groundwater. Pure phase product was noted in several onsite monitoring wells. Although oil-water separation will not remove dissolved or emulsified constituents, it would protect subsequent treatment units from fouling by pure phase product. Oil-water separation could be accomplished with a gravity separator (e.g., an API oil-water separator), a coolescing separator, or an oil-absorbent material that would remove the oil from the water. Use of a gravity separator will probably suffice as a pretreatment step. Final selection would be made after pilot testing in the predesign phase.

The oil product recovered would probably be considered a K001 liquid hazardous waste requiring treatment such as offsite incineration. Because the oil at the site is heavier than water, the particulates and oil that settle out of the collected groundwater would be commingled. This mixture also would require management as a hazardous waste.

Flotation

Flotation has been used in conjunction with chemical demulsifiers and coagulants to remove oily wastes from solution. As with oil-water separation, flotation would generate hazardous residues requiring further treatment. Operation of such a unit is somewhat sophisticated and sensitive to waste loading, hydraulic loading, and chemical additives. A pilot study would be necessary to investigate the effectiveness of this alternative.

Granular Activated Carbon Adsorption

Carbon adsorption is a highly effective treatment method for PAHs because of their low solubility and high partition coefficient. Removal of organic chemicals such as those at the site often can be expected to range from 90 to 99 percent.

Spent carbon would be regenerated offsite for reuse or disposed of offsite at an appropriate hazardous waste receptor. The incineration of the spent carbon as part of the regeneration process would result in destruction of the contaminants.

Membrane Processes

Membrane processes can be used to remove materials larger than the effective pore size of the membrane providing the solution to be treated does not act as a solvent of the membrane. The use of membrane processes for groundwater treatment typically requires groundwater pretreatment and results in a more concentrated waste stream requiring further treatment and disposal. Membrane processes are subject to fouling and deterioration from microbial growth, and typically require high pressure pumping to provide a sufficient "driving force."

Chemical Oxidation

Chemical oxidation is a process by which organic contaminants are decomposed into more simple, innocuous compounds. In some instances, oxidizing agents can oxidize the organic contaminants in the waste stream to completion (water and carbon dioxide), or at least to a state where the residual compounds are more treatable by another process. Chemical oxidation has been used to effectively treat inorganics such as cyanide and has also been demonstrated on a pilot scale to be effective for treating PAHs.

The possibility of treating groundwater without producing a treatment residual makes chemical oxidation an attractive technology. A major limitation of chemical oxidation is that incomplete oxidation may yield toxic byproducts that themselves need treatment. The process does not perform well with complex waste streams, and the oxidants used tend to be hazardous chemicals (e.g., hydrogen peroxide and ozone). Because of the reactive nature of the oxidants, implementation of the process is complicated, and laboratory and pilot-scale testing is needed to select appropriate oxidants and feed rates.

Photolysis

In photolysis, the chemical bonds of a contaminant are broken under the influence of ultraviolet light. When used in combination with ozone, ultraviolet light can be an effective groundwater treatment. Ultraviolet light and ozone induce a strong photochemical oxidant that can break down many organic compounds, including chlorinated hydrocarbons, pesticides, and PCBs.

An advantage of ultraviolet/ozone oxidation is that it destroys hazardous chemicals rather than separating them from groundwater, as is done in air stripping or carbon adsorption. Ultraviolet/ozone oxidation is an emerging technology and its effectiveness has not been documented as conclusively as some other technologies. Its operation may be more sophisticated than that of activated carbon, yet it appears to be a technology that may be effective, implementable, and economical.

Biological Treatment/Adsorption

Because of the low solubility of PAHs and the long time period required to effectively degrade these compounds, biological treatment of PAHs would probably require a process by which the PAHs are sorbed to solids that are recycled through the treatment system. A biological contactor or proprietary powdered activated carbon system would possibly work if the solids retention time were sufficiently long enough to allow biodegradation. A potential problem with a biological system is the groundwater would not support a viable microbial community without the addition of a substrate (food for microorganisms) and nutrients.

In Situ Treatment (Bioreclamation)

In situ treatment of contaminated groundwater has received increased attention and application over the past several years. In situ treatment typically relies upon stimulation of indigenous organisms to degrade the contaminants present in the groundwater. This "stimulation" can be effected through the addition of nutrients, oxygen, and possibly co-metabolites into the contaminated zone of the aquifer. Hence, a critical aspect of the effectiveness of this technology is how well and how easily the oxygen and nutrients can be injected into the groundwater. Once injected, the oxygen and nutrients must be distributed to the contamination in the groundwater and adsorbed on the soil. Problems with clogging of injection wells and poor distribution of oxygen and nutrients have not been uncommon.

Because of the heterogeneous nature of the aquifer, the relatively low contaminant concentrations and limited plume distribution, the poor transmissivity, the Moss-American site is not considered a good candidate for in situ bioreclamation. Groundwater collection with trenches (see Appendix E) and above-ground treatment is considered a more effective and reliable means for addressing the existing groundwater problem; therefore, in situ treatment was not considered in the detailed alternatives.

Biological Land Treatment

Land treatment is similar to in situ treatment except the extracted groundwater would be distributed over soil underlain by a leachate collection system. The water could be sprayed or irrigated over the land treatment beds, continuously recycling the leachate collected in the underdrains of the treatment system. As a treatment process in itself, it would be significantly more costly than other forms of treatment. If, however, a land treatment facility is constructed to treat contaminated soil or sludge, additional water will be required. In this case, use of collected groundwater to provide the required moisture would be a cost-effective approach to treatment. The limitation of this treatment approach would be that groundwater would be collected continuously, whereas the water needs for land application would be negligible during wet weather periods and winter. Furthermore, the duration of groundwater treatment could be many more years than land treatment. Therefore, alternative groundwater treatment and disposal methods may be required in conjunction with this technology to provide treatment when land treatment is not available.

REMOVAL OF INORGANIC CONTAMINANTS

While some metals (copper, lead, and zinc) are estimated to exceed water quality criteria, those estimates are based on unfiltered groundwater samples. The filtered samples contained significantly lower amounts of metals. Depending on how well the collection system and aquifer filter suspended material, specific treatment for metals may not be required. This FS assumes that no treatment specifically for metals will be required as part of groundwater remediation, but this assumption must be verified through testing of the extracted groundwater after installation of the collection drain.

SURFACE WATER DILUTION

Table F-4 lists the estimated concentrations of the contaminants in the groundwater collected in the trench drain. If untreated groundwater is discharged to the river during average flow conditions, the resultant contaminant concentrations in the river would be reduced by dilution to concentrations below the surface water quality standards. The average (yearly) flow of the Little Menomonee River is 10 cfs (4,500 gpm) at Brown Deer Road and 17 cfs (7,630 gpm) at the confluence with the Menomonee River. At a groundwater discharge rate of 10 gpm, an average dilution ratio of about 450:1 (based on the flow at Brown Deer Road) may be possible.

The monthly or seasonal flow rate for the Little Menomonee River at Brown Deer Road is unknown. Factors influencing the flow include groundwater contribution, precipitation, and soil conditions. River flow rates will be higher during spring because of rain and snowmelt. Likewise, river flow will decrease during dry months or seasons of low snow accumulation.

Considering the effects of dilution, groundwater treatment may not be required to meet surface water quality criteria. It is still expected some treatment will be required to meet requirements for BATEA; the following section describes a likely groundwater treatment system.

SELECTION OF TECHNOLOGIES FOR SURFACE WATER DISCHARGE

The technologies discussed above were evaluated in terms of effectiveness, implementability, and cost. Table F-5 is a summary of this technology review. Although several technologies or combinations of technologies may be capable of achieving groundwater treatment goals, gravity separation of oil and creosote followed by granular activated carbon adsorption was selected as appropriate. Gravity separation was chosen to remove free product and some particulates to protect the carbon columns from fouling and because it is comparatively simple and low maintenance separation process.

Carbon adsorption was chosen for removal of organics because it is the single treatment alternative appropriate for all PAHs; it results in the greatest removal of contaminants; it does not require additional pretreatment such as nutrient or coagulant addition; it requires less operator attention and maintenance than other technologies; and offsite regeneration of carbon reduces liability associated with residuals. This system is expected to meet the discharge criteria and fulfill the BATEA requirement. While not as proven a technology as activated carbon, UV/ozone and UV/peroxide technologies have been demonstrated to be effective at destroying PAHs in contaminated groundwater. Because UV/ozone or UV/peroxide could be more economical than granular activated carbon adsorption and could alleviate residual management problems with granular activated carbon adsorption, predesign investigations should evaluate these technologies in greater detail, using bench or pilot-scale tests to more accurately determine their effectiveness and relative cost.

Table F-6 describes potential design parameters. These parameters were based on information developed in this text and the referenced EPA documents.

Table F-5
GROUNDWATER TREATMENT TECHNOLOGY COMPARISON

Process	Effectiveness	Implementability	Relative Cost
GAC Adsorption	Widely used and demonstrated effectiveness in removing organic compounds.	Readily implementable, but needs pilot testing.	Moderate
Membrane	Highly probable effective organic removal system, especially reverse osmosis.	Units available, but requires extensive pretreatment, pilot work, and operator skill and attention.	High
Chemical Oxidation	Demonstrated effective in laboratory. Effectiveness in field uncertain.	Difficult to implement, extensive pilot work needed.	High
Photolysis	Effectiveness uncertain.	Difficult.	High
Biological	Little demonstrated ability to remove low concentrations of organics.	Difficult to establish and maintain microbial population.	Moderate/High
Coagulation	Potentially not as effective as those cited above.	Equipment available, but extensive pilot testing needed.	Moderate
Flotation	Potentially not as effective as those above.	Readily implementable, following pilot testing.	Moderate
Gravity Separation	Least effective, but removes free product quite well.	Readily available.	Low
New Biotechnologies	Unknown	Maybe difficult to support biologicaly activity.	Moderate

Table F-6
GROUNDWATER TREATMENT SYSTEM
CONCEPTUAL DESIGN PARAMETERS

Item	Design Parameter
Flow	15 gpm
Organic chemical concentration in influent	15 mg/l
Gravity separator	1 unit
Carbon column	2 columns
Column loading	5 gpm/ft^2
Adsorbability	20 lb carbon/1 lb organic contaminant
Carbon usage	60,000 lb carbon/yr

OFFSITE GROUNDWATER TREATMENT

TREATMENT AT THE POTW

Groundwater could be discharged with little or no treatment to the POTW. The Jones Island POTW requires the total VOC concentration to be less than 5 mg/l for discharge to the POTW system without treatment. If the VOC concentration is above 5 mg/l, a discharge permit may be denied or restrictions may be added to the permit. Although pretreatment requirements for discharge of PAH-contaminated groundwater to the POTW have not been established, a Notice of Intent to Discharge Industrial Wastewater must be filed with the POTW. Notices are reviewed on a case-by-case basis.

Because of the low flow and low pollutant loading, it is likely that a simple oil/water gravity separation would meet requirements. The low loadings would meet the general guidelines of NR 211, in that operation of the plant and disposal of sludge would not be impaired, and the organic contaminants would receive some degree of treatment. Inorganic pollutants are not expected to be of concern because much of the insoluble fraction would be captured in the separation unit.

The most stringent pretreatment that could be required is BATEA. The treatment system consisting of oil/water separation combined with activated carbon would likely meet BATEA requirements. However, the implementation of such a system would successfully treat the groundwater such that little additional removal would take place at the POTW. Therefore, it is presumed that for discharge to the POTW the pretreatment requirements will consist only of gravity separation for removal of free product and settleable solids.

TREATMENT AT A RCRA FACILITY

An alternative to onsite treatment or discharge to the POTW is offsite treatment at a RCRA permitted treatment facility. This option greatly simplifies remediation because onsite treatment systems are eliminated and capital costs are low. Further, it eliminates the activities involved with permitting the treatment facilities and establishment of effluent requirements. Disadvantages of this alternative are the need to coordinate and document the collection and transportation of contaminated groundwater, and the relatively high cost of transportation to and treatment at a RCRA facility.

SUMMARY

Pretreatment using gravity separation and discharge to the POTW is the preferred groundwater treatment alternative. If discharge to the POTW cannot be implemented, then onsite groundwater treatment by separation and adsorption followed by discharge to the Little Menomonee River is considered the most cost-effective approach to groundwater treatment. The implementability of this option is dependent on the MMSD's willingness to accept the discharge.

To estimate the length of time required for groundwater treatment, it is generally necessary to estimate the travel times of the contaminants from their location in the soil to the point of collection. This has traditionally been done with models that assume the concentrations of organic contaminants in groundwater are limited by their solubility. However, it has been shown in EPA studies that modeling may not be the correct approach for sites where pure phase oil exist. Instead of contaminant concentrations being limited by solubility (which is low for PAHs) much higher concentrations of contaminants can exist as micro-droplets of oil. These micro-droplets of pure phase product have been observed to travel in sandy soil seams at velocities much faster than would be predicted for dissolved organic contaminants. Alternatively, at a site such as Moss-American where contaminants have been present for several decades in complex strata, nonaqueous phase liquids have had an opportunity to permeate clay lenses through advection and diffusion. As the groundwater is flushed by clean water, the release of contaminants from the clayey strata will be relatively slow compared to the more sandy strata, resulting in a long-term release of contaminants into the aquifer during remediation.

The evaluation of groundwater collection systems is presented in Appendix E. Assuming a collection drain arrangement with one drain running parallel to the river and another perpendicular to the river along the axis of the settling ponds, the length of time to remove one pore volume of groundwater on the site west of the river is estimated to be about 3 years. The length of time required to reduce the concentration of contaminants in groundwater to levels that would not require treatment to meet discharge limits is estimated to be more than 50 years without removal of source soil. The length of time required to reduce the concentrations of PAHs in groundwater to levels that would not require treatment to meet discharge limits would be less than a few years with source soil removal. This assumes that no source of benzene exists upgradient of the site.

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Appendix G
CONTAINMENT OF CONTAMINATED SOIL AND SEDIMENT

Appendix G
CONTAINMENT OF CONTAMINATED SOIL AND SEDIMENT

This appendix evaluates soil and sediment containment technologies retained after the preliminary screening based upon their effectiveness, implementability, and relative cost. Containment technologies that survived the preliminary screening of technologies included:

- Soil covers
- Caps
- Sediment control barriers

Soil covers and caps could contain soil or sediment in place, contain soil or sediment that has been consolidated from different areas of contamination, or contain treated soil or sediment. Containment of sediment in place using a soil cover or cap would require rerouting the river. Sediment control barriers are technologies that could be used to contain sediment in place without rerouting the river.

The following discussion of soil covers and caps will focus on the containment of soil and treatment residues; the section on sediment control barriers is relevant only to sediment.

SOIL COVERS

A soil cover would consist of a 2-foot layer of common borrow soil and a 6-inch layer of topsoil placed over the area of soil or sediment contamination. The site would be graded to direct surface water off the cover and seeded to control cover erosion.

Covering the site would lessen the possibility of direct human or animal contact with the contained hazardous materials. A soil cover would also limit contaminant transport by windblown dust or by surface water runoff and soil erosion.

A soil cover is a low-cost technology that is easy to construct and maintain. Because a soil cover does not significantly reduce infiltration, it is considered appropriate for use only when contaminants are predominately below the water table, when groundwater contamination from a source in the unsaturated zone is not a concern, when the contaminated soil or sediment is in an area unlikely to be developed, or when groundwater collection downgradient of the source is implemented. Because contaminated sediment was found below the water table and occurs in an area unlikely to be developed, use of a soil cover was retained for alternatives involving in-place containment of sediment and rerouting the river. Use of a soil cover was also retained for alternatives that will collect groundwater downgradient from contaminant source areas, since groundwater contamination is already present under areas of vadose zone contamination and the use of impermeable covers would provide marginal benefit (and also would prevent "flushing" of contaminants into the groundwater collection and treatment system). Use of a soil cover was also retained for covering soil and sediment that is treated. The use of soil covers for certain conditions may be restricted by ARARs derived from RCRA and Land Disposal Restrictions. Appendix A provides more details on those issues.

CAPS

Caps differ from soil covers in that a layer of low permeability material is an integral part of the cap. Capping the site would reduce the possibility of contact with the waste by reducing contaminant transport by windblown dust, soil erosion, and water infiltration through the site and into the waste. Caps require periodic maintenance to repair or prevent breeches caused by differential settlement at the site, burrowing animals, deep-rooted plants, erosion, and vehicles.

The following discussion addresses both single- and multilayer caps. The multilayer caps can be either single- or multiple-barrier designs.

SINGLE-LAYER CAPS

Single-layer caps consist of a layer of low permeability material, usually an asphaltic or bituminous concrete or a compacted clay. They are often suggested as a low-cost containment technology to restrict infiltration of water, despite poor durability and reliability.

Asphaltic concrete cannot be placed as a primary cap when low infiltration tolerances are specified. It is very difficult to produce an asphaltic concrete with zero porosity in the field. In addition, oxidation, viscous deformation, and chemical compatibility all lessen the effectiveness of asphaltic caps. Low permeability clays used for cap construction are loosened by frost action in the winter and crack as they dry during the summer. The detrimental effects of drying and frost on the long-term performance of single-layer caps are so severe that they are best suited for short-term emergency repairs.

In consideration of these factors, single-layer caps were not retained for further consideration.

MULTILAYER CAPS

Multilayer caps are designed to protect against surface water infiltration by combining layers of low permeability material with other layers of various design functions. Varying the type and number of layers and barriers within the cap will change the level of protection against infiltration.

Multilayer caps should consist of at least three distinct layers: a topsoil and fill layer, a drainage layer, and a barrier layer. If the site is expected to produce gases, a gas vent is needed to release gas from beneath the barrier layer. Gas generation is not anticipated at the Moss-American site.

Topsoil and fill material typically consist of local borrow soil and topsoil. The topsoil and fill layer separates the barrier layer from the environment and prevents damage to the barrier layer by frost, drying, vehicles, or animals. Vegetation planted on the surface helps reduce erosion and increases evapotranspiration.

The drainage layer allows removal of water that has infiltrated the topsoil and fill layer. Precipitation and meltwater seep through the top layer until they are blocked by the barrier layer. Installing a drainage layer allows seeping water to be removed, thus reducing the possibility that it will penetrate the barrier layer. Materials used in the drainage layer can consist of geosynthetic drainage media, clean sand, and gravel. The granular drainage layer is covered with a geotextile filter to prevent it from clogging with fine-grained soil from the topsoil and fill layer.

The barrier layer minimizes the volume of surface water that infiltrates to the contaminated material. Barrier layers typically consist of compacted clays, geomembranes (flexible synthetic liners), or some combination of the two to form a composite barrier layer.

Soil-Clay Cap

The soil-clay cap (Figure G-1) is a single-barrier, multilayer cap that consists of a clay barrier covered with a drainage layer covered in turn with clay and topsoil. If the cap is designed, installed, and maintained properly and is not subjected to excessive settlement distortion, it should remain intact and effective.

A low permeability clay layer (less than 1×10^{-7} cm/s) installed under ideal conditions should allow only minimal seepage into the site. Conditions are rarely ideal, however, and it is frequently difficult to compact the clay properly because of subgrade conditions. If the subgrade is soft, the efficiency of the compaction equipment is reduced and the clay cannot be compacted to obtain the low permeability desired. Even though the clay layer is protected from frost action and drying by the topsoil and fill layer, settlement distortion can still disturb the clay and increase seepage. The degree to which disturbance occurs will depend on the settlement at the site, the type of clay used, and the method of placement.

Soil-Clay Cap with Drainage Layer

The soil-clay cap with drainage layer (Figure G-1) is a single-barrier, multilayer cap similar to the soil-clay cap except that it includes a drainage layer between the cover soil layer and the clay. The drainage layer helps reduce infiltration even further by draining moisture away from the clay layer. The drainage layer would consist of 1 foot of gravel. This type of cover design would meet the requirements for covers for solid waste landfills, as outlined in NR 504.07.

Soil-Geomembrane Cap

The soil-geomembrane cap (Figure G-1) is a single-barrier, multilayer cap that differs from the soil-clay cap in that the barrier layer is a single layer of geomembrane. A properly installed geomembrane is nearly impermeable, so leachate production is lower than in caps with clay barrier layers. Geomembranes also are more tolerant than clay to tensile strains that arise from settlement distortion. Geomembranes can endure strains ranging from 10 to more than 100 percent along their length, depending on the geomembrane, and still maintain their effectiveness as barriers. Clays, however, begin to lose their effectiveness at very small strains.

If a geomembrane ruptures, it will no longer impede flow into the area around the rupture. For that reason, quality control is very important during installation of the geomembrane. Discontinuous or improperly welded seams can fail, creating holes that make the geomembrane ineffective as a barrier. The geomembrane must also be protected from puncture and impact during construction. If the soil that contacts the geomembrane contains angular gravel or other debris, a nonwoven geotextile should be placed between the membrane and the adjacent soil to protect the membrane.

Manufacturers of geomembranes claim design lives ranging from 30 years to more than 100 years. While some synthetic liners have been in use for more than 20 years (mostly in fresh water applications), longevity in hazardous waste applications is not well documented because of the short length of time they have been in use.

Soil-Geomembrane-Clay Cap

The soil-geomembrane-clay cap (Figure G-1) is a multibarrier, multilayer cap that combines the two types of barrier layers so that the geomembrane is placed directly over the clay layer to form a composite barrier. This technology is considered to be the most effective of the three alternatives in controlling infiltration because it combines the flexibility and permeability characteristics of the geomembrane with the longevity and resilience of the clay layer. The clay isolates ruptures in the geomembrane, and the geomembrane protects the clay from drying and cracking during construction.

The maximum benefits of the composite cap are obtained only if continuous contact between the geomembrane and the clay layer is maintained during construction. Leakage rates have been shown to be up to three orders of magnitude lower through a hole in a geomembrane firmly backed with a clay layer than through the same size hole in a geomembrane alone (EPA 1987).

U.S. EPA Guidance on Covers for CERCLA Sites

For covers at Superfund sites, the EPA's policy has generally been that covers should be designed to meet the requirements for RCRA caps, as specified in 40 CFR 264.310. These regulations are performance based, and require that the cover be designed and constructed to:

- Provide long-term minimization of migration of liquids through the closed landfill
- Function with minimum maintenance
- Promote drainage and minimize erosion or abrasion of the cover
- Accommodate settling and subsidence to maintain the integrity of the cover
- Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present

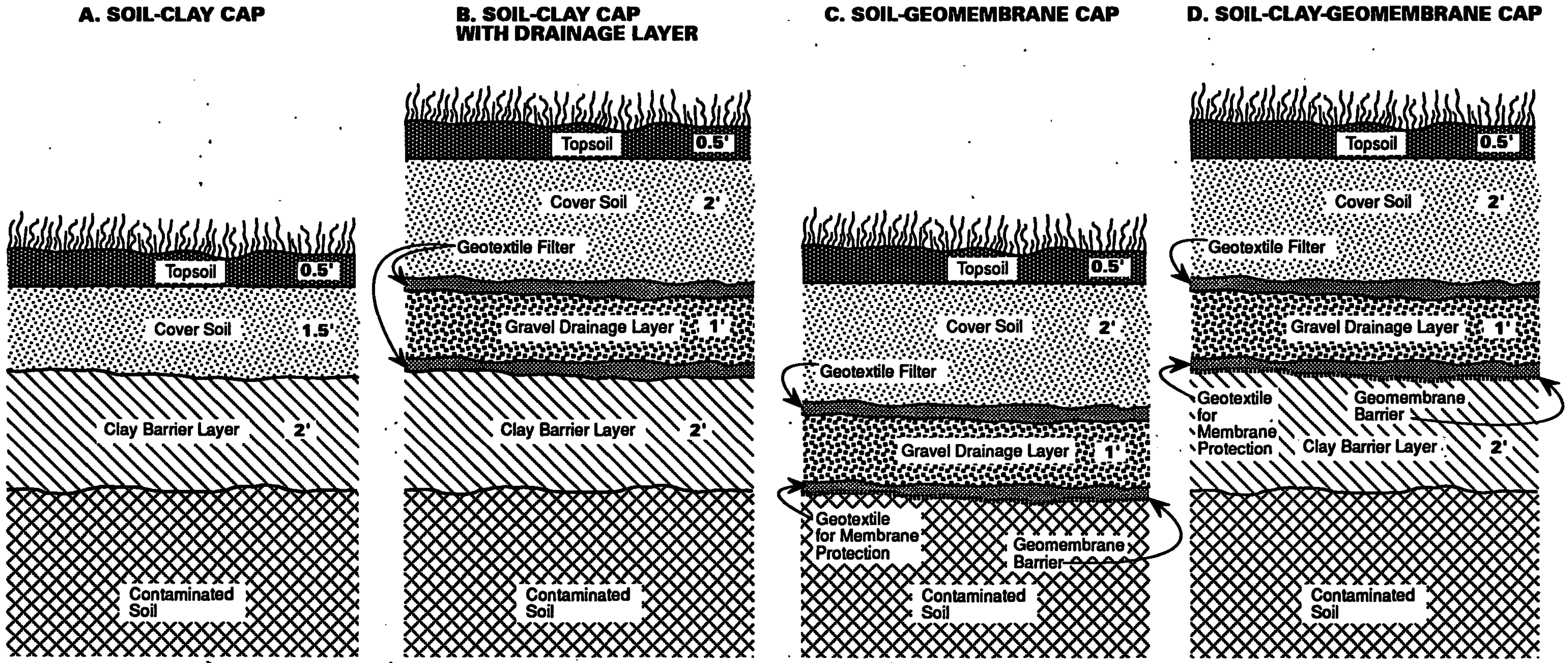

FIGURE G-1
TYPICAL MULTILAYER CAP SECTIONS
MOSS-AMERICAN FS

The EPA has established guidance that provides more quantitative specifications for the design of covers and caps for CERCLA sites. The guidance expands on the performance-based regulations, and provides an interpretation as to what the cover should consist of to achieve the regulations. The EPA has noted that, because the regulations are performance based, some flexibility will be allowed for in the design, as long as the design contains the same basic components as outlined below. The EPA has also noted that caps incorporating the following specifications would achieve the regulatory requirements:

- A vegetated top layer, at least 2 feet thick, with slope of 3 to 5 percent after subsidence
- A middle drainage layer, at least 12 inches thick, saturated conductivity not less than 10^{-3} cm/s, with a slope no less than 2 percent, overlain by a fabric filter to prevent clogging
- A low-permeability bottom layer, consisting of a synthetic membrane (minimum 20 ml thickness), underlain by a 2-foot layer of soil having a permeability less than 10^{-7} cm/s

The cover described earlier as the soil-geomembrane-clay cap would achieve the requirements established by this guidance.

Multilayer Cap Summary

The soil-clay and soil-geomembrane multilayer caps are roughly equivalent with regard to effectiveness. However, the soil-geomembrane-clay cap combines the good characteristics of the clay and geomembrane barrier layers to produce an option that is expected to perform the best of the caps discussed. The geomembrane is less susceptible to damage caused by settlement and serves as a barrier layer and a protection layer for the clay. The clay serves as a backup barrier for the membrane by limiting the amount of infiltration through the barrier system if the geomembrane develops holes. In addition, clay caps have been in use for a longer period of time and their long-term performance is better.

The cost of the caps will depend on the availability of the necessary soil materials. If clay is located onsite, the soil-clay cap will be the lowest in cost. Because clay will probably be imported, the cost of the soil-clay cap could approach or exceed that of the soil-geomembrane cap. Since the soil-geomembrane-clay cap contains both elements, it is the most expensive option.

Although the Wisconsin DNR and U.S. EPA have indicated that an engineered cover or cap would be required for containment of contaminated soil or treated sediment or soil to meet ARARs, the multilayer cap was not retained for inclusion in detailed alternatives since a large fraction of contaminant moss is below the seasonal high water table, and the reduction in the amount of infiltration through the contaminant mass in the unsaturated zone will help little in achieving remedial action goals or affecting groundwater quality.

SEDIMENT CONTROL BARRIERS

Sediment control barriers include silt curtains to mitigate downstream migration of resuspended sediment, and synthetic membranes to cover contaminated sediment in place.

Silt curtains are commonly used in heavy construction to limit the amount of settleable solids washed downstream of the construction activity. Because this technology is not believed to be effective in controlling the very fine-grained particles to which most of the contaminants are likely to adhere, it was not considered as a remedial technology.

Use of synthetic membranes placed over sediment has gained increased attention as a means of preventing exposure to contaminated sediment. This technology, however, has had only limited application and only with large basins, such as harbors. The long-term effectiveness of the technology in the shallow Little Menomonee River is questionable. The need for a means of anchoring the membrane to the river bed (such as riprap) could complicate stream channel hydraulics, and the long-term integrity of the liner is questionable since portions could be subject to sunlight and prone to puncture by debris and children. The implementation of this technology could be hindered by the poor support provided by soft sediment, and tree roots surrounding forested areas could complicate anchoring in river banks. Also, it is questionable whether this technology would provide an environment suitable for aquatic life. Sediment control barriers were not retained for consideration in detailed alternatives.

POTENTIAL MIGRATION OF CONTAMINANTS IN BURIED SEDIMENT

The migration of contaminants from buried sediments to the new river channel is a concern for Alternatives 2, 3A, and 3B. Migration of creosote-related contaminants could occur by one of three mechanisms:

- As a dissolved phase
- As a pure phase
- As an emulsion

Traditionally, sorption models have been used to predict the movement of dissolved organic contaminants in groundwater. This approach estimates that PAH movement of the dissolved phase will be so slow as to have a negligible effect on surface water and sediment of the new river channel if migration occurs toward the river. Therefore, it is unlikely that migration of the dissolved phase could result in exceeding the surface water quality criteria or sediment quality criteria for the new river.

Contaminant migration as the pure phase has probably had the most significant impact on groundwater quality in the vicinity of the process area. Groundwater sampling indicates that PAHs have not migrated great distances from areas of pure phase. It is unlikely that PAH migration to the new river channel will occur in the pure phase for several reasons:

- In the absence of any oil source (such as a lagoon), the major driving force will be the hydraulic gradient.

- The limited research information available suggests that pure phase movement is not strongly motivated by hydraulic gradients.

- Movement as a pure phase would probably be lateral or downward, and therefore could not reach the new riverbed if the new bed elevation is the same as the old bed elevation.

The migration of contaminants as emulsions (or micelles) is not well understood, and specific conclusions as to their potential impact cannot be drawn at this time. Laboratory scale studies may be required to determine the potential for contaminant migration in this phase, and its potential for readsorption or dissolution into the riverbed sediments or river water.

REFERENCES

U.S. Environmental Protection Agency. 1987.

GLT938/003.51

Appendix H
SOIL AND SEDIMENT TREATMENT

Appendix H
SOIL AND SEDIMENT TREATMENT

INTRODUCTION

This appendix presents an evaluation of potentially applicable treatment technologies (Table H-1) for contaminated soil and sediment at the Moss-American site. Treatment technologies that remained after the initial screening are evaluated in terms of their effectiveness, implementability, and relative cost. The treatment technologies considered to be the most appropriate were incorporated into the detailed alternatives described in Chapter 3.

CHARACTERISTICS OF THE CONTAMINATED SOIL AND SEDIMENT

Contamination of soil and sediment resulted from the storage and release of creosote wastes during the operation of the wood-treating facility. Although a chemical analysis of the specific creosote used at the Moss-American site is not available, it is known that the creosote was a mixture of 50 percent coal tar creosote and 50 percent fuel oil. Creosote is a complex mixture of organic compounds, primarily from the PAH and phenolic compound groups. The typical composition of creosote is listed in Table H-2.

The estimated volumes and characteristics of contaminated soil and sediment are presented in Appendix C and summarized in Table H-3. The volumes of contaminated soil and sediment were predominately dependent on the concentrations of carcinogenic PAHs present. The levels of inorganic contaminants found were below or near background levels. Maximum concentrations of arsenic and chromium, for example, were 12 mg/kg and 100 mg/kg, respectively. Concentrations of dibenzo-p-dioxins and furans (2,3,7,8-tetrachlorodibenzo-p-dioxin equivalents) were found to be less than 1 ppb for any given sample.

TREATMENT TECHNOLOGIES

Treatment technologies were initially screened to remove those clearly inappropriate for the types of materials to be treated. The technologies that remained after screening were soil washing, solvent extraction, slurry bioreactor, land treatment, incineration, in situ bioreclamation, vitrification, and soil flushing. These potentially applicable technologies are analyzed in more detail in the following sections.

Most of the following references relate to contaminated soil and not sediment because most remedial actions and studies performed to date have been done with soil. The differences in effectiveness between the application of a given technology to soil or sediment, however, are generally insignificant. Because the technologies retained for sediment are essentially the same as those retained for soil, the technologies are discussed without regard to specific application to either soil or sediment.

Table H-1
TREATMENT TECHNOLOGIES FOR SOIL AND SEDIMENT EVALUATION

Operable Unit	Remedial Technology	Process Options Retained from Initial Screening
Soil	Solidification/Stabilization	None
	Biological	Slurry Bioreactor Land Treatment In Situ Bioreclamation
	Physical/Chemical	Soil Washing Solvent Extraction In Situ Vitrification Soil Flushing
	Thermal Treatment	Incineration
Sediment	Solidification/Stabilization	None
	Biological	Slurry Bioreactor Land Treatment In Situ Bioreclamation
	Physical/Chemical	Solids Dewatering Soil Washing Sediment Flushing Solvent Extraction

GLT938/016.51

Table H-2
CHEMICAL COMPOSITION OF UNITED STATES CREOSOTE

Compound or Component	Percent of Total
Naphthalene	3.0
Methyl naphthalene	2.1
Diphenyl dimethylnaphthalene	---
Biphenyl	0.8
Acenaphthene	9.0
Dimethylnaphthalene	2.0
Diphenyloxide	---
Dibenzofuran	5.0
Fluorene-related compounds	10.0
Methyl fluorenes	3.0
Phenanthrene	21.0
Anthracene	2.0
Carbazole	2.0
Methylphenanthrene	3.0
Methyl anthracenes	4.0
Fluoranthene	10.0
Pyrene	8.5
Benzofluorene	2.0
Chrysene	3.0
Total	90.4

Source: McGinnis, July 1987.

GLT938/015.51

Table H-3
PHYSICAL CHARACTERISTICS OF SOIL AND SEDIMENT

Contaminated Soil[a]	Estimated	Range
Concentration of PAHs (mg/kg)	2,700	1,500 to 32,000
Concentration of Carcinogenic PAHs (mg/kg)	330	0 to 1,900
Volume exceeding 10^{-4} targets (yd^3)	207,000	----
Volume exceeding 10^{-6} targets (yd^3)	210,000	----
Moisture content (%)	20	9 to 52
TOC (mg/kg)	57,000	4,100 to 130,000
Ash (% dry basis)	67	45 to 85
Heating value (Btu/lb)	<500	----
Contaminated Sediment		
Concentration of PAHs (mg/kg)	700	2 to 6,000
Concentration of Carcinogenic PAHs	100	1 to 500
Volume exceeding 10^{-4} targets (yd^3)	3,500	----
Volume exceeding 10^{-6} targets (yd^3)	36,300	----
Moisture content (%)	39	24 to 56
TOC (mg/kg)	32,000	10,000 to 57,000
Ash (% dry basis)	49	36 to 63
Heating value (Btu/lb)	<500	----

[a]Based upon surface soil data only.

GLT938/005.51

BIOLOGICAL TREATMENT TECHNOLOGIES

The risk assessment determined that carcinogenic polycyclic aromatic hydrocarbons (PAHs), that are the principal components of creosote, are the major cause of risk to human health at the site. While these compounds are considered difficult to biodegrade, degradation of PAHs has been observed, and the primary route of degradation was biological. Studies have shown that 2- and 3-ring PAHs are biodegraded under aerobic conditions relatively quickly and that the rate of degradation of the 4-ring compounds and greater is much slower and can be highly dependent on the presence of other 2- and 3-ring cosubstrates (Mueller et al. 1989; Kobayashi and Rittman 1982). Leinkenheil and Piontek (1987) reported that all the 2- and 3-ring compounds, except anthracene, degraded to the detection limit or lower within the duration of a 90-day land treatment pilot study at a wood preserving facility in Minnesota. Results from several studies suggest that 4- to 6-ring compounds cannot be metabolized as quickly as the 2- and 3-ring PAHs because their lower solubilities and hydrophobic properties make them less available to microorganisms.

Because it is known that PAHs can be biodegraded, more important questions are: (1) How long will it take to degrade the contaminants to an acceptable level? and (2) What residual concentrations are obtainable in a reasonable amount of time? The rate of biodegradation of contaminants in a soil or sediment medium depends largely on whether an adequate population of microbes is present to metabolize the compounds and whether conditions are suitable for their growth. Because degradation rates for 4+ ring PAHs are slow, the cleanup criteria will also affect the viability of biotreatment over other treatment options.

Environmental conditions are important to the success of site remediation by biodegradation. Temperature, pH, oxygen, moisture, and essential nutrients must be conducive to microbial activity. Thus, the effectiveness of any biotreatment process relies on the ability of the system to control the environmental conditions important for microbial growth.

Because the characteristics of contaminated soils and climatological conditions vary from site to site, biodegradation rates and efficiencies for biotreatment systems proposed for the Moss-American site cannot be predicted with a high degree of confidence from literature values or from bench-scale studies. Information available in the literature, however, is used in this FS to estimate the upper and lower limits expected for degradation rates. Table H-4 presents some degradation rates for PAHs reported in the literature. Half-lives observed in treatability tests conducted on sediment and soil samples from the Moss American site are presented in Table H-4. A comparison of the rates observed in the treatability test to those observed in other research projects suggests that higher rates might be achievable than observed in the treatability study.

Several technologies have been demonstrated to be effective in biodegrading PAHs in creosote-contaminated soil and sediment (Kuhn and Piontek 1988). The principal biological treatment technologies considered in this appendix are land treatment, slurry bioreactor treatment, and in situ bioreclamation.

Table H-4
FIRST ORDER DEGRADATION CONSTANTS

Compound	Range Observed in Mixed System[a]		Range Observed in Soil Column	
	Treatability Study Results (day-1)[a]	Reported in Literature (day-1)[d]	Treatability Study Results (day-1)[b]	Reported in Literature (day-1)[d]
Benzo[a]anthracene	0.003-0.011	0.044-0.234	0.004-0.019	0.021-0.019
Benzo[k]fluoranthene	0.000-0.005	---	0.000-0.011	---
Benzo[a]pyrene	---	0.020-0.048	---	0.000-0.011
Benzo[g,h,i]perlyene	0.000-0.005	---	0.000-0.001	---
Chrysene	0.006-0.017	0.132-0.015	0.007-0.023	0.0002-0.012
Naphthalene	0.019	0.002-0.039	---	0.014-0.025
Phenanthrene	0.016-0.120	---	---	0.029-0.048
Pyrene	0.014-0.022	0.025-0.050	0.013-0.023	0.002-0.022

[a]Simulates a slurry bioreactor system.
[b]Simulates a land treatment system.
[c]Corresponding half-life given by $t_{1/2} = 0.693/k$; where k = first order constant.
[d]Reference: B. D. Symons, et al.

Land Treatment

Description of Technology. Land treatment is a process in which contaminated solids are spread over the land surface to promote aerobic biodegradation of contaminants. This process applies basic concepts from agriculture to enhance microbial activity. The soils are spread in layers approximately 1 foot thick and tilled periodically. Water and nutrients are added to maintain conditions favorable for aerobic degradation of the organic contaminants.

A schematic of a potential land treatment facility (one of several types of designs) is shown in Figure H-1. The system consists of lined treatment beds, a leachate collection system, and a treatment zone having a thickness of approximately 1-foot. Surface slope would be maintained between 1 and 2 percent to prevent ponding and control runoff. The sides of the beds are bermed to control runoff and runon. For an enclosed system, an overhead irrigation system could provide water. For an open system, irrigation could be provided by any of a variety of common agricultural techniques. Nutrients could be applied either through the irrigation system or by incorporation into the soil by spreading and tilling. The treatment beds could be enclosed by a greenhouse or covered with plastic sheeting to maintain warmer soil temperatures in winter and to help control VOC emissions and odor. It is doubtful that this would be economical because of the extreme cold temperatures in Wisconsin during winter, and because RI report data do not suggest that volatiles are present in a high enough concentration to present concern.

To collect and control leachate, the bottom of the treatment bed would be underlain by a high-density synthetic liner. The liner would be covered with sand, which would collect and transport the leachate to perforated piping and then to a sump. Contaminated leachate would be collected in a sump from where it could either be pumped back to the site, treated, or discharged to the POTW. The leachate is not expected to contain an appreciable amount of PAHs. These compounds have been found to percolate very slowly downward through soil (Symons et al. 1988). The liner could be used as part of a long-term leachate containment system.

Technology Status. Land treatment of oily waste from petroleum refineries has been practiced for several decades. Over 200 land treatment facilities (most of which do not incorporate leachate collection) are currently in operation in the United States. Land treatment facilities for RCRA wastes are regulated under RCRA.

Wood preservation wastes have been demonstrated to be biodegradable by land treatment. However, the rate and degree of biodegradation varies and depends on a number of factors including:

- Soil type
- Soil pH (near 7 is optimal)
- Soil moisture (from 30 to 70 percent of the moisture-holding capacity of the soil must be maintained)
- Availability of nutrients

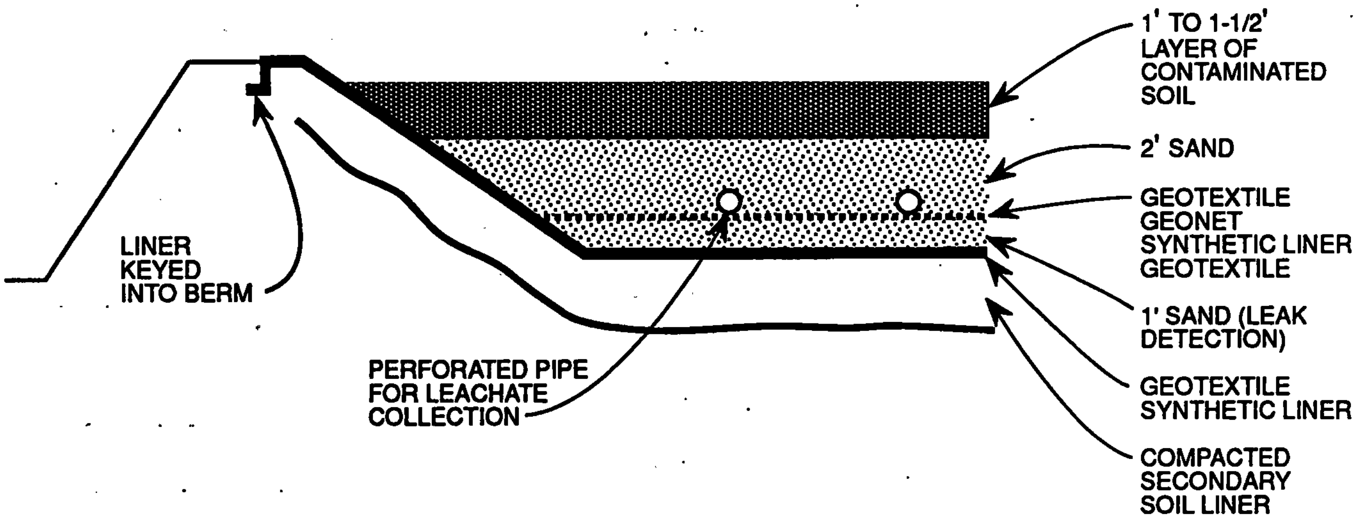

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FIGURE H-1
CONCEPTUAL CROSS SECTION OF LAND TREATMENT BED
MOSS-AMERICAN FS

- Temperature (temperatures above 10°C are required to maintain good microbial activity)

- Tilling frequency

A basic requirement for land treatment of soils contaminated with organic compounds is to provide sufficient nutrients and air for microorganisms. Sims and Bass (1984) suggest that nitrogen and phosphorous should be added if the ratio of organic carbon:nitrogen:phosphorus is greater than 300:15:1. Leinkenheil and Piontek (1987) suggest that C:N ratios be kept in a smaller ratio of 25:1 to 50:1. In demonstration tests on a Superfund site in Minnesota, manure was used to provide the desired C:N ratio. Similarly, Ramsey et al. (1981) used composted sewage sludge to provide a microbial population, to optimize the moisture-holding capacity of sandy soil, and to enhance soil structure in clayey soil, allowing better water and gas exchange within the soil and promoting a more aerobic environment. Soil moisture should be kept near the fluid capacity of the soil (without saturating the pore space), and nutrients should be added frequently. Aerobic conditions are necessary—and lack of oxygen is often cited in literature as one of the factors limiting biodegradation. Typically, a pH of 6 to 7 is optimal for microbial growth, and biodegradation rates appear to increase with temperature.

Applications and Limitations. With the exception of temperature, the major factors limiting degradation could be controlled at the Moss-American site. Degradation rates would be expected to decrease significantly during winter months. Leinkenheil and Piontek (1987) reported that little or no degradation of PAHs occurred during winter months. This FS assumes that land treatment operations would be suspended during the winter.

Degradation during winter could be enhanced by using an acclimated microbial population. Commercially developed bacterial strains can be purchased for this purpose. Several researchers have reported that inoculation of creosote-contaminated soils with cultured, creosote-degrading bacteria have met with only limited success (Mueller et al. 1989). Specially cultured bacteria are often less robust than indigenous strains and are more quickly affected by adverse environmental conditions. An acclimated population is expected to exist in the contaminated soil at the Moss-American site. Thus it appears more feasible to enhance the acclimated existing population than to introduce new organisms.

The principal advantages of land treatment are:

- Relatively low capital and operating costs
- Proven performance in northern climates
- Simple technology

The process does, however, have a number of disadvantages:

- It requires relatively large amounts of land.

- It is management-intensive.

- The period of time required for treatment may be several years if the goal concentration of 4-, 5-, and 6-ring PAHs is fewer than a few ppm.

- Materials handling and fugitive loss can be a problem.

- Air emissions and odors are a potential source of nuisance and possibly a health hazard to onsite workers.

- The effectiveness of the system during the winter will be diminished unless the treatment cells are enclosed.

- The treatment area might not be allowed to be outside the "area of contamination" without bringing RCRA regulations and the need for permitting into effect. This might limit the area required for the treatment facilities.

- Stockpiling and staging will be required during construction of the treatment beds and periodically during inclement weather.

The degree of treatment required would probably be dictated by the RCRA LDRs, the details of which are found in 40 CFR 268. These rules present concentration limits (cleanup criteria) for specific compounds of specific waste types. Table H-5 lists the limits for K001 waste. The U.S. EPA recognizes that these requirements may not be appropriate for contaminated soil and is setting LDR standards specifically for soil and debris. Until these standards are complete, the EPA recommends pursuit of a "treatability variance" to establish alternative treatment limits. OSWER Directive 9347.3-O6FS outlines the procedure to obtain a treatability variance. Under a treatability variance, alternative treatment levels are established based on data from actual treatment of soil or best management practices for debris. Justification for a variance can be based on:

- Remediation goals for the site
- Site-specific conditions
- Performance capabilities of the technologies being considered

The directive indicates that treatability data may be used as justification for a variance if studies indicate that the LDR standards cannot be consistently met with the specific technology. When treatability data are not available, other data such as values reported in literature for similar wastes may be used. Obtaining a treatability variance may require justifying why a specific technology is considered the most appropriate. It also requires that the justification and rationale be presented in the FS. The FS should specify the level ranges that the proposed technology would attain for each waste constituent restricted under the LDRs and the primary contaminants of concern identified in the baseline risk assessment.

Bench-scale testing of land treatment was performed as part of the RI. Results of these tests indicated that treatment times to reduce the concentration of carcinogenic PAHs by 95 percent could be approximately 6 months to a year. Appendix K provides greater detail on the methods and results of this study. This FS assumes that soil and sediment that is land treated would be treated for 1.5 treatment seasons

Table H-5
TREATMENT STANDARDS FOR K001 WASTES

Chemical	Concentration After Treatment (mg/kg)
Naphthalene	8
Pentachlorophenol	37
Phenanthrene	8
Pyrene	7.3
Toluene	0.14
Xylene	0.16

Source: 40 CFR 268.43

GLT938/017.51

(1.5 years) to achieve the desired cleanup goal, which is assumed to be a 95 percent reduction.

Conclusion. Because land treatment has been demonstrated to be an effective treatment of PAH-contaminated soil and because it is a relatively low-cost treatment option, it was retained for use in detailed alternatives.

Slurry Bioreactor Treatment

Description of Technology. Slurry bioreactors treat contaminated soil by slurrying it, then mixing the soil slurry with microorganisms in an aerated reactor. The reactor (a large tank with mixers or aeration equipment) provides a favorable environment for microbial growth and maintains contact between the contaminants and microorganisms performing the degradation. As with other biotreatment processes, temperature, pH, oxygen, and contact between contaminants and microorganisms are critical factors controlling the rate of degradation. Because these parameters can be more easily controlled in an enclosed reactor than in a treatment bed, slurry bioreactors can achieve faster rates of degradation. Figure H-2 is a conceptual process flow schematic for a slurry bioreactor system.

Removal of contaminated soil at the Moss-American site would be by dry excavation. Because most of the contaminated soil that would be treated is located above the seasonal high water table, the soil moisture content would probably be less than 15 percent and, therefore, slurrying would be necessary. Contaminated sediment, however, could be removed by either wet dredging or by dry excavation (see Appendix D). In the case of removal by dredging, the material would already be in slurry form (probably between 10 to 30 percent solids) and would not require a significant amount of pretreatment to produce an acceptable slurry. In the case of dry excavation, the sediment would probably be in the range of 20 to 40 percent solids and would not require slurrying.

The excavated soil and sediment would be screened to remove the non-slurryable fraction. Screening devices commonly used include a vibrating screen and the trommel screen. These devices can remove stones and other materials greater than ¼ inch. If large clumps of clay persist, then a rod mill or attrition scrubber could be used to break the clumps before screening. Oversized material is either crushed separately, disposed of, or decontaminated and disposed of. A pretreatment step could separate fine solids from coarse solids if it appears that most of the contaminants are adhered to the fine solids.

Following screening, the material would be pumped to a reactor vessel, where the slurry would be mixed and aerated. Mixing can be performed through aeration, mechanical agitation, slurry recycle, or a combination of these. Mixing promotes contact between microorganisms and organic contaminants and produces a homogeneous mixture with respect to contaminants, biomass, and oxygen. Nutrients can be added to enhance degradation.

Following degradation in treatment tanks, the slurry would be piped to a thickener for separation of the solids from the liquid. Solids would be further dewatered before replacement onsite, while the liquid phase would be recycled. Dewatering would be performed by gravity settling and filtering in a press. These systems should be

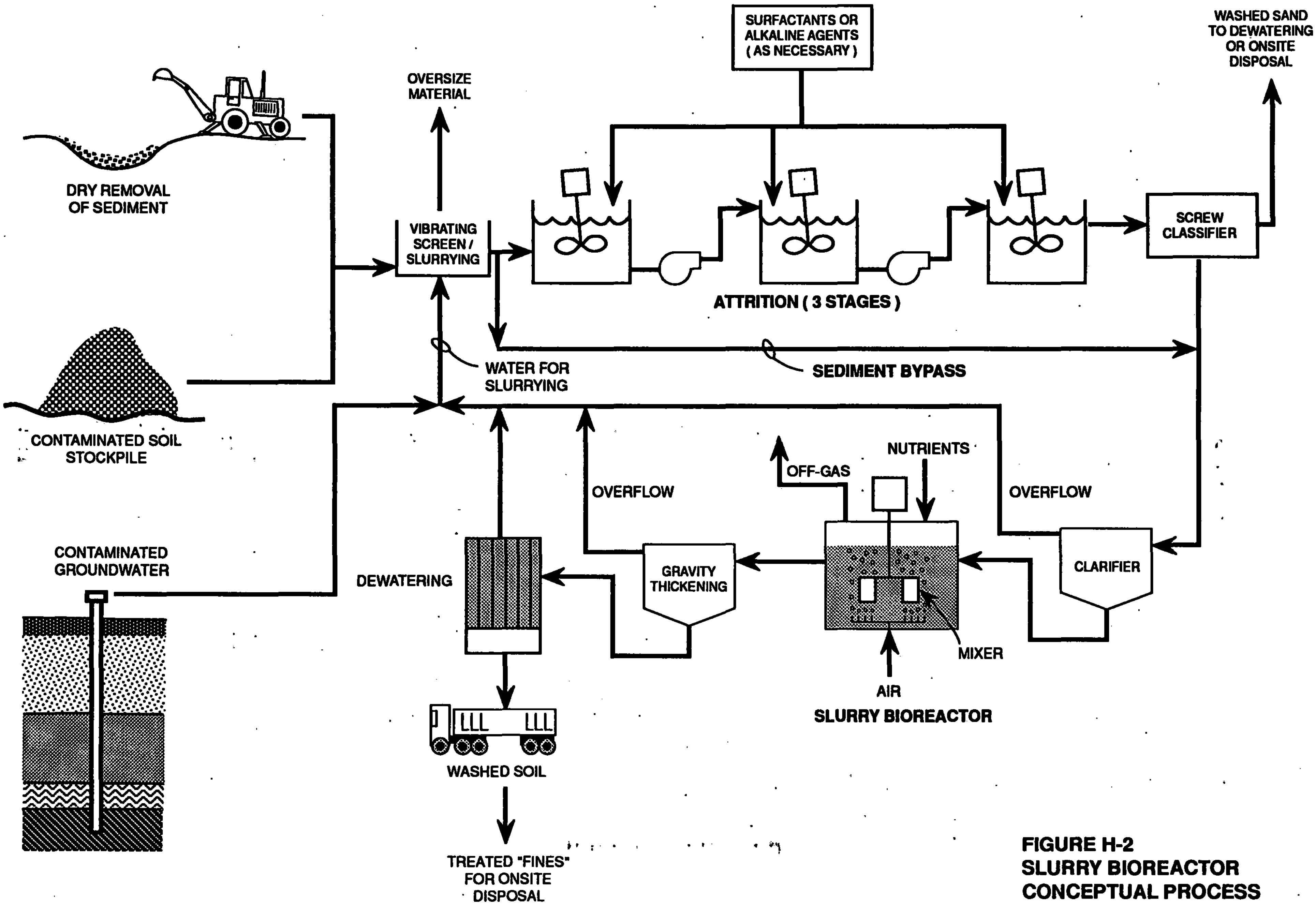

FIGURE H-2
SLURRY BIOREACTOR CONCEPTUAL PROCESS FLOW SCHEMATIC
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capable of producing a cake with solids content greater than 50 percent. It is assumed that the treated residuals could be replaced and contained onsite.

Wastewater generated from the dewatering step would either be recycled for slurrying or treated onsite prior to discharge to the river or POTW. Solids settling treatment processes are evaluated in detail in Appendix F. Activated carbon or filtration could be employed before discharge if necessary.

An important feature in the design of the bioreactor is the length of time required to aerate the slurry to achieve the desired level of degradation. This hydraulic retention time is based on the concentration of contaminants in the feed, the desired effluent concentrations, and the rate of degradation. Very limited information is available from studies on rates of degradation observed in bioreactors and, therefore, bench- and pilot-scale studies would be required during the preliminary design.

Technology Status. While treatment of sediments contaminated with PAHs in a slurry bioreactor is considered an innovative technology, the basic components of the technology are proven. Biodegradation of PAHs has been practiced for years in land treatment of petroleum hydrocarbons. Slurry reactors have also been used extensively in various applications. The use of a slurry bioreactor to treat sediments is similar to the use of aerobic or anaerobic digesters to treat municipal and industrial wastewaters. Mining process applications of slurry reactors have established appropriate procedures for the materials feeding, slurry mixing, and solid dewatering components required in a slurry bioreactor application. Slurry bioreactors have reportedly been successfully used to treat solids contaminated with PAHs at other sites. Information on these applications is not, however, generally available in the technical literature.

As with most bioremediation applications, the feasibility of using slurry bioreactors is a site-specific consideration. Key issues are solids handling and the ability to meet cleanup criteria.

Applications and Limitations. One of the factors influencing the effectiveness and implementability of this system is the nature of the material to be slurried. The degree to which the contaminated materials remain in suspension greatly affects the performance and energy costs of the system. Generally the sediments at the Moss-American site are silty clay and organic material and should remain in suspension with little agitation. The contaminated soil is silty sand and some silty gravel. Much of the soil may not be suitable for a slurry bioreactor. A series of simple settleability tests should be performed prior to design of the system.

For sediments, another factor affecting degradation rate could be the organic content of the sediments. Higher organic fractions could promote co-metabolism and thus enhance biodegradation. On the other hand, the organics could decrease the availability of the compounds because of the high degree of adsorption. Again, site-specific testing would be required to determine the effect of these constituents.

The homogeneity of the slurry that can be achieved is uncertain and would require pilot testing. Pilot testing should also help determine how well pure phase free product would mix in the slurry reactor.

Because of the vigorous aeration of soil in reactors, the potential of volatilization is enhanced. Based on RI results, this does not appear to be a problem (PAHs and other principal contaminants have low volatility). If pilot-scale tests indicate a need for control of volatized contaminants, the air could be pretreated with GAC before it is discharged to the atmosphere.

Bench-scale testing of a system similar to slurry biotreatment was performed as part of the RI. Results of these tests indicate that treatment times to reduce concentrations of carcinogenic PAHs by 90 percent would be approximately 13 to 150 days (see Appendix K). It is likely that this range of treatment times is conservative for a full-scale system since the bench test samples were not continuously stirred or aerated. Based on limited information on pilot-scale tests of slurry biotreatment of creosote-contaminated soil, the FS assumes a 15-day retention time would achieve the desired cleanup goal, which is assumed to be a 95 percent reduction. For soil having average concentration of carcinogenic PAHs of 300 mg/kg, a 95 percent reduction would still leave residues with risk levels slightly greater than 1×10^{-4} (excess lifetime cancer risk). If this option is selected as part of the remedial action, pilot tests should be performed to more accurately determine achievable levels of treatment.

Malfunctions of the mechanical systems, such as pumps and rakes in clarifiers could pose difficulties in implementing this technology. Thus, effective equipment maintenance would be required.

Conclusions. Compared to land treatment or incineration, this is a relatively new technology with limited demonstration. The potential advantages of the slurry bioreactor over land treatment are:

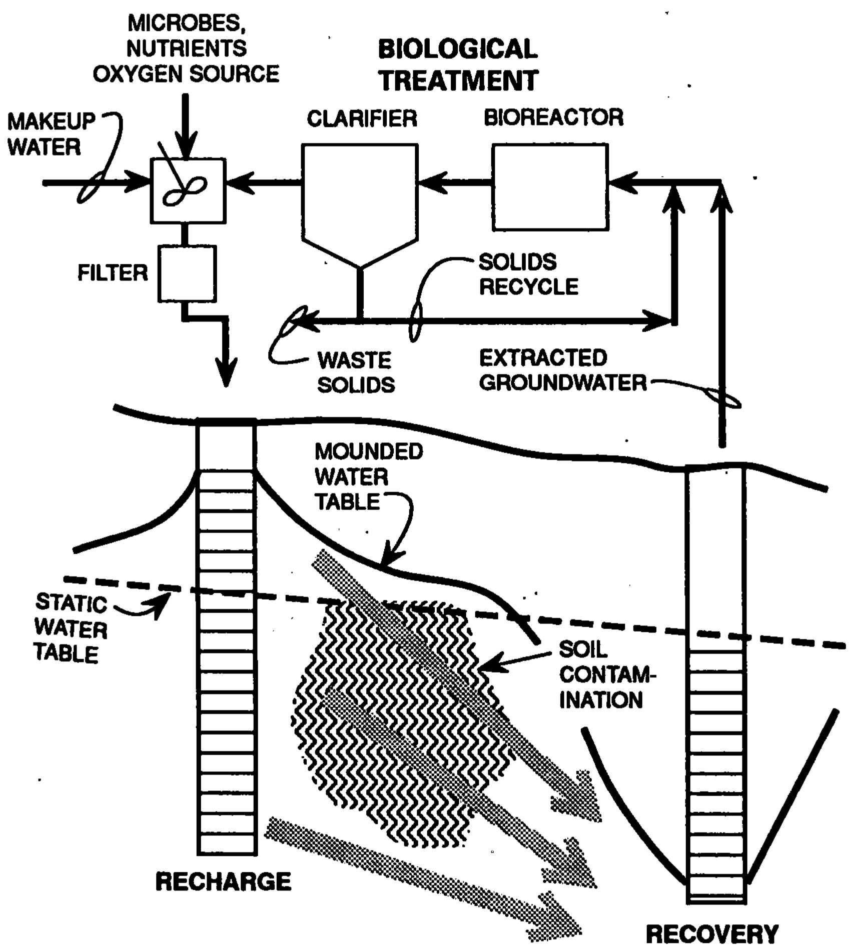
- Better control of parameters such as temperature
- Better control of nutrient levels
- Increased contact between contaminants and microorganisms
- Faster acclimation rates and degradation rates
- Less area required

Slurry biotreatment was retained for use in detailed alternatives.

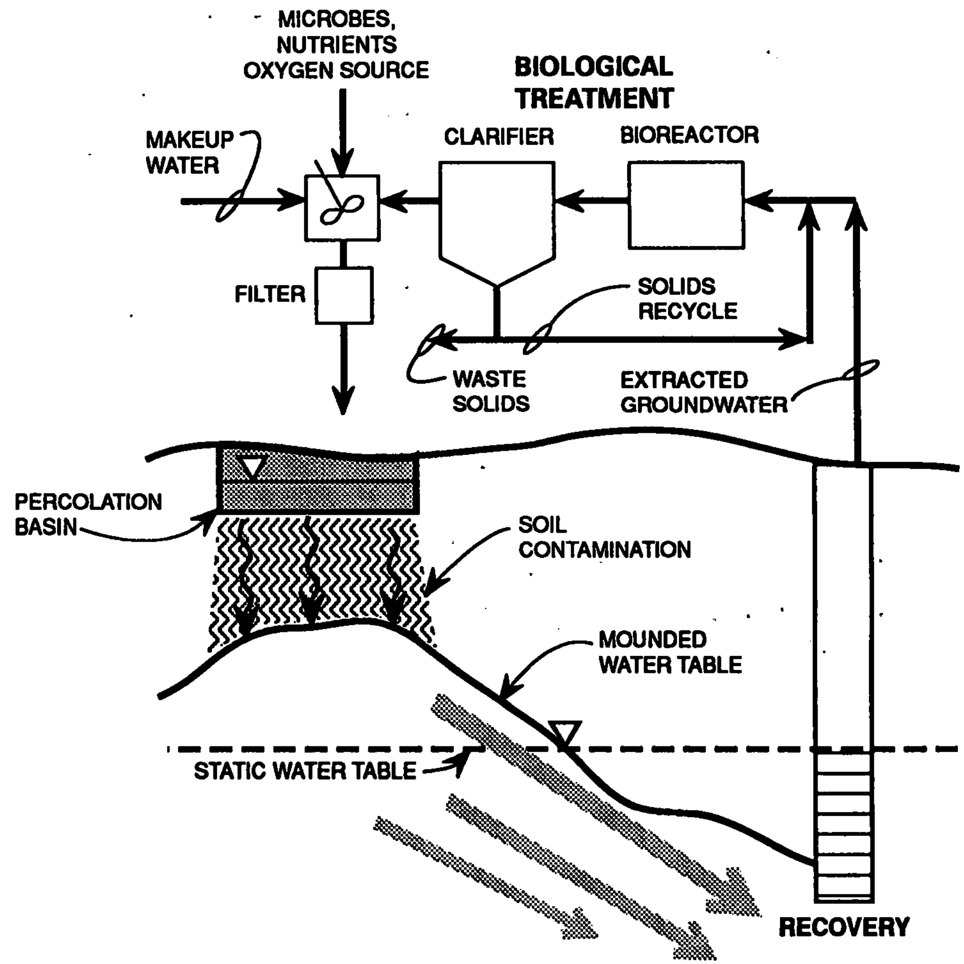
In Situ Bioreclamation

Description of Technology. In situ bioreclamation is similar to land treatment and slurry bioreactor treatment in that contaminants are oxidized through microbial metabolism. In situ bioremediation is different from land treatment and slurry bioreactors in that the soil is treated in place.

For contaminated soil in the saturated zone, the groundwater is used to transport oxygen and nutrients to the microbes. In situ biodegradation systems typically consist of a groundwater treatment system, a groundwater extraction system, and a groundwater recharge system. A conceptual system is presented in Figure H-3. Groundwater is pumped from downgradient wells or drains to a treatment system and then returned to recharge wells where it is reintroduced to the groundwater upgradient of the contaminated zone. Nutrients and oxygen are added after removing



(a) IN SITU BIORECLAMATION USING RECHARGE WELLS OR TRENCHES



(b) IN SITU BIORECLAMATION USING INFILTRATION

FIGURE H-3
IN SITU BIORECLAMATION ARRANGEMENTS
MOSS-AMERICAN FS

biodegradable contaminants. Contaminated groundwater and soil are tested simultaneously.

Technology Status. While some attempts have been made to introduce to a site microbes that are capable of degrading contaminants, these attempts have had only limited success. Conditions unique to a site such as temperature, pH, levels of oxygen, nutrients, and carbon source may prevent exogenous microbes from achieving their degradation potential. The contaminants at the Moss-American site have existed in the soil for several years, and so some microbial populations probably have acclimated themselves to the contaminants already. In situ bioremediation activities would concentrate on stimulating the indigenous microbes.

Applications and Limitations. While much of the success of in situ biodegradation depends on having a microbial population that can degrade the contaminants, success also depends on several suitable subsurface physical conditions. First, relatively high hydraulic conductivities are needed to inject and extract sufficient quantities of water to carry the needed oxygen and nutrients. (A general rule-of-thumb is a minimum hydraulic conductivity of 10^{-4} cm/s.) Second, the homogeneity of the subsurface soil effects flow through the contaminated media. Seams of soil with higher hydraulic conductivities tend to cause groundwater to short circuit through the media. Third, the soil needs to have a low chemical oxygen demand. If there are other demands on the oxygen in addition to the demand from organic contaminants, oxygen may not be available to the microbes degrading the organic contaminants. Fourth, a relatively uniform distribution of contaminants facilitates treatment. Localized areas of high contamination or areas of pure phase product are less amenable to in situ biodegradation.

Several site-specific characteristics may limit the effectiveness of in situ bioreclamation. Perhaps the most significant of these is the heterogeneity of the soil and contamination. Numerous excavations and fills have been made on the site. Consequently, several areas on the site exhibit different physical and chemical characteristics. For example, depending on the area, subsurface material ranges from a gravelly fill to a silty clay. Mixed into this are layers of wood chips, bricks, old railroad ties, and other rubbish. Within this mixture are levels of contaminants that range from 0 to 1,900 ppm. Visual observation has detected both clean and oil-saturated soil.

A problem caused by the heterogeneity of the subsurface material is the variability in hydraulic conductivities. Hydraulic conductivities of the silt and clay are much lower than those of the sand. Consequently, the groundwater tends to flow through the sandy material and around the silt and clay.

Another problem is the organic matter other than the contaminants in the soil. The soil has a high percentage of naturally-occurring carbon and the buried refuse wood chips also exert some oxygen demand. Chemical oxygen demand in the soil was not measured, but chemical oxygen demand in the groundwater ranges from 10 mg/l to 650 mg/l. Again this shows the high variability of the contamination.

Conclusions. It is not likely that sufficient groundwater control could be achieved with such variable wastes. The groundwater and the added oxygen and nutrients could tend to short circuit through the sand lenses on the site. Furthermore, with the high variability in concentrations and distribution of contaminants, it is not likely that the oxygen and nutrients would be delivered to places where it was needed most. In areas of pure phase creosote, in situ biodegradation would be a slow process. Several other sources of oxygen demand could deprive the microbes degrading the carcinogenic PAHs of needed oxygen. Much of the contaminant mass is in the upper 4 feet of the soil column. During parts of the year, the contaminants would be above the water table and would not be affected by the in situ bioremediation. In summary, several site characteristics would hinder effective use of in situ bioreclamation and, therefore, it was not retained for further analysis.

New Biotechnologies

New biotechnologies include the development of organisms that are cultured in a laboratory environment to consume specific contaminants. A significant amount of research and publicity has been focused on the development of these exogenous "superbugs." To date, however, the introduction of special microorganisms into a contaminated environment has not been demonstrated to be effective.

Because contaminants have been present at the site for a long time, an acclimated microbial population capable of degrading PAHs may already exist at the site. Most studies have noted that indigenous microorganisms can be stimulated to metabolize the contaminants present. The general opinion of researchers and engineers appears to be that stimulation of indigenous organisms is a superior approach since they are already acclimated to the environment and may have developed a propensity to consume the contaminants of concern.

PHYSICAL/CHEMICAL TREATMENT TECHNOLOGIES

Soil Flushing

Description of Technology. Figure H-4 is a schematic of an in situ soil washing or "soil flushing" process. A solution of water with surfactants and alkaline agents is mixed above ground and injected into the subsurface. The surfactants and alkaline agents act to emulsify oils and increase their mobility. Groundwater containing these oils is extracted downgradient from the zone of contamination and treated or recycled for reinjection.

Technology Status. Soil flushing has been demonstrated to achieve contaminant removal higher than 98 percent in coarse soil matrices (Kuhn and Piontek 1988).

Applications and Limitations. In general, soil flushing has been applied only to cases where contaminants are below the water table in relatively permeable, sandy soils.

Conclusions. Because a large fraction of contaminated soil at the Moss-American site is in a low-permeability soil and because most of the contaminants are above the water table, soil flushing was not considered appropriate for the site and was not retained for further consideration.

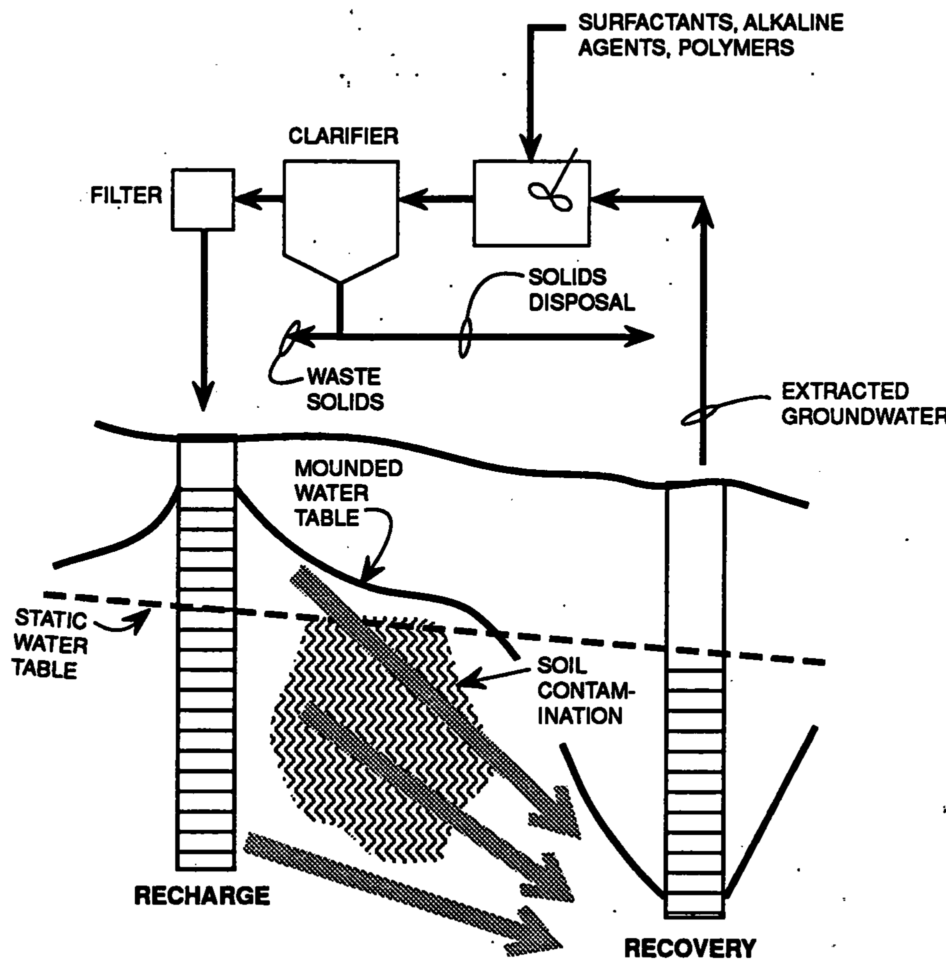


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FIGURE H-4
SOIL FLUSHING
MOSS-AMERICAN FS

Soil Washing

Description of Technology. Soil washing is a process by which excavated soil is mixed vigorously in a tank and contaminants adhering to soil are removed from the soil and put into a washing solution. The washing solution is treated in another process. Soil washing has been performed on excavated soils using process equipment derived from the mining industry.

The effectiveness of a soil washing system depends on how tightly the contaminants are adsorbed to the soil. The degree of adsorption is affected by the solubility of the compound in the solvent (in this case water) and the characteristics of the sorbing matrix, such as particle size (which affects interfacial tension) and organic content. In general, water alone is an inadequate solvent for removal of contaminants from soil. Surfactants, emulsifying agents, and alkaline agents are normally added to water to help desorb compounds (Kuhn and Piontek 1988).

Soil washing systems currently available have been effective in removing contaminants from coarser sands, but they only perform a physical separation of contaminated fines from the "washable" coarser particles. The fines are then treated subsequently by another process such as biotreatment or incineration. Although ex situ soil washing is not a treatment process, it can reduce the volume of soil requiring treatment. Soil washing of soils which have a higher fraction of fines is less economical because the fraction requiring handling and treatment a second time is higher. A study of soil washing vendors in Europe found they have a practical upper limit for the fraction of fines in the soil to be treated of 20 to 30 percent (Nunno et al. 1989).

A schematic of a commercially available ex situ soil washing system is illustrated in Figure H-5. Excavated soil is first screened to remove large debris (greater than ¼ inch). Large material is reduced by shredding or crushing and then subjected to an intense scrubbing step. Undersize materials are slurried with water, surfactants and alkaline agents, then mixed vigorously in countercurrent washing stages and a froth flotation stage. These stages produce three major waste streams: cleaned (washed) coarse soil, a wastewater containing contaminants released from the coarse soil, and a suspension of fine particles in the effluent from the flotation system. The two aqueous streams are combined for subsequent biological treatment in a slurry bioreactor.

Applications and Limitations. Because many organic compounds, such as PAHs, are adsorbed more strongly to organic and clay particles, surfactants are largely ineffective in removing contaminants from them. Ex-situ soil washing systems rely on physical segregation of fine and organic particles that cannot be treated effectively with the soil washing desorption processes.

Conclusions. Because it is likely that nearly all of the sediment at the Moss-American site will consist of fines, and because a significant organic fraction is probably present as well, soil washing would probably not be effective in removing contaminants from sediment or reducing the volume requiring subsequent treatment. For onsite soil, the contamination is distributed between coarse and fine soils, so soil washing could be useful in removing contaminants from the coarse soil and reducing the volume of soil requiring subsequent treatment; however, it would not be effective by itself. Because the soil would be slurried as part of the washing process, slurry

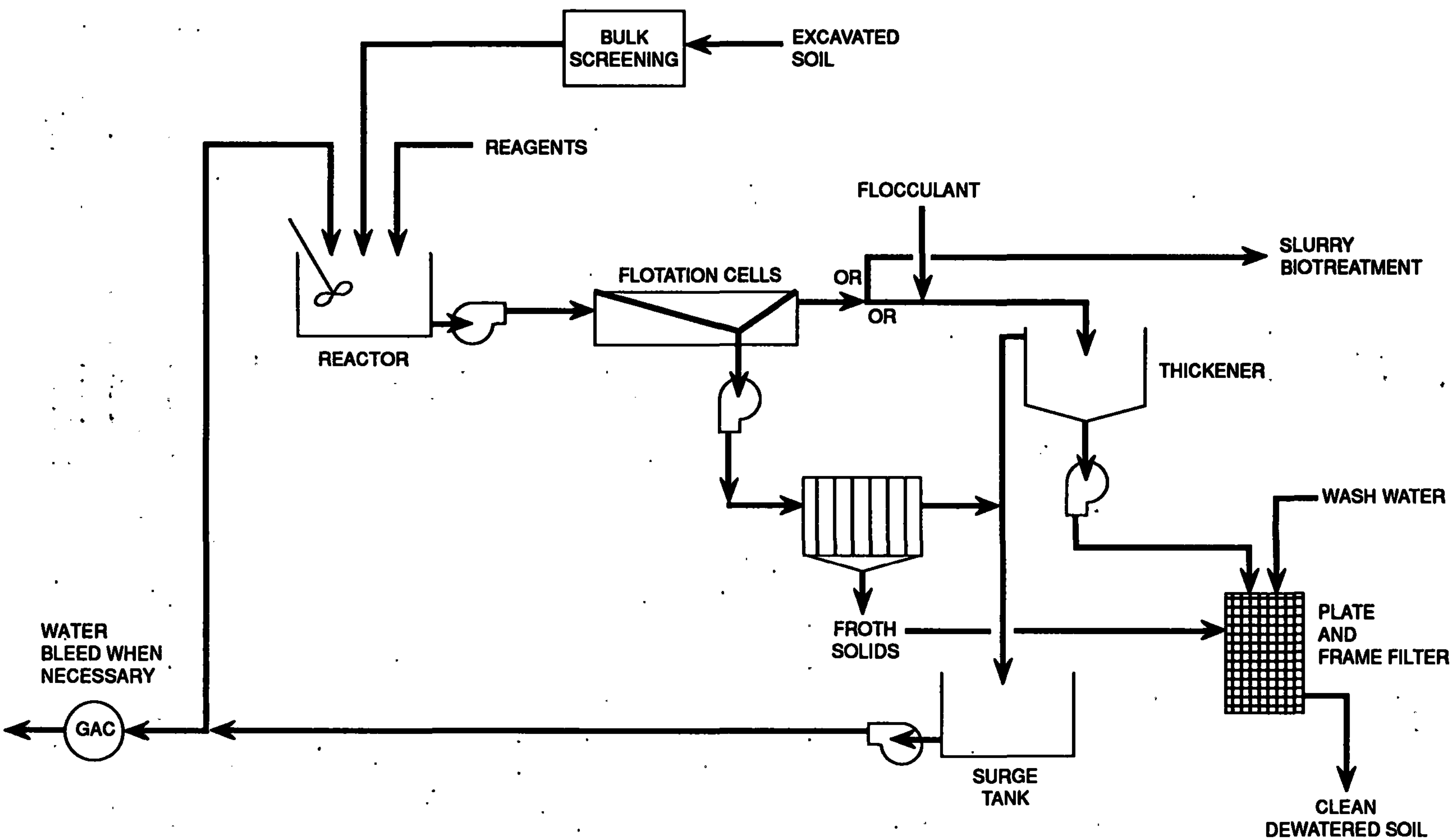

FIGURE H - 5
SOIL WASHING
MOSS-AMERICAN FS

biotreatment appears to be more applicable for the subsequent treatment than incineration or land treatment. Thus, soil washing was retained for inclusion with alternatives that include biotreatment of onsite soils. Bench-scale testing would be performed to determine the most effective types and combinations of surfactants, alkaline agents, and polymers.

Solvent Extraction

Description of Technology. Solvent extraction is a process whereby components are separated from solution according to dynamic equilibrium distribution between immiscible phases. On completion of the extraction procedure, the immiscible fluids may be treated to recover solutes and solvent. This process may also be applicable to the leaching of soluble components from solids.

Technology Status. Although solvent extraction has been in use for many years in industries such as CPI, metallurgy, and food processing, it has only recently been applied to the treatment of wastes. Because this process is considered BDAT for the petroleum industry, recent application of the technology has been in management of oily wastes. Validation of this use has provided impetus for development of specific processes to isolate oily or otherwise water-insoluble compounds from soil.

Applications and Limitations. Although water may act as a solvent for many organic and inorganic compounds, most organic PAH compounds present at the Moss-American site are relatively insoluble in water and thus probably adsorbed to the site soils. It is possible to add an extraction solvent to the contaminated soil to dissolve and transfer the compounds to the extraction solvent. The liquid may then be separated from the soil solids. The liquid, containing the contaminants and water from the soil, may then undergo further treatment wherein the immiscible liquid phases are separated, the extraction solvent recovered (possibly similar to rectification in distillation), and the contaminants and raffinate disposed of. The treated soils could be replaced onsite.

The advantages of using of solvent extraction at the Moss-American site are that the soil may be reclaimed and the volume of material to be disposed of may be reduced. Also, energy costs are relatively lower than those for incineration, and air emission problems are eliminated. Disadvantages are that the solvent may be a hazardous material, and varying soil characteristics (such as TOC) may adversely affect process efficiency.

Solvent extraction technologies currently in use have some limitations. Although many have undergone bench- and pilot-scale testing and some have been developed to full-scale units, they have often been subjected to a narrow range of wastes with little variability. Such testing under controlled circumstances may not be representative of performance under actual field conditions of variable waste characteristics and feed rates.

The product waste streams of the processes may require further treatment prior to disposal and waste treatment guidelines for all of the processes may not yet be developed. Also, the solvents used in the processes may be toxic and more or less effective in extracting differing compounds. The fact that feed material requires classification and sizing must not be ignored because good contact with the solvent is essential for system performance. Finally, waste treatment guidelines for all of the processes may not yet be developed.

Conclusions. Solvent extraction shows promise in successful treatment of soils, sediment, sludges, and water contaminated with organic compounds, but the processes have not been optimized or have not performed with reliable and satisfactory results, especially when challenged with wastes of differing characteristics. Continued study in such programs as the EPA's SITE program is warranted because the technology could effectively remediate sites at feasible costs and reduce the volume of material requiring ultimate disposal (such as incineration), and because it is a recovery process rather than a destructive process. Because process performance cannot be reliably predicted and performance is specific to site and solvent, solvent extraction was not retained as a means for remediating contaminated soil or sludge at the Moss-American site.

In Situ Vitrification

Description of Technology. In situ vitrification is an energy-intensive process by which soils and wastes are thermally solidified in place. The soil and wastes are converted into a chemically inert and stable glassy, solid matrix. Conversion is achieved by passing an electrical current through electrodes embedded in the ground, which produces heat in the surrounding soils to temperatures exceeding 1,900°F. Silaceous soils are melted and inorganic wastes are bound in the molten glass and the organic contaminants are pyrolyzed. Pyrolyzed compounds migrate to the surface where they are partially oxidized in the presence of air. The combustion products are then usually drawn into an offgas treatment system, which can be customized to treat specific site contaminants. The offgas treatment system may consist of scrubbers, absorbers, and filters.

After the electric power is turned off, the crystalline structure begins to cool. The molten glass can take up to 1 year to cool to ambient temperatures. During the cooling process, a 10 to 15 percent reduction in soil volume occurs. This creates a depression in the soil that may be backfilled after a few weeks.

Applications and Limitations. Site soil permeability inhibits the in situ vitrification process, and marginal performance occurs with permeabilities of 10^{-5} and greater. Soil containing heavy metals and inorganic chemicals is suitable for in situ vitrification. While the high operating temperature of the process pyrolyzes most organic contaminants, soils contaminated with sludge, plating wastes, semivolatile organic compounds, oils, greases, and PCBs should be tested before full-scale operation.

The moisture content of the soil affects the process. As moisture content increases, power requirements increase. The time required to vitrify the soil also increases as the moisture content increases because additional water must be evaporated before pyrolysis begins. For these reasons the use of in situ vitrification on the sediment at the Moss-American site would be difficult because the sediment is below the water table. Site conditions also affect in situ vitrification. In general, vitrification depths range from 6 to 30 feet, with the actual depth dependent on the spacing of the electrodes. The maximum achievable melting depth is inversely proportional to the electrode spacing. The terrain must be level or have gently rolling slopes for the process to work properly.

While the vertical extent of contamination in soil at the site is suitable for this technology, the following conditions at the Moss-American site indicate that in situ vitrification would not be a feasible treatment technology for soil:

- The location of the water table varies from the ground surface to about 10 feet below ground and a swamp is present in the northwest area.
- The makeup of the site subsurface is primarily heterogeneous. Surface conditions include silts, clays, wood chips, roots, gravel, rubbish, railroad ties, and plastic.
- Contaminants at the site include oils, PAHs, and other semivolatile organic compounds.

Conclusions. While the contaminants are located relatively close to the surface, the swamp and high water table would hamper operation of the in situ vitrification process. Engineered barriers, such as isolation trenches or groundwater recovery wells, would be necessary to isolate the soil from the groundwater. Also, the heterogeneous nature of the subsurface soils, and hence the variability in the permeability of the soil, would not be adaptable to the process. Therefore, in situ vitrification was not considered further as a feasible technology.

THERMAL TREATMENT

Description of Technology

Several thermal treatment process options have been demonstrated for treating contaminated soils, including rotary kilns, infrared reactors, and circulating bed incinerators. The most common unit used for thermal treatment of bulk soils is the rotary kiln incinerator. Although there are distinct advantages to other units, such as lower air emissions with the infrared unit, the rotary kiln has the longest record of application and performance and, therefore, is considered the representative option for the purposes of technology description.

A rotary kiln incinerator destroys the organic contaminants by thermally oxidizing them into inert components. Oxidation occurs in a long, inclined, rotating cylinder through which the soil passes. The cylinder is rotated to agitate the soil for greater oxidative efficiency, and to promote transport of solids through the kiln. The temperature within the refractory-lined kiln is normally maintained in the range of 1,500°F to 2,000°F.

Solids travel to the low end of the kiln, where they are discharged to an ash sump. Ash is cooled and discharged to containers for sampling to determine if it meets cleanup criteria. Ash that passes cleanup criteria may either be disposed of onsite or held until delisted for offsite disposal. Because inorganic compounds such as heavy metals may concentrate in the ash and may leach from the material, stabilization or some form of solidification may be necessary prior to disposal.

Hot gases and suspended particulates in the kiln pass into a second combustion chamber (called the afterburner) designed for complete combustion of the organics and offgases. Offgas must be treated before release to the atmosphere to remove particulates or acid-forming compounds. This is often done with venturi scrubbers or electrostatic precipitators.

Technology Status

For several decades, rotary kilns have been in use for incineration of industrial wastes, for production of cement and other mineral aggregates, and for other thermal processing. The technology is commercially available from a number of vendors in the United States and overseas. In the past 5 years, these units have been constructed on trailers so that small rotary kilns can be transported to appropriate sites.

Incinerators have been designed to accept wastes of varying characteristics and packaging types. They are capable of accepting liquids, gases, loose solids, packaged solids, sludges, or mixtures of these wastes. They have been operated primarily with excess oxygen, but for special purposes, they may be operated in an oxygen-starved mode.

Application and Limitations

Thermal treatment using rotary kiln incinerators is a proven advantageous technology because:

- It provides effective destruction of organic contaminants.
- The ash residue is innocuous when few inorganic chemicals exist in the soil since the organic contaminants are destroyed.

Its disadvantages include:

- Complexity of mobilizing and burning
- High power requirements
- Need for air pollution control devices
- Potential opposition from the community

Conclusions

Incineration provides the highest degree of contaminant destruction efficiency of all treatment options. However, onsite implementation is very complex and involves siting, permitting, construction, and test burns prior to startup. The cost of such a system is high compared to the other options.

In summary, incineration was retained for detailed analysis because it is well demonstrated and it can provide rapid and complete treatment of contaminants.

COMPARISON OF TECHNOLOGIES

Table H-6 summarizes a comparison of treatment technologies based on effectiveness, implementability, and relative cost.

Table H-6 (Page 1 of 2)
COMPARISON OF TREATMENT TECHNOLOGIES

Process Option	Effectiveness	Implementability	Relative Cost	Retained
Soil Washing	Effective on removing PAHs from coarse soil materials. Probably not adequately effective in removing PAHs from clays.	Equipment has been demonstrated and is available for full-scale operation.	Low	Yes
Vitrification	Effectiveness could be hindered by absence of sandy soil in some portions, presence of high water table, and presence of debris and wood chips.	Implementation would require significant site preparation, such as lowering water table and removal of debris and wood.	Moderate	No
Soil Flushing	Effectiveness will be hampered by non-homogeneity of soil, and low permeability of some soil.	Implementability could be hindered by ARARs restricting injection of chemicals into ground.	Low	No
Slurry Bioreactor	Demonstrated effective in degradation of CPAHs. May not achieve current LDR treatment standards.	Technology has been demonstrated on mining wastes and equipment is available.	Moderate	Yes
Land Treatment	Demonstrated effective on degradation of CPAHs. May require long period to achieve LDR treat- ment standards or to provide significant reduction in 4-, 5-, and 6-ring CPAHs.	Land is available for treatment beds. ARAR that bans land treatment in Wisconsin may make it difficult to implement.	Moderate	Yes

Table H-6 (Page 2 of 2)

Process Option	Effectiveness	Implementability	Relative Cost	Retained
Incineration	Demonstrated to be effective on destroying CPAHs. Could achieve LDR treatment standards.	Technology and equipment are available. Public concerns regarding air quality could hinder implementation.	High	Yes
In situ Bioreclamation	Effectiveness will be hampered by non-homogeneity of soil, and low permeability of some soil.	Implementability could be hindered by ARARs restricting injection of chemicals or wastewater into ground.	Low to moderate	No
Solvent Extraction	Demonstrated to be effective in removing PAHs from sandy soils. May not achieve remediation goals. Could be effective as a pre-treatment step on highly contaminated soil (about 600 yd) where pure product is mixed with soil.	Equipment is avail- able for full-scale operation. Would require some pilot testing.	Moderate to high if used on small volume.	No

CONCLUSIONS

Because they have been demonstrated to be effective in treating soil with characteristics similar to those at the Moss-American site, incineration, land treatment and the slurry bioreactor were retained for detailed analysis. Soil washing was also retained for use in conjunction with slurry biotreatment of soil.

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GLT938/089.51

Appendix I
DETAILED COST ESTIMATES

Appendix I
DETAILED COST ESTIMATES

This information supplements the detailed descriptions and cost estimates for the alternatives presented in Chapter 4. Cost estimate tables are presented in Attachment 1.

Cost estimates for alternatives were prepared for guidance in project evaluation and implementation using information available. Actual costs will depend on labor and material cost, site conditions, productivity, competitive market conditions, final project scope, final project schedule, the firm selected for the final engineering design, and other variable factors. As a result, the final cost will vary from the estimates presented in this report. Because of these factors, funding must be carefully reviewed before making specific financial decisions or establishing final budgets.

The feasibility level cost estimates are order-of-magnitude estimates with an intended accuracy range of +50 percent and -30 percent for the identified alternative. This range applies only to those alternatives defined in Chapter 4 and does not account for changes in the scope of the alternatives. The scope outlined for each alternative or process is not intended to limit the scope of the remedial design, but to provide a basis for evaluating, comparing, and selecting a remedial action. The scope and estimated cost of the selected remedial action will be further refined in the final design.

Unit prices were developed in accordance with the REM IV Cost Estimating Guide (CH2M HILL 1987). They are also based on the Cost of Remedial Action (CORA) computer model, construction cost data (Means 1988), engineers' cost estimates for similar work, quotes from vendors and contractors, and engineering judgment.

OVERVIEW OF FEASIBILITY LEVEL COST

Cost estimates prepared for the detailed analysis of alternatives are intended to provide a measure of total resource cost over time. The estimates include total capital cost, annual operating cost, and total present worth of each alternative.

TOTAL CAPITAL COST

Capital costs are direct and indirect costs required to initiate and install a remedial action. They include only the expenditures initially incurred to design and implement a remedial action (e.g., installation of a cap) and exclude cost required to maintain the action throughout its lifetime.

Direct costs are expenditures necessary for installation of remedial actions, such as costs for construction, land and site development, and buildings and services. Constriction costs include cost of materials, labor, and equipment necessary to construct or implement the remedial action. Site preparation for remedial action equipment, installation of monitoring wells, or excavation of contaminated materials are included in this category.

Indirect capital costs consist of engineering, financial, supervision, licenses and permits, and other service costs necessary to carry out the remedial actions. Indirect costs are not incurred as part of the actual remedial actions, but are supplementary to direct costs. Indirect costs include contingencies that attempt to reduce the possibility of budget overruns. Indirect capital costs incurred by the U.S. EPA or the State of Wisconsin are not included in these cost estimates. The design costs presented in these estimated do not include costs for additional studies that may be required as part of preliminary design; e.g., additional investigations to characterize flood plain soil.

The FS is conceptual and based on currently available data; therefore, bid and scope contingencies are estimated to account for unknown cost. Bid contingencies account for cost associated with constructing a given project, such as general economic conditions at the time of bidding, adverse weather conditions, strikes by material suppliers, and geotechnical unknowns. Scope contingencies cover changes that invariably occur during the final design and implementation. Scope contingencies also include provisions for items such as inherent uncertainties that may affect FS assumptions. Scope contingencies also reflect the performance history or complexity of the remedial action. Scope contingencies do not account for significant increases in the volume of soil, sediment, or groundwater to be managed.

Bid and scope contingencies are not necessarily uniform for all alternatives. Allowances for price inflation and abnormal technical difficulties are not accounted for in the contingencies.

ANNUAL OPERATING COST

Annual operating cost for a remedial action include the operation and maintenance (O&M) cost incurred each year following implementation of the remedial action. Annual O&M costs are assumed to be paid at the end of the year in which they occur.

ECONOMIC ANALYSIS

The present worth analysis provides a method for evaluating and comparing costs that occur over different time periods by discounting future expenditures to the present year. Present worth calculations were developed for a 30-year period and are presented for 3, 5, and 10 percent discount rates in accordance with the Office of Management and Budget guidance. O&M cost may be incurred for periods less than or greater than 30 years, and therefore O&M present worth was also developed for periods of time anticipated to be required for operation of the groundwater extraction and treatment system. Future costs were not escalated to account for inflation.

MAJOR COST ESTIMATE ASSUMPTIONS

The development of FS cost estimates required making numerous assumptions, including the site conditions, extent and method of soil and sediment removal, overall remedial action implementation methods, and level of worker protection required. The following descriptions outline the major assumptions made to prepare the cost estimates. All assumptions made in preparing the individual cost estimate, though, are not presented in this text. Also, assumptions of previous alternatives, unless specifically stated otherwise, shall apply to subsequent cost estimates. For example, the clearing and grubbing assumptions for Alternative 2 are the same for Alternative 3A unless the description states differently.

ALTERNATIVE 2

Health and Safety

The level of protection for the workers is assumed to be Level D, unless the working area is uncontaminated or covered with soil. In that case, worker protection would not be required. Net productivity multipliers were applied to the labor and equipment cost to take into account the lower productivity associated with work on CERCLA sites. The Level D multiplier assumed for the cost estimates is 1.2. It is also assumed that all workers associated with the remedial action implementation activities would be health and safety trained and monitored.

Access Roads

Access roads were assumed to be required over the approximate 6-mile length of the new river bed excavation. The roads are 10 feet wide with an 8-inch-thick gravel base. At the end of the remedial action implementation in the area of the old river bed, the roads would be removed. After the road base is removed, a 6-inch topsoil cover would be placed over the soil, the area would be hydroseeded, and trees and bushes would be planted.

Clearing and Grubbing

It was assumed that clearing and grubbing would be required in and around the area of the old and new river beds. The clearing and grubbing would permit the construction of the access roads and provide a stockpile area for spoils excavated from the new river bed. The cleared area provides a 30-foot buffer zone between the old and new river beds for stockpiling the new river bed excavation spoils and construction of the access roads.

Parallel River Bed

The cost estimate for a new river channel assumed a channel with average dimensions as illustrated in Appendix B.

Roadway Crossing Transitions

Eleven roadway crossing transitions were assumed to be necessary during the relocation of the river. The transitions would be required to use the existing river bed beneath bridges. The cost estimate provides for removal of the contaminated sediment from the old, dewatered sections of river bed beneath the bridges while the river flow is temporarily diverted. Pumps temporarily transfer the river flow around the roadway crossing. Following completion of the sediment removal, the river would be permitted to flow from the new river channel, through the old river bed under the crossing, and then downstream back into the new river channel.

Tributary Crossing Extensions

Five tributary crossings were assumed in the cost estimate. The crossings would either extend or shorten the existing tributary inlets to meet the new river bed. Each crossing is estimated to be 100 feet long and would require excavation and backfilling for placement of a transition pipe.

Old River Bed

The filling of the old river bed was assumed to take place using spoils excavated from the new river bed. However, all excavated material from the new river bed could not be placed in the old river bed. It is assumed that the excess spoils could be placed in the adjacent park land outside the flood plain. A 6-inch topsoil cap and hydroseed would be placed on top of the old river bed.

Soil Cover

After consolidation of the contaminated soil from the site (movement of contaminated soil out of the flood plain and consolidation from the southeast landfill area), a soil cover cap would be constructed over the contaminated soil; it would cover an area of approximately 300,000 square feet and be located on the west side of the Little Menomonee River and out of the site flood plain. The cap would be constructed of the following layers:

- 6-inch hydroseeded topsoil
- 2-foot cover soil

Groundwater Collection System

A groundwater collection system was assumed to be constructed along a portion of the Little Menomonee River. The system includes trenching to a depth of 15 feet to install the perforated collection pipe and vertical barrier membrane. The drainage pipe and vertical barrier would also be surrounded by a layer of gravel to increase drainage. A collection sump would collect the groundwater and pump it to an oil/water separator, where any free oil would be removed and collected for offsite disposal.

Groundwater Treatment

Onsite groundwater treatment is based on an oil/water separator and an activated carbon unit. The cost estimate assumes the use of two carbon columns in series, each containing 10,000 pounds of carbon. The rate of carbon use is difficult to predict without performing a pilot test, especially for waste streams with numerous contaminants. Based on the organic chemical concentrations detected in the groundwater, it is assumed for the purposes of this cost estimate that approximately 20,000 pounds of carbon would be used annually (on average).

ALTERNATIVE 3A

Parallel River Bed

Construction of the new river bed, including transitions and tributary extensions, would proceed and cost similar to Alternative 2.

Sediment Excavation

It is assumed that 5,200 cubic yards of visibly contaminated sediment (plus 25 percent noncontaminated sediment mixed in) will be excavated from the river bed. Most of the contaminated sediment is assumed to be located within 2.5 miles of the site. Transportation of the excavated sediment to the site would be by lined dump trucks over public roads. The cost estimate assumes the sediment would be dewatered somewhat during excavation after the river flow is diverted and the exposed river bed dewatered.

Soil Excavation

It is assumed that 80,000 cubic yards of visibly contaminated soil will be removed from the area of the original property, including the Northeast Landfill. The cost estimate assumes some dewatering would be required to remove soils at depths of 10 to 20 feet.

Slurry Bioreactor System

The cost estimate for the slurry bioreactors is based on the treatment process presented in Chapter 3. The process consists of a vibrating screen, an attrition scrubber, a screw classifier, the slurry bioreactors, thickeners, and a belt filter press for sludge dewatering. Included in the cost estimate are costs for equipment acquisition, setup, operation, and maintenance. The slurry bioreactors are sized based on a 15-day retention time of a 35 percent solids slurry.

Groundwater Collection System

The groundwater collection system for this alternative is a scaled-down version of that assumed for Alternative 2. There would be only one collection drain parallel to the river. The collection system is not as extensive as Alternative 2 since a bulk of the contaminated soil in the central area of the property would be removed.

Soil Cover

Alternative 3A assumes the use of a soil cover. After biotreatment is completed, the treated soil and sediment would be spread evenly over the site, and the soil cover would be placed over them. The cover would prevent direct contact with the soil and sediment, but not limit infiltration.

Offsite Disposal

Residues (treated sludge) generated from the treatment of soil form the Northeast Landfill would be disposed of offsite in a RCRA landfill. Oversize material removed from contaminated soil would be disposed of in a special waste landfill. Oil and sludge collected by the groundwater extraction system would be incinerated offsite.

ALTERNATIVE 3B

The major difference between Alternatives 3A and 3B is the type of treatment technology used on soil and sediment.

Land Treatment

The cost estimate assumes that two 5-acre cells are constructed with a liner and a leachate collection system. Based on the volume of each cell and the assumption that the residence time for the soil in the treatment cell is 1.5 treatment seasons, it is estimated that treatment would last approximately 8 to 15 years. The cost estimate includes construction of the cells and placement and handling the contaminated soil.

The land treatment system would treat 33,000 cubic yards of excavated river bed sediment and 80,000 cubic yards of contaminated site soil. The land treatment system consists of the following major components:

- Two 5-acre treatment beds
- Leachate collection system
- Nutrient distribution system

The treatment beds are assumed to consist of the following:

- 5-foot-high berm enclosing each bed
- 2-foot clay bottom soil, overlain by a
- synthetic liner, overlain by a
- 12-inch sand drainage layer, overlain by
- synthetic liners, overlain by a
- 2-foot sand drainage layer

Bench- and pilot-scale testing are included in the cost estimate to provide additional data for the land treatment process degradation time. A tractor and tilling attachment would be used to work and rotate the contaminated soil and sediment in the treatment bed.

Offsite Disposal

Offsite disposal actions would be similar to Alternative 3A except the oil and sludge collected in the groundwater collection system would be treated onsite.

Nutrient Distribution System

The nutrient distribution system is assumed to consist of a header and branch piping laid on the treatment bed surface. Sprinkler heads, installed on stub pipes extending into the air, distribute the nutrients. The nutrients are stored in two 40,000-gallon tanks before being pumped through the distribution piping. The piping would be capable of being dismantled to allow the tractor to till the entire treatment beds.

ALTERNATIVE 4

Alternative 4 does not include rerouting of the river or treatment of contaminated soil, except soil from the Northeast Landfill. Alternative 4 assumes 33,000 cubic yards of sediment will be excavated from the river, which corresponds to the amount estimated to have contaminant levels above background (26,000 cubic yards); the remaining 7,000 cubic yards of noncontaminated sediment were added as an allowance for limitations of the excavating equipment to remove only contaminated sediment.

Temporary Dam Construction

Temporary dams are necessary to divert the water around the excavation area during removal of contaminated sediment. Thirty-one dams (15 along the river, 1 at each of the 11 crossings, and 1 at each of the 5 tributaries) along the extent of the remedial action of the old river bed are assumed to provide temporary water storage and diversion of the river flow. Each dam would provide storage of river water and runoff and also allow diversion of the overflow by gravity through a diversion pipe downstream around the excavation area. Refer to Appendix B for the diversion pipe sizing criteria. A runoff diversion sump would collect seepage through the upstream dam and pump the water back to the upstream side.

The excavation would take place over the entire 6-mile reach of the Little Menomonee River from Brown Deer Road to the confluence with the Menomonee River. The average one-way hauling distance over public roads is estimated to be 5 miles. The treated residue from the slurry bioreactors would be placed beneath a soil cover described for Alternative 2.

Offsite Disposal

Offsite disposal actions would be similar to those for Alternative 3A.

ALTERNATIVE 5

The major difference between Alternative 5 and Alternative 3A is that the former includes removal of all contaminated sediment exceeding background levels and does not include rerouting the river. The cost assumptions regarding removal of sediment from the river would be the same as for Alternative 4.

ALTERNATIVE 6

The major difference between Alternative 6 and preceding alternatives is the method and volume of treatment for the excavated soil and sediment. This alternative assumes using an onsite incinerator to destroy the contaminants in the sediment and soil. The treated residue would be placed beneath a soil cover. Unlike preceding alternatives (except no action), groundwater collection and treatment would not be required.

The cost estimate for Alternative 6 includes the cost of incinerating 160,000 cubic yards of excavated river bed sediment (33,000 cubic yards) and contaminated soil above the water table exceeding the 1×10^{-6} excess lifetime cancer risk target concentrations (130,000 cubic yards). While numerous thermal treatment technologies may be applicable for the site, the cost estimate assumes the use of rotary kiln incinerators. Because of the large volume of contaminated material, the cost estimate also assumes the use of two mobile units onsite. The soil and sediment treatment is estimated to be completed in 4 to 5 years. Included in the cost estimate are allowances for mobilization, test burns of the incinerators, operational expenses, and water treatment cost for the scrubber blowdown.

REFERENCES

CH2M HILL, Inc. *Cost of Remedial Action (CORA) Model.* Version 2.1. Corvallis, Oregon. April 1989.

CH2M HILL, Inc. *REM IV Cost Estimating Guide.* Corvallis, Oregon. 1987.

R. S. Means Company, Inc. 1989. *Building Construction Cost Data: 1989.* Kingston, Massachusetts. 1988.

GLT938/009.51

Attachment 1
COST ESTIMATE TABLES

TABLE I-1. ALTERNATIVE 2
CONTAINMENT OF SEDIMENT AND SOIL, TREATMENT OF GROUNDWATER

DESCRIPTION	QUANTITY	UNIT	WORK LEVEL	LABOR FACTOR	CONVENTIONAL LABOR UNIT PRICE (DOLLARS)	SITE LABOR UNIT RATE (DOLLARS)	COST	SUBTOTAL	ASSUMPTIONS
CAPITAL COST DURING OPERATION									
Health and Safety									
Plans, Train'g, Equip, officer	1	LS	E	1.0	$138,000	$138,000	$140,000		
								$140,000	
Clearing/Grubbing									
Trees and Stumps	44	ACRE	E	1.0	$11,500	$11,500	$500,000		cut and chip, max. 24" dia., stumps removed, 021-104-0300,0350
Terrain clearing	44	ACRE	E	1.0	$3,800	$3,800	$170,000		dozer and brush rake, adverse conditions, 022-286-0100
Topsoil stripping	44,000	CY	E	1.0	$1.40	$1.40	$62,000		200 hp dozer, 300' haul, top 6", 022-286-0100
								$740,000	
Access Roads	35,200	SY	E	1.0	$4.71	$4.71	$170,000		8" gravel depth, no surface, 015-552-0100
								$170,000	
Parallel River Bed									
Excavation of new bed	320,000	CY	E	1.0	$4.00	$4.00	$1,280,000		1 CY backhoe, 022-254-1300
Grading channel sides	350,000	SY	E	1.0	$0.12	$0.12	$40,000		025-122-3300
Place cobble/rubble	500	CY	E	1.0	$26.00	$26.00	$13,000		2.5in-10in dia cobble/rubble; 022-712-0100
Place gravel	1,300	CY	E	1.0	$20.00	$20.00	$26,000		0.1-2.5 in dia gravel; 022-262-1100
Place rip-rap	900	CY	E	1.0	$25.00	$25.00	$22,500		estim judgement
								$1,400,000	
Roadway Crossing Transition									
Number of transitions	11								
Excavate contaminated sediment	1,650	CY	D	1.2	$8.00	$9.60	$15,800		1 CY backhoe, estim judgement/022-254-1300
Move sediment to old bed	1,800	CY	D	1.2	$1.72	$2.06	$3,700		2.5 CY FE loader, 300 foot haul, 022-262-0170
Construct transition dams	13,420	CY	D	1.2	$1.72	$2.06	$28,000		2.5 CY FE loader, 300 foot haul, 022-262-0170
Compact dam	13,420	CY	D	1.2	$2.89	$3.47	$47,000		vibrating plate, 022-254-1900
Runoff diversion sumps	22	EA	D	1.2	$815	$978	$21,500		4 foot dia. x 6' deep, concrete, 027-152-0500
Runoff diversion sump pumps	2	EA	D	1.2	$3,000	$3,600	$7,200		pumped upstream of dam, Flygt quote, Alumax
Bypass diversion pumps	2	EA	D	1.2	$10,000	$12,000	$24,000		temporary bypass pumps, 5,000 gpm each
Bypass diversion piping	1,000	LF	D	1.2	$26	$31	$31,000		24" dia CMP, 027-164-2140
Sheet piling		LS	D	1.2	$220,000	$264,000	$264,000		
Silt curtains	1	LS	D	1.2	$20,000	$24,000	$24,000		
								$466,000	
Tributary Crossings Extensions									
number of crossings	5								
Excavate trench	500	CY	D	1.2	$2.14	$2.57	$1,300		2.5 CY backhoe, 6 feet to 10 feet deep, 022-254-0620
Tributary pipe	500	LF	D	1.2	$64.00	$76.80	$38,000		36" dia culvert, 027-162-2060
Drainage Layer Granular Fill	75	CY	D	1.2	$41.00	$49.20	$3,700		pea gravel, 029-504-0900
Backfill Trench	500	CY	D	1.2	$1.46	$1.75	$900		1 CY FE Loader, minimal haul, 022-254-3020
Compact area	500	CY	D	1.2	$2.89	$3.47	$1,700		vibrating plate, 022-254-1900
Seeding	5,000	SF	D	1.2	$0.04	$0.05	$200		hydraulic seeding, 029-308-1300
								$46,000	

TABLE I-1. ALTERNATIVE 2
CONTAINMENT OF SEDIMENT AND SOIL, TREATMENT OF GROUNDWATER

DESCRIPTION	QUANTITY	UNIT	WORK LEVEL	LABOR FACTOR	CONVENTIONAL LABOR UNIT PRICE (DOLLARS)	SITE LABOR UNIT RATE (DOLLARS)	COST	SUBTOTAL	ASSUMPTIONS
Fill Old River Bed									
Dewatering Sump	10	EA	D	1.2	$890	$1,100	$11,000		4 foot dia. x 8' deep, precast concrete, 027-152-1130
Dewatering Pump	2	EA	D	1.2	$3,000	$3,600	$7,200		pumped upstream of dam, Flygt quote, Alumax
Place backfill in channel	180,000	CY	D	1.2	$1.51	$1.81	$330,000		1 CY FE Loader, minimal haul, 022-254-3020
Compact river bed cover	180,000	CY	D	1.2	$0.35	$0.42	$80,000		Riding, vibrating roller, 022-226-5020
Spread excess spoils	210,000	CY	E	1.0	$1.21	$1.21	$250,000		Grading at dump; 022-266-1600
Compact spread spoils	210,000	CY	E	1.0	$0.89	$0.89	$190,000		Sheepsfoot roller;022-226-6030
Seed area	2,800	MSF	E	1.0	$40.00	$40.00	$110,000		

								$980,000	
Soil Cover Over Old River Bed									old river bed
Top Soil	18,000	CY	E	1.0	$4.00	$4.00	$70,000		Furnish and place top 6", from stripped area
Seeding	140,000	SY	E	1.0	$0.36	$0.36	$50,000		hydraulic seeding, 029-308-1300

								$120,000	
Soil Consolidation at Site									contaminated soil
Excavation and placement of soil	50,000	CY	D	1.2	$6.85	$8.22	$410,000		200 Hp bulldozer, 300 foot haul, 022-242-4440
Grading	60,000	CY	D	1.2	$1.21	$1.45	$90,000		Grading at dump; 022-266-1600

								$500,000	
Soil Cover at Site									for 10-6 contaminated soils; assumes area of about 870,000 sf
Cover Soil	64,000	CY	D	1.2	$10.00	$12.00	$800,000		Estim. judgement
Compaction	64,000	CY	D	1.2	$0.67	$0.80	$50,000		022-222-0300
Top Soil	16,000	CY	D	1.2	$18.00	$21.60	$350,000		3 ", Furnish and place, 022-286-0700
Seeding	900	MSF	E	1.0	$40.00	$40.00	$36,000		hydraulic seeding, 029-308-1300
Fence	7,000	LF	E	1.0	$15.00	$15.00	$105,000		

								$1,300,000	
Offsite incineration of Northeast Landfill soil									
Excavation of soil	1,000	CY	D	1.2	$4.00	$4.80	$5,000		
Drum waste	1,200	CY	D	1.2	$93.00	$111.60	$134,000		assumes 2.5 fiber drums/cy; 3 men 0.5 hrs to fill 2.5 drums
Haul to RCRA TSD	1,200	CY	E	1.0	$80.00	$80.00	$96,000		
Incineration charge	1,200	CY	E	1.0	$1,650.00	$1,650.00	$1,980,000		assumes 0.75/lb;includes surcharge for residue disposal
								------------	
								$2,200,000	

TABLE I-1. ALTERNATIVE 2
CONTAINMENT OF SEDIMENT AND SOIL, TREATMENT OF GROUNDWATER

DESCRIPTION	QUANTITY	UNIT	WORK LEVEL	LABOR FACTOR	CONVENTIONAL LABOR UNIT PRICE (DOLLARS)	SITE LABOR UNIT RATE (DOLLARS)	COST	SUBTOTAL	ASSUMPTIONS
Groundwater Collection Drains									near river
Excavation/Trenching	7,300	CY	D	1.2	$1.98	$2.38	$17,000		1.5 CY backhoe, 022-254-0610
Drainage Layer Granular Fill	5,900	CY	D	1.2	$41.00	$49.20	$290,000		pea gravel, 029-504-0900
Drainage Piping	3,300	LF	D	1.2	$2.52	$3.02	$10,000		perforated, 4" dia. PVC, 027-168-2000
Vertical Barrier	10,000	SF	D	1.2	$0.60	$0.72	$7,200		60 mil, John Heineke
Cover Soil	1,500	CY	D	1.2	$10.00	$12.00	$18,000		2'depth, Bob Lawson/RDD, Merrideth-Baxter Cost Estimate
Compaction/Tamping	1,500	CY	D	1.2	$2.89	$3.47	$5,200		Vibrating plate, 022-254-1900
Collection sump	1	EA	D	1.2	$890	$1,100	$1,100		4 foot dia. x 8' deep, precast concrete, 027-152-1130
Collection Pumps	2	EA	D	1.2	$3,000	$3,600	$7,200		pumped to sanitary sewers, Flygt quote, Alumax
Piping to and from treatment	200	LF	D	1.2	$6.45	$7.74	$1,500		2"PVC:0266862700:0222580750: 1750

								$360,000	
Groundwater Monitoring									
Install Wells	4	EA	D	1.2	$3,000	$3,600	$14,000		M & B Cost Estim; 12 along river, 4 onsite
								------------	
								$14,000	
Access Road Revegetation									
Top Soil	9,000	CY	E	1.0	$3.46	$3.46	$31,000		Spread from piles, 6", FE loader, 022-286-0400
Tree planting	2,100	EA	E	1.0	$100.00	$100.00	$210,000		Dogwood and willow;
Brush planting	2,100	EA	E	1.0	$40.00	$40.00	$84,000		bush, 029-528-0500
Seeding	600	MSF	E	1.0	$40.00	$40.00	$24,000		hydraulic seeding, 029-308-1300
Oat Straw	600	MSF	E	1.0	$29.00	$29.00	$17,000		1" deep w/ large mulcher, 029-516-0700
Remove access road gravel	7,800	CY	E	1.0	$1.25	$1.25	$9,800		2.5 CY FE loader, load onto truck, 022-238-1600
Haul access road gravel	7,800	CY	E	1.0	$6.10	$6.10	$48,000		12 CY truck, 5 mile round trip, 022-266-0540

								$420,000	
Groundwater Treatment									
Oil/water separator	1	EA	D	1.2	$26,000	$31,200	$31,000		coalescing plate type
Recovered Oil Holding Tank	1	EA	D	1.2	$2,000	$2,400	$2,400		1000 gal tank
Oily Sludge Pump	2	EA	D	1.2	$3,000	$3,600	$7,200		
Carbon units	2	EA	D	1.2	$78,000	$93,600	$190,000		
Concrete pad	1	LS	D	1.2	$5,000	$6,000	$6,000		
Outfall and monitoring equip	1	LS	D	1.2	$17,000	$20,400	$20,400		

								$260,000	
Traffic Control								$25,000	
Security								$25,000	
Decon Facilities								$55,000	

TABLE I-1. ALTERNATIVE 2
CONTAINMENT OF SEDIMENT AND SOIL, TREATMENT OF GROUNDWATER

DESCRIPTION	QUANTITY	UNIT	WORK LEVEL	LABOR FACTOR	CONVENTIONAL LABOR UNIT PRICE (DOLLARS)	SITE LABOR UNIT RATE (DOLLARS)	COST	SUBTOTAL	ASSUMPTIONS
Allowances									
Mobilize/Demobilize (5%)							$460,000		Mobilization/demobilization; bond, insurance; temporary facilities
Field Detail Allowance (5%)							$460,000		Accounts for known items not quantified (eg. wasted soil, etc.)

								$900,000	
								============	
CONSTRUCTION SUBTOTAL								$10,100,000	
Contingencies									
Bid (10%)							$1,000,000		
Scope (15%)							$1,500,000		

								$2,500,000	
								============	
CONSTRUCTION TOTAL								$12,600,000	
Other									
Administrative (5%)							$630,000		Services to comply with substantive requirements
Permitting and legal (@2%)							$250,000		
Services During Construction(7%)							$880,000		

								$1,800,000	
								============	
TOTAL IMPLEMENTATION COST								$14,400,000	
Engineering Design Cost							$400,000		Includes $100K geotechnical allowance
								------------	
								$400,000	
TOTAL CAPITAL COST								$15,000,000	

TABLE 1-2. ALTERNATIVE 2 - CONTAINMENT OF SOIL AND SEDIMENT

DESCRIPTIONS	QUANTITY	UNIT	UNIT PRICE (DOLLARS)	COST	PRESENT WORTH 3%	5%	10%	ASSUMPTIONS
OPERATION AND MAINTENANCE COST					PW OF COSTS OVER 30 YEARS			
INSPECTION AND REPAIRS								
Years of Operation	30	YRS						
Soil Cover	1	LS	$20,000	20,000 /YR	$392,000	$307,000	$189,000	1% of soil cover repaired each year
Groundwater Collection System	1	LS	$4,000	4,000 /YR	$78,000	$61,000	$38,000	
SUBTOTAL				$24,000 /YR	$470,000	$368,000	$227,000	
GROUNDWATER TREATMENT SYSTEM								
Years of Operation	30	YRS						
Labor	400	HRS	$42	16,800 /YR	$329,000	$258,000	$158,000	
Analytical Costs	12	EA	$1,500	18,000 /YR	$353,000	$277,000	$170,000	
General Maintenance	1	LS	$10,400	10,400 /YR	$204,000	$160,000	$98,000	4% cap cost
Carbon Replacement	1	LS	$20,000	20,000 /YR	$392,000	$307,000	$189,000	
Utilities	1	LS	$2,000	2,000 /YR	$39,000	$31,000	$19,000	
Oily Sludge Disposal	2,600	GAL	$1	2,600 /YR	$51,000	$40,000	$25,000	
SUBTOTAL				$69,800 /YR	$1,368,000	$1,073,000	$659,000	
GROUNDWATER SAMPLING	24	EA	$1,500	36,000 /YR	$706,000	$553,000	$339,000	
SUBTOTAL				$36,000 /YR	$706,000	$553,000	$339,000	
TOTAL O & M COST				$129,800 /YR	$2,500,000	$2,000,000	$1,200,000	

ALTERNATIVE 2 -- COST ESTIMATE SUMMARY

DESCRIPTION	PRESENT WORTH @30 YRS 3%	5%	10%	PRESENT WORTH @ 100 YRS 3%	5%	10%
TOTAL CAPITAL COST DURING OPERATION	$15,000,000	$15,000,000	$15,000,000	$15,000,000	$15,000,000	$15,000,000
OPERATION & MAINTENANCE COSTS	$2,500,000	$2,000,000	$1,200,000	$4,100,000	$2,600,000	$1,300,000
TOTAL PRESENT WORTH	$17,500,000	$17,000,000	$16,200,000	$19,100,000	$17,600,000	$16,300,000

TABLE I-3. ALTERNATIVE 3A
PARTIAL REMOVAL AND TREATMENT OF SOIL AND SEDIMENT, CONTAINMENT OF REMAINING SOIL AND SEDIMENT, AND TREATMENT OF GROUNDWATER

DESCRIPTION	QUANTITY	UNIT	WORK LEVEL	LABOR FACTOR	CONVENTIONAL LABOR UNIT PRICE (DOLLARS)	SITE LABOR UNIT RATE (DOLLARS)	COST	SUBTOTAL	ASSUMPTIONS
CAPITAL COST DURING OPERATION									
Health and Safety									
Plans, train'g, equip,officer	1	LS	E	1	$163,000.00	$163,000	$163,000		
Air monitoring	1	LS	E	1	$150,000.00	$150,000	$150,000		allowance; estim judgement
								------------	
								$310,000	
Clearing/Grubbing									
Trees and Stumps	44	ACRE	E	1.0	$11,500	$11,500	$510,000		cut and chip, max. 24" dia., stumps removed, 021-104-0300,0350
Terrain clearing	44	ACRE	E	1.0	$3,800	$3,800	$170,000		dozer and brush rake, adverse conditions, 021-108-0600
Topsoil stripping	44,000	CY	E	1.0	$1.40	$1.40	$62,000		200 hp dozer, top 6", 300' haul, 022-286-0100

								$740,000	
Access Roads	35,200	SY	E	1.0	$4.71	$4.71	$170,000		8" gravel depth, no surface, 015-552-0100

								$170,000	
Parallel River Bed									
Excavation of new bed	320,000	CY	E	1.0	$4.00	$4.00	$1,280,000		1 CY backhoe, 022-254-1300
Grading channel sides	350,000	SY	E	1.0	$0.12	$0.12	$40,000		025-122-3300
Place cobble/rubble	500	CY	E	1.0	$26.00	$26.00	$13,000		2.5in-10in dia cobble/rubble: 022-712-0100
Place gravel	1,300	CY	E	1.0	$20.00	$20.00	$26,000		0.1-2.5 in dia gravel; 022-262-1100
Place rip-rap	900	CY	E	1.0	$25.00	$25.00	$22,500		6" riprap; estim. judgement
								------------	
								$1,400,000	
Roadway Crossing Transition									
Number of transitions	11								
Excavate contaminated sediment	1,650	CY	D	1.2	$8.00	$9.60	$15,800		1 CY backhoe, estim judgement, 022-254-1300
Move sediment to old bed	1,800	CY	D	1.2	$2.72	$3.26	$5,900		2.5 CY FE loader, 300 foot haul, 022-262-0170+$1/CY compact
Construct transition dams	13,420	CY	D	1.2	$1.72	$2.06	$28,000		2.5 CY FE loader, 300 foot haul, 022-262-0170
Compact dam	13,420	CY	D	1.2	$2.89	$3.47	$47,000		Vibrating plate, 022-254-1900
Runoff diversion sumps	22	EA	D	1.2	$815	$978	$21,500		4 foot dia. X 6' deep, concrete, 027-152-0500
Runoff diversion sump pumps	2	EA	D	1.2	$3,000	$3,600	$7,200		pumped upstream of dam, Flygt quote, Alumax
Bypass diversion pumps	2	EA	D	1.2	$10,000	$12,000	$24,000		temporary bypass pumps, 5,000 gpm each
Bypass diversion piping	1,000	LF	D	1.2	$26	$31	$31,000		24" dia CMP, 027-164-2140
Sheet piling		LS	D	1.2	$220,000	$264,000	$264,000		
Silt curtains		LS	D	1.2	$20,000	$24,000	$24,000		

								$470,000	

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TABLE I-3. ALTERNATIVE 3A
PARTIAL REMOVAL AND TREATMENT OF SOIL AND SEDIMENT, CONTAINMENT OF REMAINING SOIL AND SEDIMENT, AND TREATMENT OF GROUNDWATER

DESCRIPTION	QUANTITY	UNIT	WORK LEVEL	LABOR FACTOR	CONVENTIONAL LABOR UNIT PRICE (DOLLARS)	SITE LABOR UNIT RATE (DOLLARS)	COST	SUBTOTAL	ASSUMPTIONS
Tributary Crossings Extensions									
number of crossings	5								
Excavate trench	500	CY	D	1.2	$2.14	$2.57	$1,300		2.5 CY backhoe, 6 feet to 10 feet deep, 022-254-0620
Tributary pipe	500	LF	D	1.2	$64.00	$76.80	$38,000		36" dia culvert, 027-162-2060
Drainage Layer Granular Fill	75	CY	D	1.2	$41.00	$49.20	$3,700		pea gravel, 029-504-0900
Backfill Trench	500	CY	D	1.2	$1.46	$1.75	$900		1 CY FE Loader, minimal haul, 022-254-3020
Compact area	500	CY	D	1.2	$2.89	$3.47	$1,700		vibrating plate, 022-254-1900
Seeding	5,000	SF	D	1.2	$0.04	$0.05	$200		hydraulic seeding, 029-308-1300

								$46,000	
Fill Old River Bed									
Dewatering Sump	10	EA	D	1.2	$890	$1,068	$10,700		4 foot dia. x 8' deep, precast concrete, 027-152-1130
Dewatering Pump	2	EA	D	1.2	$3,000	$3,600	$7,200		pumped upstream of dam, Flygt quote, Alumax
Place backfill in channel	180,000	CY	D	1.2	$1.51	$1.81	$326,200		1 CY FE Loader, minimal haul, 022-254-3020
Compact river bed cover	180,000	CY	D	1.2	$0.35	$0.42	$80,000		Riding, vibrating roller, 022-226-5020
Spread excess spoils	210,000	CY	E	1.0	$1.21	$1.21	$254,100		Grading at dump; 022-266-1600
Compact spread spoils	210,000	CY	E	1.0	$0.89	$0.89	$190,000		Sheepsfoot roller;022-226-6030
Seeding	2,800	MSF	E	1.0	$40.00	$40.00	$110,000		

								$980,000	
Soil Cover over Old River Bed									old river bed
Top Soil	18,000	CY	E	1.0	$4.00	$4.00	$72,000		Furnish and place top 6", from stripped area
Seeding	140,000	SF	E	1.0	$0.36	$0.36	$50,000		hydraulic seeding, 029-308-1300

								$120,000	
Soil Consolidation									contaminated soil in floodplain that is not treated
Excavate and consolidate soil	15,000	CY	D	1.2	$6.85	$8.22	$120,000		200 Hp bulldozer, 300 foot haul, 022-242-4440
Grading	18,000	CY	D	1.2	$1.21	$1.45	$26,000		022-266-1600

								$150,000	
Soil excavation									for treatment
Excavation and stockpile soil	80,000	CY	D	1.2	$6.85	$8.22	$657,600		200 Hp bulldozer, 300 foot haul, 022-242-4440
Dewatering during excavation		LS	D	1.2	$50,000	$60,000	$60,000		estim. judgement/allowance
								------------	
								$720,000	

TABLE I-3. ALTERNATIVE 3A
PARTIAL REMOVAL AND TREATMENT OF SOIL AND SEDIMENT, CONTAINMENT OF REMAINING SOIL AND SEDIMENT, AND TREATMENT OF GROUNDWATER

DESCRIPTION	QUANTITY	UNIT	WORK LEVEL	LABOR FACTOR	CONVENTIONAL LABOR UNIT PRICE (DOLLARS)	SITE LABOR UNIT RATE (DOLLARS)	COST	SUBTOTAL	ASSUMPTIONS
Sediment Excavation & Haul									sediments only
Excavation and load sediment	6,500	CY	D	1.2	$8.00	$9.60	$62,400		1 CY backhoe, estim. judgement/022-254-1300
Haul to site	7,200	CY	D	1.2	$7.93	$9.52	$68,500		12 CY dump truck, 5 mile heavy traffic round trip, 022-266-0540
Sediment staging pad	1	LS	D	1.2	$55,000	$66,000	$66,000		80 x 80 concrete pad with leak detection + pad demo.

								$200,000	
Field Pilot Study									6 month study
Develop study and plan	1	LS	E	1.0	$15,000.00	$15,000.00	$15,000		Purchase and construct 5 test cells, sprinklers, tilling equip.
Experiment setup	1	LS	D	1.2	$25,000.00	$30,000.00	$30,000		Purchase and construct 5 test cells, sprinklers, tilling equip.
Sample collection	1	LS	D	1.2	$6,000.00	$7,200.00	$7,200		Routine analysis for nutrients, moisture content, pH, etc.
Sediment Characterization.	1	LS	D	1.2	$9,000.00	$10,800.00	$10,800		Routine analysis for nutrients, moisture content, pH, etc.
PAH Analyses	1	LS	D	1.2	$25,000.00	$30,000.00	$30,000		7 sampling events with 12 samples including QC
Data Reduction and Reporting	1	LS	D	1.2	$7,000.00	$8,400.00	$8,400		Prepare technical memo including graphics and reporduction
								------------	
								$100,000	
Slurry Bioreactor System									
Transfer waste to system	103,000	CY	D	1.2	$1.00	$1.20	$123,600		2.5 CY FE Loader, from stockpile to system, 022-238-1600
Equipment Pad	1	LS	D	1.2	$12,000	$14,400	$14,400		
Vibrating screen	1	EA	D	1.2	$12,500	$15,000	$15,000		CORA, cost assumes 50% salvage
Attrition Scrubber	1	EA	D	1.2	$15,000	$18,000	$18,000		CORA, cost assumes 50% salvage
Screw Classifier	1	EA	D	1.2	$9,000	$10,800	$10,800		CORA, cost assumes 50% salvage
Slurry pumps, poly feed	1	EA	D	1.2	$10,500	$12,600	$12,600		CORA, cost assumes 50% salvage
Bioreactors	2	EA	D	1.2	$600,000	$720,000	$1,440,000		CORA, cost assumes 50% salvage
Dewatering equipment	1	EA	D	1.2	$80,000	$96,000	$96,000		CORA, cost assumes 50% salvage
Instrumentation	1	LS	D	1.2	$87,240	$104,688	$104,700		12% of equipment costs
Elect & Mech.	1	LS	D	1.2	$145,400	$174,480	$174,500		20% of equipment costs
Labor	79,000	HR	D	1.2	$30	$36	$2,844,000		Assumes 3 man crew, 24 hours; 3 yrs
Power	2.1E+06	KW	E	1.0	$0.08	$0.08	$171,200		
Chemicals	1	LS	E	1.0	$100,000	$100,000	$100,000		
Parts, supplies	1	LS	E	1.0	$80,000	$80,000	$80,000		
Analytical	1	LS	E	1.0	$360,000	$360,000	$360,000		

								$5,600,000	
Transport Residue to Containment Area									
Haul residue to containment area	103,000	CY	D	1.2	$2.02	$2.42	$249,700		022-262-0170
Grading	103,000	CY	D	1.2	$1.21	$1.45	$149,600		022-266-1600

								$400,000	
Transport NE Landfill Residue to TSD									
Load in dump truck	1,000	CY	D	1.2	$1.00	$1.20	$1,200		
Hauling cost	1,200	CY	E	1.0	$80.00	$80.00	$96,000		
Disposal cost	1,200	CY	E	1.0	$150.00	$150.00	$180,000		

								$280,000	

TABLE I-3. ALTERNATIVE 3A
PARTIAL REMOVAL AND TREATMENT OF SOIL AND SEDIMENT, CONTAINMENT OF REMAINING SOIL AND SEDIMENT, AND TREATMENT OF GROUNDWATER

DESCRIPTION	QUANTITY	UNIT	WORK LEVEL	LABOR FACTOR	CONVENTIONAL LABOR UNIT PRICE (DOLLARS)	SITE LABOR UNIT RATE (DOLLARS)	COST	SUBTOTAL	ASSUMPTIONS
Transport oversize to SW Landfill									
Load in dump truck	3,000	CY	D	1.2	$1.50	$1.80	$5,400		Estim judgement
Hauling cost	3,000	CY	E	1.0	$15.00	$15.00	$45,000		Estim judgement
Disposal cost	3,000	CY	E	1.0	$30.00	$30.00	$90,000		Estim judgement
								------------	
								$140,000	
Groundwater Collection Drains									near river and beneath contaminated soil
Excavation/Trenching	2,400	CY	D	1.2	$1.98	$2.38	$5,700		1.5 CY backhoe, 022-254-0610
Drainage Layer - gravel	2,000	CY	D	1.2	$41.00	$49.20	$98,400		pea gravel, 029-504-0900
Drainage Piping	1,100	LF	D	1.2	$2.52	$3.02	$3,300		perforated, 4" dia. PVC, 027-168-2000
Vertical Barrier	10,000	SF	D	1.2	$0.60	$0.72	$7,200		60 mil, John Heineke
Cover Soil	490	CY	D	1.2	$10.00	$12.00	$5,900		2'depth, Bob Lawson/RDD, Merrideth-Baxter Cost Estimate
Compaction/Tamping	490	CY	D	1.2	$2.89	$3.47	$1,700		vibrating plate, 022-254-1900
Collection sump	1	EA	D	1.2	$890.00	$1,068.00	$1,100		4 foot dia. x 8' deep, precast concrete, 027-152-1130
Collection Pumps	2	EA	D	1.2	$3,000.00	$3,600.00	$7,200		pumped to sanitary sewers, Flygt quote, Alumax
Discharge Piping	200	LF	D	1.2	$6.45	$7.74	$1,500		4" dia. PVC, 151-550-0750

								$130,000	
Monitoring wells	4	EA	D	1.2	$3,000.00	$3,600.00	$14,400		

								$14,000	
Groundwater Treatment									
Oil/water separator	1	EA	D	1.2	$26,000.00	$31,200.00	$31,200		coalescing plate type
Recovered Oil Holding Tank	1	EA	D	1.2	$2,000.00	$2,400.00	$2,400		1000 gal tank
Oily Sludge Pump	2	EA	D	1.2	$3,000.00	$3,600.00	$7,200		
Carbon units	2	EA	D	1.2	$78,000.00	$93,600.00	$190,000		
Concrete pad	1	LS	D	1.2	$5,000.00	$6,000.00	$6,000		
Outfall and monitoring equip	1	LS	D	1.2	$17,000.00	$20,400.00	$20,400		

								$260,000	
Soil Cover									assumes all contam'd soil consolidated under 870,000 sf area
Cover Soil	64,000	CY	D	1.2	$10.00	$12.00	$768,000		Estim. judgement
Compaction	64,000	CY	D	1.2	$0.67	$0.80	$51,500		
Top Soil	16,000	CY	D	1.2	$18.00	$21.60	$345,600		3 ", furnish and place, 022-286-0700
Seeding	870	MSF	E	1.0	$40.00	$40.00	$34,800		hydraulic seeding, 029-308-1300
Fence	7,000	LF	E	1.0	$15.00	$15.00	$105,000		

								$1,300,000	

TABLE I-3. ALTERNATIVE 3A
PARTIAL REMOVAL AND TREATMENT OF SOIL AND SEDIMENT, CONTAINMENT OF REMAINING SOIL AND SEDIMENT, AND TREATMENT OF GROUNDWATER

DESCRIPTION	QUANTITY	UNIT	WORK LEVEL	LABOR FACTOR	CONVENTIONAL LABOR UNIT PRICE (DOLLARS)	SITE LABOR UNIT RATE (DOLLARS)	COST	SUBTOTAL	ASSUMPTIONS
Access Road revegetation									
Top Soil	9,000	CY	E	1.0	$3.46	$3.46	$31,000		Spread from piles, 6", FE loader, 022-286-0400
Tree planting	2,100	EA	E	1.0	$100.00	$100.00	$210,000		Dogwood and willow; 029-536
Brush planting	2,100	EA	E	1.0	$40.00	$40.00	$84,000		bush, 029-528-0500
Seeding	600	MSF	E	1.0	$40.00	$40.00	$24,000		hydraulic seeding, 029-308-1300
Oat Straw	600	MSF	E	1.0	$29.00	$29.00	$17,400		1" deep w/ large mulcher, 029-516-0700
Remove access road gravel	7,800	CY	E	1.0	$1.25	$1.25	$9,800		2.5 CY FE loader, load onto truck, 022-238-1600
Haul access road gravel	7,800	CY	E	1.0	$6.10	$6.10	$48,000		12 CY truck, 5 mile round trip, 022-266-0540

								$420,000	
Traffic control								$50,000	
Security								$50,000	
Decon facilities								$85,000	
Verification Sampling		LS	D	1.2	$140,000	$168,000	$168,000		onsite lab for 20 weeks
								------------	
								$170,000	
Allowances									
Mobilize/Demobilize (5%)							$720,000		Mobilization/demobilization; bond and insurance; temporary facilit
Field Detail Allowance (5%)							$720,000		Accounts for known items not quantified (eg. wasted soil, etc.)

								$1,400,000	

CONSTRUCTION SUBTOTAL								$15,700,000	
Contingencies									
Bid (15%)							$2,360,000		
Scope (20%)							$3,140,000		

								$5,500,000	

CONSTRUCTION TOTAL								$21,200,000	

TABLE I-3. ALTERNATIVE 3A
PARTIAL REMOVAL AND TREATMENT OF SOIL AND SEDIMENT, CONTAINMENT OF REMAINING SOIL AND SEDIMENT, AND TREATMENT OF GROUNDWATER

DESCRIPTION	QUANTITY	UNIT	WORK LEVEL	LABOR FACTOR	CONVENTIONAL LABOR UNIT PRICE (DOLLARS)	SITE LABOR UNIT RATE (DOLLARS)	COST	SUBTOTAL	ASSUMPTIONS
Other									
Administrative (5%)							$1,060,000		Services to comply with substantive requirements
Permitting and legal (2%)							$420,000		
Services During Construction							$1,480,000		

								$3,000,000	

TOTAL IMPLEMENTATION COST								$24,200,000	
Engineering Design Cost							$500,000		

								$500,000	
TOTAL CAPITAL COST DURING OPERATION								$25,000,000	

TABLE I-4. ALTERNATIVE 3A - PARTIAL REMOVAL AND TREATMENT OF SOIL AND SEDIMENT

DESCRIPTIONS	QUANTITY	UNIT	UNIT PRICE (DOLLARS)	COST	PRESENT WORTH 3%	5%	10%	ASSUMPTIONS
OPERATION AND MAINTENANCE COST					PW OF COSTS OVER 30 YEARS			
INSPECTION AND REPAIRS								
Years of Operation	30	YRS						
Soil Cover	1	LS	$20,000	20,000 /YR	$392,000	$307,000	$189,000	1% of soil cover repaired each year
Groundwater Collection System	1	LS	$1,500	1,500 /YR	$29,000	$23,000	$14,000	
SUBTOTAL				$21,500 /YR	$421,000	$330,000	$203,000	
GROUNDWATER TREATMENT SYSTEM								
Years of Operation	30	YRS						
Labor	400	HRS	$42	16,800 /YR	$329,000	$258,000	$158,000	
Analytical Costs	12	EA	$1,500	18,000 /YR	$353,000	$277,000	$170,000	
General Maintenance	1	LS	$10,400	10,400 /YR	$204,000	$160,000	$98,000	
Carbon Replacement	1	LS	$20,000	20,000 /YR	$392,000	$307,000	$189,000	
Utilities	1	LS	$2,000	2,000 /YR	$39,000	$31,000	$19,000	
Oily Sludge Disposal	2,600	GAL	$1	2,600 /YR	$51,000	$40,000	$25,000	
SUBTOTAL				$69,800 /YR	$1,368,000	$1,073,000	$659,000	
GROUNDWATER SAMPLING	24	EA	$1,500	36,000 /YR	$706,000	$553,000	$339,000	
SUBTOTAL				$36,000 /YR	$706,000	$553,000	$339,000	
TOTAL O & M COST				$127,300 /YR	$2,500,000	$2,000,000	$1,200,000	

ALTERNATIVE 3A -- COST ESTIMATE SUMMARY

DESCRIPTION	PRESENT WORTH @30 YRS 3%	5%	10%	PRESENT WORTH @ 10 YRS 3%	5%	10%
TOTAL CAPITAL COST DURING OPERATION	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000	$25,000,000
OPERATION & MAINTENANCE COSTS	$2,500,000	$2,000,000	$1,200,000	$1,086,000	$983,000	$782,000
TOTAL PRESENT WORTH	$27,500,000	$27,000,000	$26,200,000	$26,100,000	$26,000,000	$25,800,000

TABLE I-5. ALTERNATIVE 3B
PARTIAL REMOVAL AND LAND TREATMENT OF SEDIMENTS AND SOIL, CONTAINMENT OF REMAINING SEDIMENT AND SOIL, AND TREATMENT OF GROUNDWATER

DESCRIPTION	QUANTITY	UNIT	WORK LEVEL	LABOR FACTOR	CONVENTIONAL LABOR UNIT PRICE (DOLLARS)	SITE LABOR UNIT RATE (DOLLARS)	COST	SUBTOTAL	ASSUMPTIONS
CAPITAL COST DURING OPERATION									
Health and Safety									
Plans, train'g, equip, officer	1	LS	E	1	$158,000.00	$158,000	$158,000		
Air monitoring	1	LS	E	1	$150,000.00	$150,000	$150,000		allowance; estim. judgement
								------------	
								$310,000	
Clearing/Grubbing									
Trees and Stumps	44	ACRE	E	1.0	$11,500.00	$11,500.00	$500,000		cut and chip, max. 24" dia., stumps removed, 021-104-0300,0350
Terrain clearing	44	ACRE	E	1.0	$3,800.00	$3,800.00	$170,000		dozer and brush rake, adverse conditions, 021-108-0600
Topsoil stripping	44,000	CY	E	1.0	$1.40	$1.40	$62,000		200 hp dozer, top 6", 300' haul, 022-286-0100

								$730,000	
Access Roads	35,200	SY	E	1.0	$4.71	$4.71	$170,000		8" gravel depth, no surface, 015-552-0100

								$170,000	
Parallel River Bed									
Excavation of new bed	320,000	CY	E	1.0	$4.00	$4.00	$1,280,000		1 CY backhoe, 022-254-1300
Grading channel sides	350,000	SY	E	1.0	$0.12	$0.12	$40,000		025-122-3300
Place cobble/rubble	500	CY	E	1.0	$26.00	$26.00	$13,000		2.5in-10in dia cobble/rubble; 022-712-0100
Place gravel	1,300	CY	E	1.0	$20.00	$20.00	$26,000		0.1-2.5 in dia gravel; 022-262-1100
Place rip-rap	900	CY	E	1.0	$25.00	$25.00	$22,500		6" riprap; estim. judgement
								------------	
								$1,400,000	
Roadway Crossing Transition									
Number of transitions	11								
Excavate contaminated sediment	1,650	CY	D	1.2	$8.00	$9.60	$15,800		1 CY backhoe, 14-20' deep, 022-254-1300
Move sediment to old bed	1,800	CY	D	1.2	$2.72	$3.26	$5,900		2.5 CY FE loader, 300 foot haul, 022-262-0170 + $1/CY compact
Construct transition dams	13,420	CY	D	1.2	$1.72	$2.06	$28,000		2.5 CY FE loader, 300 foot haul, 022-262-0170
Compact dam	13,420	CY	D	1.2	$2.89	$3.47	$47,000		vibrating plate, 022-254-1900
Runoff diversion sumps	22	EA	D	1.2	$815.00	$978.00	$22,000		4 foot dia. x 6' deep, concrete, 027-152-0500
Runoff diversion sump pumps	2	EA	D	1.2	$3,000.00	$3,600.00	$7,200		pumped upstream of dam, Flygt quote, Alumax
Bypass diversion pumps	2	EA	D	1.2	$10,000.00	$12,000.00	$24,000		temporary bypass pumps, 5,000 gpm each
Bypass diversion piping	1,000	LF	D	1.2	$26.00	$31.20	$31,000		24" dia CMP, 027-164-2140
Sheet piling		LS	D	1.2	$220,000	$264,000	$264,000		
Silt curtains		LS	D	1.2	$20,000	$24,000	$24,000		

								$470,000	

TABLE I-5. ALTERNATIVE 3B
PARTIAL REMOVAL AND LAND TREATMENT OF SEDIMENTS AND SOIL, CONTAINMENT OF REMAINING SEDIMENT AND SOIL, AND TREATMENT OF GROUNDWATER

DESCRIPTION	QUANTITY	UNIT	WORK LEVEL	LABOR FACTOR	CONVENTIONAL LABOR UNIT PRICE (DOLLARS)	SITE LABOR UNIT RATE (DOLLARS)	COST	SUBTOTAL	ASSUMPTIONS
Tributary Crossings Extensions									
number of crossings	5								
Excavate trench	500	CY	D	1.2	$2.14	$2.57	$1,300		2.5 CY backhoe, 6 feet to 10 feet deep, 022-254-0620
Tributary pipe	500	LF	D	1.2	$64.00	$76.80	$38,000		36" dia culvert, 027-162-2060
Drainage Layer Granular Fill	75	CY	D	1.2	$41.00	$49.20	$3,700		pea gravel, 029-504-0900
Backfill Trench	500	CY	D	1.2	$1.46	$1.75	$900		1 CY FE Loader, minimal haul, 022-254-3020
Compact area	500	CY	D	1.2	$2.89	$3.47	$1,700		vibrating plate, 022-254-1900
Seeding	5,000	SF	D	1.2	$0.04	$0.05	$200		hydraulic seeding, 029-308-1300

								$46,000	
Fill Old River Bed									
Dewatering Sump	10	EA	D	1.2	$890.00	$1,068.00	$11,000		4 foot dia. x 8' deep, precast concrete, 027-152-1130
Dewatering Pump	2	EA	D	1.2	$3,000.00	$3,600.00	$7,200		pumped upstream of dam, Flygt quote, Alumax
Place backfill in channel	180,000	CY	D	1.2	$1.51	$1.81	$330,000		1 CY FE Loader, minimal haul, 022-254-3020
Compact river bed cover	180,000	CY	D	1.2	$0.35	$0.42	$80,000		Riding, vibrating roller, 022-226-5020
Spread excess spoils	210,000	CY	E	1.0	$1.21	$1.21	$250,000		Grading at dump: 022-266-1600
Compact spread spoils	210,000	CY	E	1.0	$0.89	$0.89	$190,000		Sheepsfoot roller:022-226-6030
Seed area	2,800	MSF	E	1.0	$40.00	$40.00	$110,000		

								$980,000	
Soil Cover over Old River Bed									old river bed
Top Soil	18,000	CY	E	1.0	$4.00	$4.00	$72,000		Furnish and place top 6", from stripped area
Seeding	140,000	SF	E	1.0	$0.36	$0.36	$50,000		hydraulic seeding, 029-308-1300

								$120,000	
Soil Consolidation									contaminated soil
Excavate and consolidate soil	15,000	CY	D	1.2	$6.85	$8.22	$123,000		200 Hp bulldozer, 300 foot haul, 022-242-4440
Grading	18,000	CY	D	1.2	$1.21	$1.45	$26,100		022-266-1600

								$150,000	
Sediment Excavation									sediments only
Excavation and load sediment	6,500	CY	D	1.2	$8.00	$9.60	$62,000		
Haul to site and place on beds	7,200	CY	D	1.2	$7.93	$9.52	$69,000		12 CY dump truck, 10 mile heavy traffic round trip, 022-266-0550

								$130,000	

TABLE I-5. ALTERNATIVE 3B
PARTIAL REMOVAL AND LAND TREATMENT OF SEDIMENTS AND SOIL, CONTAINMENT OF REMAINING SEDIMENT AND SOIL, AND TREATMENT OF GROUNDWATER

DESCRIPTION	QUANTITY	UNIT	WORK LEVEL	LABOR FACTOR	CONVENTIONAL LABOR UNIT PRICE (DOLLARS)	SITE LABOR UNIT RATE (DOLLARS)	COST	SUBTOTAL	ASSUMPTIONS
Field Pilot Study									6 month study
Study and Plan	1	LS	E	1.0	$15,000	$15,000	$15,000		
Sample Collection	1	LS	D	1.2	$4,000	$4,000	$4,800		
Experiment Setup	1	LS	D	1.2	$25,000	$30,000	$30,000		Purchase and construct 5 test cells, sprinklers, tilling equip.
Soil Sampling and Charact.	1	LS	D	1.2	$9,000	$10,800	$10,800		Routine analysis for nutrients, moisture content, pH, etc.
PAH Analyses	1	LS	D	1.2	$25,000	$30,000	$30,000		7 sampling events with 12 samples including QC
Data Reduction and Reporting	1	LS	D	1.2	$7,000	$8,400	$8,400		Prepare technical memo including graghics and reporduction
								------------	
								$99,000	
Land Treatment Beds									
Excavation of contaminated soil	80,000	CY	D	1.2	$6.85	$8.22	$660,000		200 HP bulldozer, 300' haul; 0222424440
Dewatering		LS	D	1.2	$50,000	$60,000	$60,000		allowance
Access roads	4,800	SY	D	1.2	$4.71	$5.65	$30,000		8" gravel depth, no surface, 0155520100
Berm construction	14,000	CY	D	1.2	$6.85	$8.22	$120,000		200 HP bulldozer, 300' haul; 0222424440
2 foot clay	35,000	CY	D	1.2	$18.00	$21.60	$760,000		Estim judgmnt/onal.
Geotextile/synthetic liner	55,000	SY	D	1.2	$10.00	$12.00	$660,000		80 mil thick+geotextile
Leak detection layer -sand	17,000	CY	D	1.2	$25.00	$30.00	$510,000		Screened and washed, 30 mi haul, 0410320300
Geotextile/synth liner/geonet	55,000	SY	D	1.2	$13.00	$15.60	$860,000		80 mil thick+geotextile+geonet
Drainage layer -sand	33,000	CY	D	1.2	$25.00	$30.00	$990,000		Screened and washed, 30 mi haul, 0410320300
Drainage pipe	8,200	LF	D	1.2	$2.52	$3.02	$20,000		perforated, 4" dia PVC 0271682000

								$4,700,000	
Treatment Equipment									
Tilling tractor	1	EA	E	1.0	$25,000.00	$25,000.00	$25,000		tractor and disc harrow, M&B
Water/nutrient tank	2	EA	D	1.2	$40,000.00	$48,000.00	$96,000		40,000 gal ea. $1/gal
Nutrient pump	4	EA	D	1.0	$3,000.00	$3,000.00	$12,000		centrifugal, estim judgement
Leachate collection sump	2	EA	D	1.0	$890.00	$890.00	$1,800		4 ft dia, 8 ft deep precast; 0271521130
Leachate sump pumps	4	EA	D	1.0	$3,000.00	$3,000.00	$12,000		pumped to san sewer; flygt quote, alumax
Leachate collection tank	2	EA	D	1.0	$20,000.00	$20,000.00	$40,000		20,000 gal each; $1/gal
Sprinkler system	1	LS	D	1.0	$50,000.00	$50,000.00	$50,000		Gary Herman /DEN

								$240,000	
Transport Treated Residues to Storage									
Load residue in dump truck	74,400	CY	D	1.2	$1.00	$1.20	$89,000		2.5 CY FE Loader, from stockpile to dump truck, 022-238-1600
Haul residue to storage area	74,400	CY	D	1.2	$1.00	$1.20	$89,000		6 CY dump truck, 022-266-
								------------	
								$180,000	
Transport NE Landfill Residue to TSD									
Load in dump truck	1,000	CY	D	1.2	$1.00	$1.20	$1,200		
Hauling cost	1,000	CY	E	1.0	$80.00	$80.00	$80,000		
Disposal cost	1,000	CY	E	1.0	$150.00	$150.00	$150,000		

								$230,000	

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TABLE I-5. ALTERNATIVE 3B
PARTIAL REMOVAL AND LAND TREATMENT OF SEDIMENTS AND SOIL, CONTAINMENT OF REMAINING SEDIMENT AND SOIL, AND TREATMENT OF GROUNDWATER

DESCRIPTION	QUANTITY	UNIT	WORK LEVEL	LABOR FACTOR	CONVENTIONAL LABOR UNIT PRICE (DOLLARS)	SITE LABOR UNIT RATE (DOLLARS)	COST	SUBTOTAL	ASSUMPTIONS
Transport oversize to SW Landfill									
Load in dump truck	3,000	CY	D	1.2	$1.50	$1.80	$5,400		
Hauling cost	3,000	CY	E	1.0	$15.00	$15.00	$45,000		
Disposal cost	3,000	CY	E	1.0	$30.00	$30.00	$90,000		

								$140,000	
Groundwater Collection Drains									near river edge only
Excavation/Trenching	2,400	CY	D	1.2	$1.98	$2.38	$5,700		1.5 CY backhoe, 022-254-0610
Drainage Layer - gravel	2,000	CY	D	1.2	$41.00	$49.20	$98,400		pea gravel, 029-504-0900
Drainage Piping	1,100	LF	D	1.2	$2.52	$3.02	$3,300		perforated, 4" dia. PVC, 027-168-2000
Vertical Barrier	10,000	SF	D	1.2	$0.60	$0.72	$7,200		60 mil, John Heineke
Cover Soil	500	CY	D	1.2	$10.00	$12.00	$6,000		2'depth, Bob Lawson/RDD, Merrideth-Baxter Cost Estimate
Compaction/Tamping	500	CY	D	1.2	$2.89	$3.47	$1,700		vibrating plate, 022-254-1900
Collection sump	1	EA	D	1.2	$890.00	$1,068.00	$1,100		4 foot dia. x 8' deep, precast concrete, 027-152-1130
Collection Pumps	2	EA	D	1.2	$3,000.00	$3,600.00	$7,200		pumped to sanitary sewers, Flygt quote, Alumax
Discharge Piping	200	LF	D	1.2	$15.00	$18.00	$3,600		4" dia. PVC, 151-550-0750

								$130,000	
Groundwater Treatment System									
Oil/Water Separator	1	EA	D	1.2	$26,000.00	$31,200.00	$31,200		
Pure phase Holding Tank	1	EA	D	1.2	$3,000.00	$3,600.00	$3,600		5,000 gallons, $1/gallon
Oily sludge Pump	2	EA	D	1.2	$3,000.00	$3,600.00	$7,200		Estimator's judgement, centrifugal
Carbon Units	2	EA	D	1.2	$78,000.00	$93,600.00	$187,200		Source for costs from Paul B., files for McCormick & Baxter
Concrete Pad	1	LS	D	1.2	$5,000.00	$6,000.00	$6,000		
Outfall	1	LS	D	1.2	$17,000.00	$20,400.00	$20,400		

								$260,000	
Temporary Storage Area									from treatment beds
Excavate Area	12,500	CY	D	1.2	$6.85	$8.22	$100,000		200 Hp bulldozer, 300 foot haul, 022-242-4440
Drainage Piping	2,450	LF	D	1.2	$2.52	$3.02	$7,400		perforated, 4" dia. PVC, 027-168-2000
Drainage Layer - gravel	2,100	CY	D	1.2	$41.00	$49.20	$100,000		pea gravel, 029-504-0900
Geotextile Filter	225	MSF	D	1.2	$300.00	$360.00	$81,000		non-woven fabric, John Heineke
Geomembrane/liner	113	MSF	D	1.2	$450.00	$540.00	$61,000		30 mil, John Heineke
Place 2 ft clay	8,000	CY	D	1.2	$18.00	$21.60	$172,800		
Collection Sump	1	EA	D	1.2	$890.00	$1,068.00	$1,100		4 foot dia. x 8' deep, precast concrete, 027-152-1130
Sump Pumps	2	EA	D	1.2	$3,000.00	$3,600.00	$7,200		pumped to sanitary sewers, Flygt quote, Alumax

TABLE I-5. ALTERNATIVE 3B
PARTIAL REMOVAL AND LAND TREATMENT OF SEDIMENTS AND SOIL, CONTAINMENT OF REMAINING SEDIMENT AND SOIL, AND TREATMENT OF GROUNDWATER

DESCRIPTION	QUANTITY	UNIT	WORK LEVEL	LABOR FACTOR	CONVENTIONAL LABOR UNIT PRICE (DOLLARS)	SITE LABOR UNIT RATE (DOLLARS)	COST	SUBTOTAL	ASSUMPTIONS
Holding Tank	1	EA	D	1.2	$10,000.00	$12,000.00	$12,000		holding tank for leachate, 10,000 gal, 1$/gal
Holding Tank Pump	2	EA	D	1.2	$10,000.00	$12,000.00	$24,000		leachate tank to sanitary sewer, centrifugal, Estmator's judgement
Piping	200	LF	D	1.2	$15.00	$18.00	$3,600		4" dia. PVC, 151-550-0750

								$570,000	
Final Cover									for 10-6 contaminated soils
Cover Soil	64,000	CY	D	1.2	$10.00	$12.00	$770,000		Bob Lawson/RDD - Merrideth-Baxter Cost Estimate
Compaction	64,000	CY	D	1.2	$0.67	$0.80	$50,000		
Top Soil	16,000	CY	D	1.2	$18.00	$21.60	$350,000		3 ", furnish and place, 022-286-0700
Seeding	900	MSF	E	1.0	$40.00	$40.00	$36,000		hydraulic seeding, 029-308-1300
Fence	7,000	LF	E	1.0	$15.00	$15.00	$105,000		

								$1,300,000	
Access Road revegetation									
Top Soil	9,000	CY	E	1.0	$3.46	$3.46	$31,000		Spread from piles, 6", FE loader, 022-286-0400
Tree planting	2,100	EA	E	1.0	$100.00	$100.00	$210,000		Dogwood and willow
Brush planting	2,100	EA	E	1.0	$40.00	$40.00	$84,000		bush, 029-528-0500
Seeding	600	MSF	E	1.0	$40.00	$40.00	$24,000		hydraulic seeding, 029-308-1300
Oat Straw	600	MSF	E	1.0	$29.00	$29.00	$17,400		1" deep w/ large mulcher, 029-516-0700
Remoce access road gravel	7,800	CY	E	1.0	$1.25	$1.25	$9,800		2.5 CY FE loader, load onto truck, 022-238-1600
Haul access road gravel	7,800	CY	E	1.0	$6.10	$6.10	$48,000		12 CY truck, 5 mile round trip, 022-266-0540

								$420,000	
Traffic control								$50,000	
Security								$50,000	
Decon facilities								$85,000	
Verification Sampling	1	EA	D	1.0	$140,000	$140,000	$140,000		onsite lab for 20 weeks
								------------	
								$140,000	

TABLE I-5. ALTERNATIVE 3B
PARTIAL REMOVAL AND LAND TREATMENT OF SEDIMENTS AND SOIL, CONTAINMENT OF REMAINING SEDIMENT AND SOIL, AND TREATMENT OF GROUNDWATER

DESCRIPTION	QUANTITY	UNIT	WORK LEVEL	LABOR FACTOR	CONVENTIONAL LABOR UNIT PRICE (DOLLARS)	SITE LABOR UNIT RATE (DOLLARS)	COST	SUBTOTAL	ASSUMPTIONS
Allowances									
Mobilize/Demobilize (5%)							$660,000		Mobilization/demobilization: bond and insurance: temporary facilit
Field Detail Allowance (5%)							$660,000		Accounts for known items not quantified (eg. wasted soil, etc.)

								$1,300,000	

CONSTRUCTION SUBTOTAL								$14,000,000	
Contingencies									
Bid (10%)							$1,400,000		
Scope (20%)							$2,800,000		

								$4,200,000	

CONSTRUCTION TOTAL								$18,000,000	
Other									
Administrative (5%)							$900,000		Services to comply with substantive requirements
Permitting and legal (2%)							$400,000		
Services During Construction (7%)							$1,300,000		

								$2,600,000	

TOTAL IMPLEMENTATION COST								$21,000,000	
Engineering Design Cost							$600,000		

								$600,000	
TOTAL CAPITAL COST DURING OPERATION								$22,000,000	

TABLE I-6. ALTERNATIVE 3B - LAND TREAT SEDIMENT AND SOIL

DESCRIPTIONS	QUANTITY	UNIT	UNIT PRICE (DOLLARS)	C O S T	PRESENT WORTH 3%	5%	10%	ASSUMPTIONS
OPERATION AND MAINTENANCE COST					PW OF COSTS OVER 30 YEARS			
INSPECTION AND REPAIRS								
Years of Operation	30	YRS						
Soil Cover	1	LS	$20,000	20,000 /YR	$392,000	$307,000	$189,000	1% of soil cover repaired each year
Groundwater collection system	1	LS	$1,500	1,500 /YR	$392,000	$307,000	$189,000	1% of soil cover repaired each year
SUBTOTAL				$21,500 /YR	$784,000	$614,000	$378,000	
GROUNDWATER TREATMENT SYSTEM								
Years of Operation	30	YRS						
Labor	400	HRS	$42	16,800 /YR	$329,000	$258,000	$158,000	
Analytical Costs	12	EA	$1,500	18,000 /YR	$353,000	$277,000	$170,000	
General Maintenance	1	LS	$10,400	10,400 /YR	$204,000	$160,000	$98,000	
Carbon Replacement	1	LS	$20,000	20,000 /YR	$392,000	$307,000	$189,000	
Utilities	1	LS	$2,000	2,000 /YR	$39,000	$31,000	$19,000	
Oily Sludge Disposal	2600	GAL	$1	2,600 /YR	$51,000	$40,000	$25,000	
SUBTOTAL				$69,800 /YR	$1,368,000	$1,073,000	$659,000	
GROUNDWATER SAMPLING	24	EA	$1,500	36,000 /YR	$706,000	$553,000	$339,000	
SUBTOTAL				$127,300 /YR	$2,858,000	$2,240,000	$1,376,000	
					PW OF COSTS OVER 10 YEARS			
LAND TREATMENT BED OPERATION								
Years of Operation	10	YRS						
Haul and Spread from Stockpile	10,000	CY	$2	17,200 /YR	$147,000	$133,000	$106,000	2.5 CY FE loader, 300 ft. haul, 022-262-0170
Nutrient Amendments	5	MO	$500	2,500 /YR	$21,000	$19,000	$15,000	
Analytical - PAH	5	MO	$3,000	15,000 /YR	$128,000	$116,000	$92,000	10 samples/mo @ $300/sample
Analytical Soil Characterization	5	MO	$1,000	5,000 /YR	$43,000	$39,000	$31,000	20 samples/mo @ $50/sample for nutrients, pH, mositure content
Excavate Once Treated	13,000	CY	$9	117,000 /YR	$998,000	$903,000	$719,000	30% increase from excavating 6" gravel, 022-242-4440
Water	2.2	MGAL	$1,000	2,200 /YR	$19,000	$17,000	$14,000	$1/1,000 gal, Tony Myers
Granular Fill Replacement	3,000	CY	$57	172,200 /YR	$1,469,000	$1,330,000	$1,058,000	pea gravel, 6" top replacement 029-504-0900
Tilling and Inspection	1	LS	$15,000	15,000 /YR	$128,000	$116,000	$92,000	20 hrs/week, 1.4 multiplier, includes H&S, $25/hr
Engineering Oversight	1	LS	$25,000	25,000 /YR	$213,000	$193,000	$154,000	one engineer, quarter time
SUBTOTAL				$371,100 /YR	$3,166,000	$2,866,000	$2,281,000	
TOTAL O & M COST				$498,400 /YR	$6,000,000	$5,100,000	$3,700,000	

TABLE I-6. ALTERNATIVE 3B - LAND TREAT SEDIMENT AND SOIL

ALTERNATIVE 3B -- COST ESTIMATE SUMMARY

DESCRIPTION	PRESENT WORTH @ 30 YRS 3%	PRESENT WORTH @ 30 YRS 5%	PRESENT WORTH @ 30 YRS 10%	PRESENT WORTH @ 10 YRS 3%	PRESENT WORTH @ 10 YRS 5%	PRESENT WORTH @ 10 YRS 10%
TOTAL CAPITAL COST DURING OPERATION	$22,000,000	$22,000,000	$22,000,000	$22,000,000	$22,000,000	$22,000,000
OPERATION & MAINTENANCE COSTS	$6,000,000	$5,100,000	$3,700,000	$4,300,000	$3,800,000	$3,100,000
TOTAL PRESENT WORTH	$28,000,000	$27,100,000	$25,700,000	$26,300,000	$25,800,000	$25,100,000

TABLE I-7. ALTERNATIVE 4
REMOVE AND TREAT SEDIMENTS, CONTAINMENT OF SOIL, AND TREATMENT OF GROUNDWATER

DESCRIPTION	QUANTITY	UNIT	WORK LEVEL	LABOR FACTOR	CONVENTIONAL LABOR UNIT PRICE (DOLLARS)	SITE LABOR UNIT RATE (DOLLARS)	COST	SUBTOTAL	ASSUMPTIONS
CAPITAL COST DURING OPERATION									
Health and Safety									
Plans,train'g,equip,officer		LS	E	1	$150,000	$150,000	$150,000		
Air monitoring		LS	E	1	$150,000	$150,000	$150,000		
								$300,000	
Clearing/Grubbing									
Trees and Stumps	22	ACRE	E	1.0	$11,500	$11,500	$253,000		cut and chip, max. 24" dia., stumps removed, 021-104-0300,0350
Terrain clearing	22	ACRE	E	1.0	$3,800	$3,800	$84,000		dozer and brush rake, adverse conditions, 021-108-0600
								$340,000	
Access Roads	35,200	SY	E	1.0	$4.71	$4.71	$170,000		8" gravel depth, no surface, 015-552-0100
								$170,000	
Temporary Dam Construction									
Number of dams	31								
Construct transition dams	37,820	CY	D	1.2	$1.72	$2.06	$78,100		2.5 CY FE loader, 300 foot haul, 022-262-0170
Compact dam	37,820	CY	D	1.2	$2.89	$3.47	$131,200		vibrating plate, 022-254-1900
Runoff diversion sumps	1	EA	D	1.2	$815	$978	$1,000		4 foot dia. x 6' deep, concrete, 027-152-0500
Runoff diversion sump pumps	2	EA	D	1.2	$3,000	$3,600	$7,200		pumped upstream of dam, Flygt quote, Alumax
Bypass diversion piping	1,000	LF	D	1.2	$26	$31	$31,200		24" dia CMP, 027-164-2140
Dewatering Sump	1	EA	D	1.2	$815	$978	$1,000		4 foot dia. x 6' deep, concrete, 027-152-0500
Dewatering Pump	2	EA	D	1.2	$3,000	$3,600	$7,200		pumped upstream of dam, Flygt quote, Alumax
Sheet piling		LS	D	1.2	$520,000	$624,000	$624,000		
Silt curtains		LS	D	1.2	$20,000	$24,000	$24,000		
								$900,000	
Soil Consolidation									contaminated soil in floodplain & outliers
Excavation and placement of soil	50,000	CY	D	1.2	$6.85	$8.22	$410,000		200 Hp bulldozer, 300 foot haul, 022-242-4440
Grading	50,000	CY	D	1.2	$1.21	$1.45	$73,000		
								$480,000	
Excavation of Northeast Landfill									
Excavation and stockpile of soil	1,200	CY	D	1.2	$6.85	$8.22	$9,900		
								$10,000	
Sediment Excavation & Haul									sediments only
Excavation and load sediment	33,000	CY	D	1.2	$8.00	$9.60	$320,000		1 CY backhoe, w/15% for loading, 022-254-1300
Haul to site	36,300	CY	D	1.2	$7.93	$9.52	$350,000		12 CY dump truck, 10 mile heavy traffic round trip, 022-266-0550
Sediment Staging Pad	1	LS	D	1.2	$55,000	$66,000	$66,000		see 3A
								$740,000	

TABLE I-7. ALTERNATIVE 4
REMOVE AND TREAT SEDIMENTS, CONTAINMENT OF SOIL, AND TREATMENT OF GROUNDWATER

DESCRIPTION	QUANTITY	UNIT	WORK LEVEL	LABOR FACTOR	CONVENTIONAL LABOR UNIT PRICE (DOLLARS)	SITE LABOR UNIT RATE (DOLLARS)	COST	SUBTOTAL	ASSUMPTIONS
Channel Reconstruction									
Grading channel sides	350,000	SY	E	1.0	$0.12	$0.12	$40,000		025-122-3300
Haul and grade excess spoils	110,000	CY	E	1.0	$2.60	$2.60	$290,000		022-266-1600;-6030; +0.5/sy seeding
Erosion control netting	350,000	SY	E	1.0	$0.29	$0.29	$100,000		022-704-0300
Seeding	350,000	SY	E	1.0	$0.36	$0.36	$130,000		
Place cobble/rubble	500	CY	E	1.0	$26.00	$26.00	$13,000		2.5in-10in dia cobble/rubble: 022-712-0100
Place gravel	1,300	CY	E	1.0	$20.00	$20.00	$26,000		0.1-2.5 in dia gravel; 022-262-1100
Place rip-rap	900	CY	E	1.0	$25.00	$25.00	$22,500		6" riprap: 0227120400

								$620,000	
Field Pilot Study									6 month study
Study and plan	1	LS	E	1.0	$15,000.00	$15,000.00	$15,000		
Sample collection	1	LS	D	1.2	$4,000.00	$4,800.00	$4,800		
Experiment Setup	1	LS	D	1.2	$25,000.00	$30,000.00	$30,000		Purchase and construct 5 test cells, sprinklers, tilling equip.
Soil Sampling and Charact.	1	LS	D	1.2	$9,000.00	$10,800.00	$10,800		Routine analysis for nutrients, moisture content, pH, etc.
PAH Analyses	1	LS	D	1.2	$25,000.00	$30,000.00	$30,000		7 sampling events with 12 samples including QC
Data Reduction and Reporting	1	LS	D	1.2	$7,000.00	$8,400.00	$8,400		Prepare technical memo including graghics and reporduction
								------------	
								$100,000	
Slurry Bioreactor System									
Transfer sediment & soil to system	37,500	CY	D	1.2	$1.00	$1.20	$45,000		2.5 CY FE Loader, from stockpile to system, 022-238-1600
Equipment pad	1	LS	D	1.2	$30,000	$36,000	$36,000		
Vibrating Screens	1	EA	D	1.0	$7,200	$7,200	$7,200		CORA, assumes 70% salvage value
Attrition Scrubber	1	EA	D	1.0	$8,700	$8,700	$8,700		CORA, assumes 70% salvage value
Screw Classifier	1	EA	D	1.0	$5,400	$5,400	$5,400		CORA, assumes 70% salvage value
Slurry Bioreactor	1	EA	D	1.0	$333,000	$333,000	$333,000		CORA, assumes 70% salvage value
Dewatering	1	EA	D	1.0	$45,900	$45,900	$45,900		CORA, assumes 70% salvage value
Instrumentation	1	LS	E	1.0	$48,024	$48,024	$48,000		12% of the equipment costs
Elect & Mech.	1	LS	D	1.2	$80,040	$96,048	$96,000		20% of equipment costs
Labor	26,000	HOUR	D	1.2	$30	$36	$936,000		3 man crew, 24 hours day, 2 years
Power	1.6E+06	KW	E	1.0	$0.08	$0.08	$128,000		
Chemicals	1	LS	E	1.0	$60,000	$60,000	$60,000		
Parts, supplies	1	LS	E	1.0	$40,000	$40,000	$40,000		
Analytical	1	LS	E	1.0	$180,000	$180,000	$180,000		

								$2,000,000	

TABLE I-7. ALTERNATIVE 4
REMOVE AND TREAT SEDIMENTS, CONTAINMENT OF SOIL, AND TREATMENT OF GROUNDWATER

DESCRIPTION	QUANTITY	UNIT	WORK LEVEL	LABOR FACTOR	CONVENTIONAL LABOR UNIT PRICE (DOLLARS)	SITE LABOR UNIT RATE (DOLLARS)	COST	SUBTOTAL	ASSUMPTIONS
Transport Residue to Containment Area									
Load residue in dump truck	33,000	CY	D	1.2	$1.00	$1.20	$39,600		2.5 CY FE Loader, from stockpile to dump truck, 022-238-1600
Haul residue to containment area	33,000	CY	D	1.2	$2.02	$2.42	$80,000		0222620170
Grading Sediment	33,000	CY	D	1.2	$1.21	$1.45	$47,900		200 Hp bulldozer, 300 foot haul, 022-242-4440

								$170,000	
Transport NE Landfill Residue to TSD									
Load in dump truck	1,000	CY	D	1.2	$1.00	$1.20	$1,200		
Hauling cost	1,200	CY	E	1.0	$80.00	$80.00	$96,000		
Disposal cost	1,200	CY	E	1.0	$150.00	$150.00	$180,000		

								$280,000	
Groundwater Collection Drains									near river and beneath contaminated soil
Excavation/Trenching	7,300	CY	D	1.2	$1.98	$2.38	$17,300		1.5 CY backhoe, 022-254-0610
Drainage Layer - gravel	5,900	CY	D	1.2	$41.00	$49.20	$290,300		pea gravel, 029-504-0900
Drainage Piping	3,300	LF	D	1.2	$2.52	$3.02	$10,000		perforated, 4" dia. PVC, 027-168-2000
Vertical Barrier	10,000	SF	D	1.2	$0.60	$0.72	$7,200		60 mil, John Heineke
Cover Soil	1,500	CY	D	1.2	$10.00	$12.00	$18,000		2'depth, Bob Lawson/RDD, Merrideth-Baxter Cost Estimate
Compaction/Tamping	1,500	CY	D	1.2	$2.89	$3.47	$5,200		vibrating plate, 022-254-1900
Collection sump	1	EA	D	1.2	$890.00	$1,068.00	$1,100		4 foot dia. x 8' deep, precast concrete, 027-152-1130
Collection Pumps	2	EA	D	1.2	$3,000.00	$3,600.00	$7,200		pumped to sanitary sewers, Flygt quote, Alumax
Discharge Piping	800	LF	D	1.2	$6.45	$7.74	$6,200		4" dia. PVC, 151-550-0750

								$360,000	
Monitoring wells	4	EA	D	1.2	$3,000.00	$3,600.00	$14,400		

								$14,000	
Soil Cover									for 10-6 contaminated soils
Cover Soil	64,000	CY	D	1.2	$10.00	$12.00	$768,000		Bob Lawson/RDD - Merrideth-Baxter Cost Estimate
Compaction	64,000	CY	D	1.2	$0.67	$0.80	$51,500		022-222-0300
Top Soil	16,000	CY	D	1.2	$18.00	$21.60	$345,600		3 ", Furnish and place, 022-286-0700
Seeding	900	MSF	E	1.0	$40.00	$40.00	$36,000		hydraulic seeding, 029-308-1300
Fence	7,000	LF	E	1.0	$15.00	$15.00	$105,000		

								$1,300,000	

TABLE I-7. ALTERNATIVE 4
REMOVE AND TREAT SEDIMENTS, CONTAINMENT OF SOIL, AND TREATMENT OF GROUNDWATER

DESCRIPTION	QUANTITY	UNIT	WORK LEVEL	LABOR FACTOR	CONVENTIONAL LABOR UNIT PRICE (DOLLARS)	SITE LABOR UNIT RATE (DOLLARS)	COST	SUBTOTAL	ASSUMPTIONS
Access Road revegetation									
Top Soil	9.000	CY	E	1.0	$4.86	$4.86	$43.700		Spread from piles, 6", FE loader, 022-286-0400;0200
Tree planting	2.100	EA	E	1.0	$100.00	$100.00	$210.000		Dogwood and willow
Brush planting	2.100	EA	E	1.0	$40.00	$40.00	$84.000		bush, 029-528-0500
Seeding	600	MSF	E	1.0	$40.00	$40.00	$24.000		hydraulic seeding, 029-308-1300
Oat Straw	600	MSF	E	1.0	$29.00	$29.00	$17.400		1" deep w/ large mulcher, 029-516-0700
Remove access road gravel	7.800	CY	E	1.0	$1.25	$1.25	$9.800		2.5 CY FE loader, load onto truck, 022-238-1600
Haul access road gravel	7.800	CY	E	1.0	$6.10	$6.10	$47.600		12 CY truck, 5 mile round trip, 022-266-0540

								$440.000	
Groundwater Treatment									
Oil/water separator	1	EA	D	1.2	$26.000.00	$31.200.00	$31.000		coalescing plate type
Recovered Oil Holding Tank	1	EA	D	1.2	$2.000.00	$2.400.00	$2.400		1000 gal tank
Oily Sludge Pump	2	EA	D	1.2	$3.000.00	$3.600.00	$7.200		
Carbon units	2	EA	D	1.2	$78.000.00	$93.600.00	$190.000		
Concrete pad	1	LS	D	1.2	$5.000.00	$6.000.00	$6.000		
Outfall and monitoring equip	1	LS	D	1.2	$17.000.00	$20.400.00	$20.400		

								$260.000	
Traffic control								$50.000	
Security								$50.000	
Decon facilities								$160.000	
Verification sampling	1	LS	D	1.2	$200.000	$240.000	$240.000		mobile lab @ $15.000/mo., and sampling for 3 months
								------------	
								$240.000	
Allowances									
Mobilize/Demobilize (5%)							$450.000		Mobilization/demobilization; bond and insurance; temporary facilit
Field Detail Allowance (5%)							$450.000		Accounts for known items not quantified (eg. wasted soil, etc.)

								$900.000	

CONSTRUCTION SUBTOTAL								$10.000.000	

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TABLE I-7. ALTERNATIVE 4
REMOVE AND TREAT SEDIMENTS, CONTAINMENT OF SOIL, AND TREATMENT OF GROUNDWATER

DESCRIPTION	QUANTITY	UNIT	WORK LEVEL	LABOR FACTOR	CONVENTIONAL LABOR UNIT PRICE (DOLLARS)	SITE LABOR UNIT RATE (DOLLARS)	COST	SUBTOTAL	ASSUMPTIONS
Contingencies									
Bid (15%)							$1,500,000		
Scope (20%)							$2,000,000		

								$3,500,000	
								============	
CONSTRUCTION TOTAL								$14,000,000	
Other									
Administrative (5%)							$700,000		Services to comply with substantive requirements
Permitting and legal (2%)							$280,000		
Services During Construction (7%)							$980,000		

								$2,000,000	
								============	
TOTAL IMPLEMENTATION COST								$16,000,000	
Engineering Design Cost							$500,000		

								$500,000	
TOTAL CAPITAL COST DURING OPERATION								$17,000,000	

TABLE I-8. ALTERNATIVE 4 - REMOVAL AND TREATMENT OF SEDIMENT, CONTAIN SOIL

DESCRIPTIONS	QUANTITY	UNIT	UNIT PRICE (DOLLARS)	COST	PRESENT WORTH 3%	PRESENT WORTH 5%	PRESENT WORTH 10%	ASSUMPTIONS
OPERATION AND MAINTENANCE COST					PW OF COSTS OVER 30 YEARS			
INSPECTION AND REPAIRS								
Years of Operation	30	YRS						
Soil Cover	1	LS	$20,000	20,000 /YR	$392,000	$307,000	$189,000	1% of soil cover repaired each year
Groundwater Collection System	1	LS	$4,000	4,000 /YR	$78,000	$61,000	$38,000	
SUBTOTAL				$24,000 /YR	$470,000	$368,000	$227,000	
GROUNDWATER TREATMENT SYSTEM								
Years of Operation	30	YRS						
Labor	400	HRS	$42	16,800 /YR	$329,000	$258,000	$158,000	
Analytical Costs	12	EA	$1,500	18,000 /YR	$353,000	$277,000	$170,000	
General Maintenance	1	LS	$10,400	10,400 /YR	$204,000	$160,000	$98,000	
Carbon Replacement	1	LS	$20,000	20,000 /YR	$392,000	$307,000	$189,000	
Utilities	1	LS	$2,000	2,000 /YR	$39,000	$31,000	$19,000	
Oily Sludge Disposal	2,600	GAL	$1	2,600 /YR	$51,000	$40,000	$25,000	
SUBTOTAL				$69,800 /YR	$1,368,000	$1,073,000	$659,000	
GROUNDWATER SAMPLING	24	EA	$1,500	36,000 /YR	$706,000	$553,000	$339,000	
SUBTOTAL				$36,000 /YR	$706,000	$553,000	$339,000	
TOTAL O & M COST				$129,800 /YR	$2,500,000	$2,000,000	$1,200,000	

ALTERNATIVE 4 -- COST ESTIMATE SUMMARY

DESCRIPTION	PRESENT WORTH @ 30 YRS 3%	PRESENT WORTH @ 30 YRS 5%	PRESENT WORTH @ 30 YRS 10%	PRESENT WORTH @ 100 YRS 3%	PRESENT WORTH @ 100 YRS 5%	PRESENT WORTH @ 100 YRS 10%
TOTAL CAPITAL COST DURING OPERATION	$17,000,000	$17,000,000	$17,000,000	$17,000,000	$17,000,000	$17,000,000
OPERATION & MAINTENANCE COSTS	$2,500,000	$2,000,000	$1,200,000	$4,100,000	$2,600,000	$1,300,000
TOTAL PRESENT WORTH	$19,500,000	$19,000,000	$18,200,000	$21,100,000	$19,600,000	$18,300,000

TABLE I-9. ALTERNATIVE 5
REMOVE AND SLURRY TREAT SEDIMENTS AND PART OF SOIL, CONTAINMENT OF REMAINING SOIL, AND TREATMENT OF GROUNDWATER

DESCRIPTION	QUANTITY	UNIT	WORK LEVEL	LABOR FACTOR	CONVENTIONAL LABOR UNIT PRICE. (DOLLARS)	SITE LABOR UNIT RATE (DOLLARS)	COST	SUBTOTAL	ASSUMPTIONS
CAPITAL COST DURING OPERATION									
Health and Safety									
Plans, train'g, equip, officer		LS	E	1	$188,000	$188,000	$188,000		
Air monitoring		LS	E	1	$150,000	$150,000	$150,000		

								$338,000	
Clearing/Grubbing									
Trees and Stumps	22	ACRE	E	1.0	$11,500	$11,500	$253,000		cut and chip, max. 24" dia., stumps removed, 021-104-0300,0350
Terrain clearing	22	ACRE	E	1.0	$3,800	$3,800	$83,600		dozer and brush rake, adverse conditions, 021-108-0600

								$340,000	
Access Roads	35,200	SY	E	1.0	$4.71	$4.71	$170,000		8" gravel depth, no surface, 015-552-0100

								$170,000	
Temporary Dam Construction									berms and excavation
Number of dams	31								
Construct transition dams	37,820	CY	D	1.2	$1.72	$2.06	$78,100		2.5 CY FE loader, 300 foot haul, 022-262-0170
Compact dam	37,820	CY	D	1.2	$2.89	$3.47	$131,200		vibrating plate, 022-254-1900
Runoff diversion sumps	1	EA	D	1.2	$815	$978	$1,000		4 foot dia. x 6' deep, concrete, 027-152-0500
Runoff diversion sump pumps	2	EA	D	1.2	$3,000	$3,600	$7,200		pumped upstream of dam, Flygt quote, Alumax
Bypass diversion piping	1,000	LF	D	1.2	$26	$31	$31,200		24" dia CMP, 027-164-2140
Dewatering Sump	1	EA	D	1.2	$815	$978	$1,000		4 foot dia. x 6' deep, concrete, 027-152-0500
Dewatering Pump	2	EA	D	1.2	$3,000	$3,600	$7,200		pumped upstream of dam, Flygt quote, Alumax
Sheet piling		LS	D	1.2	$520,000	$624,000	$624,000		
Silt curtains		LS	D	1.2	$20,000	$24,000	$24,000		

								$900,000	
Soil excavation									for treatment
Excavation and stockpile soil	80,000	CY	D	1.2	$6.85	$8.22	$657,600		200 Hp bulldozer, 300 foot haul, 022-242-4440
Dewatering		LS	D	1.2	$50,000	$60,000	$60,000		allowance

								$720,000	
Soil consolidation									
Excavation and placement of soil	15,000	CY	D	1.2	$6.85	$8.22	$123,300		200 Hp bulldozer, 300 foot haul, 022-242-4440
Grading	15,000	CY	D	1.2	$1.21	$1.45	$21,800		022-266-1600

								$150,000	

TABLE I-9. ALTERNATIVE 5

REMOVE AND SLURRY TREAT SEDIMENTS AND PART OF SOIL, CONTAINMENT OF REMAINING SOIL, AND TREATMENT OF GROUNDWATER

DESCRIPTION	QUANTITY	UNIT	WORK LEVEL	LABOR FACTOR	CONVENTIONAL LABOR UNIT PRICE (DOLLARS)	SITE LABOR UNIT RATE (DOLLARS)	COST	SUBTOTAL	ASSUMPTIONS
Sediment Excavation									sediments only
Excavation and load sediment	33,000	CY	D	1.2	8.0	9.6	$316,800		estim judgement
Haul to site	36,300	CY	D	1.2	$7.93	$9.52	$345,400		12 CY dump truck, 10 mile heavy traffic round trip, 022-266-0550
Sediment Storage Pad	1	LS	D	1.2	$55,000	$66,000	$66,000		

								$730,000	
Channel reconstruction									
Grading channel sides	350,000	SY	E	1.0	$0.12	$0.12	$40,000		025-122-3300
Haul and grade excess spoils	110,000	CY	E	1.0	$2.60	$2.60	$290,000		022-266-1600;-6030; +0.5/sy seeding
Erosion control netting	350,000	SY	E	1.0	$0.29	$0.29	$100,000		022-704-0300
Seeding	350,000	SY	E	1.0	$0.36	$0.36	$130,000		
Place cobble/rubble	500	CY	E	1.0	$26.00	$26.00	$13,000		2.5in-10in dia cobble/rubble: 022-712-0100
Place gravel	1,300	CY	E	1.0	$20.00	$20.00	$26,000		0.1-2.5 in dia gravel; 022-262-1100
Place rip-rap	900	CY	E	1.0	$25.00	$25.00	$22,500		6" riprap; 0227120400

								$620,000	
Field Pilot Study									6 month study
Study and Plan	1	LS	E	1.0	$15,000	$15,000	$15,000		6 month study
Sample Collection	1	LS	D	1.2	$4,000	$4,800	$4,800		6 month study
Experiment Setup	1	LS	D	1.2	$25,000	$30,000	$30,000		Purchase and construct 5 test cells, sprinklers, tilling equip.
Soil Sampling and Charact.	1	LS	D	1.2	$9,000	$10,800	$10,800		Routine analysis for nutrients, moisture content, pH, etc.
PCP and PAH Analyses	1	LS	D	1.2	$25,000	$30,000	$30,000		7 sampling events with 12 samples including QC
Data Reduction and Reporting	1	LS	D	1.2	$7,000	$8,400	$8,400		Prepare technical memo including graghics and repórduction
								------------	
								$99,000	
Slurry Bioreactor System									
Transfer Sediment to system	36,300	CY	D	1.2	$1.00	$1.20	$43,600		2.5 CY FE Loader, from stockpile to system, 022-238-1600
Transfer Soil to system	96,000	CY	D	1.2	$1.00	$1.20	$115,200		2.5 CY FE Loader, from stockpile to system, 022-238-1600
Vibrating Screens	1	EA	D	1.0	$15,000	$15,000	$15,000		CORA, cost assume 40% salvage value
Attrition Scrubber	1	EA	D	1.0	$18,000	$18,000	$18,000		CORA, cost assume 40% salvage value
Screw Classifier	1	EA	D	1.0	$10,800	$10,800	$10,800		CORA, cost assume 40% salvage value
Slurry pumps and poly feed	1	EA	D	1.0	$12,600	$12,600	$12,600		CORA, cost assume 40% salvage value
Slurry Bioreactor	1	EA	D	1.0	$480,000	$480,000	$480,000		CORA, cost assume 40% salvage value
Dewatering	1	EA	D	1.0	$96,000	$96,000	$96,000		CORA, cost assume 40% salvage value
Instrumentation	1	LS	D	1.0	$75,888	$75,888	$75,900		12% of the equipment costs
Elect & Mech.	1	LS	D	1.0	$126,480	$126,480	$126,500		20% of capital costs
Labor	105,000	HOUR	D	1.0	$30	$30	$3,150,000		3 man crew, 24 hours/day, 4 years
Power	3.1E+06	KW	E	1.0	$0.08	$0.08	$249,600		
Chemicals	1	LS	E	1.0	$135,000	$135,000	$135,000		
Parts, supplies	1	LS	E	1.0	$120,000	$120,000	$120,000		
Analytical	1	LS	E	1.0	$540,000	$540,000	$540,000		

								$5,200,000	

TABLE I-9. ALTERNATIVE 5
REMOVE AND SLURRY TREAT SEDIMENTS AND PART OF SOIL, CONTAINMENT OF REMAINING SOIL, AND TREATMENT OF GROUNDWATER

DESCRIPTION	QUANTITY	UNIT	WORK LEVEL	LABOR FACTOR	CONVENTIONAL LABOR UNIT PRICE (DOLLARS)	SITE LABOR UNIT RATE (DOLLARS)	COST	SUBTOTAL	ASSUMPTIONS
Transport Residue to Containment Area									
Load residue in dump truck	113,000	CY	D	1.2	$1.00	$1.20	$135,600		2.5 CY FE Loader, from stockpile to dump truck, 022-238-1600
Haul residue to area	113,000	CY	D	1.2	$3.16	$3.79	$428,500		6 CY dump truck, 1 mile trip, 022-266-0040
Grading	113,000	CY	D	1.2	$6.85	$8.22	$928,900		200 HP bulldozer, 300 foot haul, 022-242-4440

								$1,500,000	
Transport NE Landfill Residue to TSD									
Load in dump truck	1,000	CY	D	1.2	$1.00	$1.20	$1,200		
Hauling cost	1,200	CY	E	1.0	$80.00	$80.00	$96,000		
Disposal cost	1,200	CY	E	1.0	$150.00	$150.00	$180,000		

								$280,000	
Transport Oversize to SW Landfill									
Load in dump truck	3,000	CY	D	1.2	$1.50	$1.80	$5,400		
Hauling cost	3,000	CY	E	1.0	$15.00	$15.00	$45,000		
Disposal cost	3,000	CY	E	1.0	$30.00	$30.00	$90,000		

								$140,000	
Groundwater Collection Drains									near river edge only
Excavation/Trenching	2,400	CY	D	1.2	$1.98	$2.38	$5,700		1.5 CY backhoe, 022-254-0610
Drainage Layer - gravel	2,000	CY	D	1.2	$41.00	$49.20	$98,400		pea gravel, 029-504-0900
Drainage Piping	1,100	LF	D	1.2	$2.52	$3.02	$3,300		perforated, 4" dia. PVC, 027-168-2000
Vertical Barrier	10,000	SF	D	1.2	$0.60	$0.72	$7,200		60 mil, John Heineke
Cover Soil	490	CY	D	1.2	$10.00	$12.00	$5,900		2'depth, Bob Lawson/RDD, Merrideth-Baxter Cost Estimate
Compaction/Tamping	490	CY	D	1.2	$2.89	$3.47	$1,700		vibrating plate, 022-254-1900
Collection sump	1	EA	D	1.2	$890.00	$1,068.00	$1,100		4 foot dia. X 8' deep, precast concrete, 027-152-1130
Collection Pumps	2	EA	D	1.2	$3,000.00	$3,600.00	$7,200		pumped to sanitary sewers, Flygt quote, Alumax
Discharge Piping	200	LF	D	1.2	$15.00	$18.00	$3,600		4" dia. PVC, 151-550-0750

								$130,000	
Groundwater Treatment System									
Oil/Water Separator	1	EA	D	1.2	$26,000.00	$31,200.00	$31,200		
Recovered Oil Holding Tank	1	EA	D	1.2	$3,000.00	$3,600.00	$3,600		5,000 gallons, $1/gallon
Oily sludge Pump	2	EA	D	1.2	$3,000.00	$3,600.00	$7,200		Estimator's judgement, centrifugal
Carbon Units	2	EA	D	1.2	$78,000.00	$93,600.00	$187,200		Source for costs from Paul B., files for McCormick & Baxter
Concrete Pad	1	LS	D	1.2	$5,000.00	$6,000.00	$6,000		
Outfall	1	LS	D	1.2	$17,000.00	$20,400.00	$20,400		

								$260,000	

TABLE I-9. ALTERNATIVE 5
REMOVE AND SLURRY TREAT SEDIMENTS AND PART OF SOIL, CONTAINMENT OF REMAINING SOIL, AND TREATMENT OF GROUNDWATER

DESCRIPTION	QUANTITY	UNIT	WORK LEVEL	LABOR FACTOR	CONVENTIONAL LABOR UNIT PRICE (DOLLARS)	SITE LABOR UNIT RATE (DOLLARS)	COST	SUBTOTAL	ASSUMPTIONS
Final Cover									for 10-6 contaminated soils
Cover Soil	64,000	CY	D	1.2	$10.00	$12.00	$800,000		Bob Lawson/RDD - Merrideth-Baxter Cost Estimate
Compaction	64,000	CY	D	1.2	$0.67	$0.80	$51,000		022-222-0300
Top Soil	16,000	CY	E	1.0	$18.00	$18.00	$290,000		3 ". Furnish and place, 022-286-0700
Seeding	900	MSF	E	1.0	$40.00	$40.00	$36,000		hydraulic seeding, 029-308-1300
Fence	7,000	MSF	E	1.0	$15.00	$15.00	$105,000		

								$1,300,000	
Access Road revegetation									
Top Soil	9,000	CY	E	1.0	$3.46	$3.46	$31,100		Spread from piles, 6", FE loader, 022-286-0400
Tree planting	2,100	EA	E	1.0	$100.00	$100.00	$210,000		Dogwood, willow
Brush planting	2,100	EA	E	1.0	$40.00	$40.00	$84,000		bush, 029-528-0500
Seeding	600	MSF	E	1.0	$40.00	$40.00	$24,000		hydraulic seeding, 029-308-1300
Oat Straw	600	MSF	E	1.0	$29.00	$29.00	$17,400		1" deep w/ large mulcher, 029-516-0700
Remove access road gravel	7,800	CY	E	1.0	$1.25	$1.25	$9,800		2.5 CY FE loader, load onto truck, 022-238-1600
Haul access road gravel	7,800	CY	E	1.0	$6.10	$6.10	$47,600		12 CY truck, 5 mile round trip, 022-266-0540

								$420,000	
Traffic control								$50,000	
Security								$50,000	
Decon facilities								$160,000	
Verification Sampling	1	LS	D	1.2	$200,000	$240,000	$240,000		onsite lab for 20 weeks
								------------	
								$240,000	
Allowances									
Mobilize/Demobilize (5%)							$690,000		Mobilization/demobilization; bond and insurance; temporary facilit
Field Detail Allowance (5%)							$690,000		Accounts for known items not quantified (eg. wasted soil, etc.)

								$1,400,000	

CONSTRUCTION SUBTOTAL								$15,000,000	

TABLE I-9. ALTERNATIVE 5
REMOVE AND SLURRY TREAT SEDIMENTS AND PART OF SOIL, CONTAINMENT OF REMAINING SOIL, AND TREATMENT OF GROUNDWATER

DESCRIPTION	QUANTITY	UNIT	WORK LEVEL	LABOR FACTOR	CONVENTIONAL LABOR UNIT PRICE (DOLLARS)	SITE LABOR UNIT RATE (DOLLARS)	COST	SUBTOTAL	ASSUMPTIONS
Contingencies									
Bid (15%)							$2,300,000		
Scope (20%)							$3,000,000		

								$5,300,000	

CONSTRUCTION TOTAL								$20,000,000	
Other									
Administrative (5%)							$1,000,000		Services to comply with substantive requirements
Permitting and legal (2%)							$400,000		
Services During Construction (7%)							$1,400,000		

								$2,800,000	

TOTAL IMPLEMENTATION COST								$22,800,000	
Engineering Design Cost							$500,000		

								$500,000	
TOTAL CAPITAL COST DURING OPERATION								$23,000,000	

TABLE I-10. ALTERNATIVE 5 - SLURRY TREATMENT OF SEDIMENT AND PART OF SOIL

DESCRIPTIONS	QUANTITY	UNIT	UNIT PRICE (DOLLARS)	COST	PRESENT WORTH 3%	5%	10%	ASSUMPTIONS
OPERATION AND MAINTENANCE COST					PW OF COSTS OVER 30 YEARS			
INSPECTION AND REPAIRS								
Years of Operation	30	YRS						
Soil Cover	1	LS	$20,000	20,000 /YR	$392,000	$307,000	$189,000	1% of soil cover repaired each year
Groundwater Collection System	1	LS	$1,500	1,500 /YR	$29,000	$23,000	$14,000	
SUBTOTAL				$21,500 /YR	$421,000	$330,000	$203,000	
GROUNDWATER TREATMENT SYSTEM								
Years of Operation	30	YRS						
Labor	400	HRS	$42	16,800 /YR	$329,000	$258,000	$158,000	
Analytical Costs	12	EA	$1,500	18,000 /YR	$353,000	$277,000	$170,000	
General Maintenance	1	LS	$10,400	10,400 /YR	$204,000	$160,000	$98,000	
Carbon Replacement	1	LS	$20,000	20,000 /YR	$392,000	$307,000	$189,000	
Utilities	1	LS	$2,000	2,000 /YR	$39,000	$31,000	$19,000	
Oily Sludge Disposal	2,600	GAL	$1	2,600 /YR	$51,000	$40,000	$25,000	
SUBTOTAL				$69,800 /YR	$1,368,000	$1,073,000	$659,000	
GROUNDWATER SAMPLING	24	EA	$1,500	36,000 /YR	$706,000	$553,000	$339,000	
SUBTOTAL				$36,000 /YR	$706,000	$553,000	$339,000	
TOTAL O & M COST				$127,300 /YR	$2,500,000	$2,000,000	$1,200,000	

ALTERNATIVE 5 -- COST ESTIMATE SUMMARY

DESCRIPTION	PRESENT WORTH @ 30YRS 3%	5%	10%	PRESENT WORTH @ 10YRS 3%	5%	10%
TOTAL CAPITAL COST DURING OPERATION	$23,000,000	$23,000,000	$23,000,000	$23,000,000	$23,000,000	$23,000,000
OPERATION & MAINTENANCE COSTS	$2,500,000	$2,000,000	$1,200,000	$1,100,000	$1,000,000	$800,000
TOTAL PRESENT WORTH	$25,500,000	$25,000,000	$24,200,000	$24,100,000	$24,000,000	$23,800,000

TABLE I-11. ALTERNATIVE 6
REMOVE AND INCINERATE SEDIMENTS AND 10E-06 SOIL

DESCRIPTION	QUANTITY	UNIT	WORK LEVEL	LABOR FACTOR	CONVENTIONAL LABOR UNIT PRICE (DOLLARS)	SITE LABOR UNIT RATE (DOLLARS)	COST	SUBTOTAL	ASSUMPTIONS
CAPITAL COST DURING OPERATION									
Health and Safety									
Plans.train'g.equip.officer	1	LS	E	1	$213,000	$213,000	$210,000		
Air monitoring	1	LS	E	1	$462,000	$462,000	$460,000		Initial study/testing + weekly thereafter
								------------	
								$670,000	
Clearing/Grubbing									
Trees and Stumps	22	ACRE	E	1.0	$11,500	$11,500	$253,000		cut and chip, max. 24" dia., stumps removed, 021-104-0300,0350
Terrain clearing	22	ACRE	E	1.0	$3,800	$3,800	$83,600		dozer and brush rake, adverse conditions, 021-108-0600

								$340,000	
Access Roads	35,200	SY	E	1.0	$4.71	$4.71	$165,800		8" gravel depth, no surface, 015-552-0100

								$170,000	
Temporary Dam Construction									
Number of dams	31								
Construct transition dams	37,820	CY	D	1.2	$1.72	$2.06	$78,100		2.5 CY FE loader, 300 foot haul, 022-262-0170
Compact dam	37,820	CY	D	1.2	$2.89	$3.47	$131,200		Vibrating plate, 022-254-1900
Runoff diversion sumps	1	EA	D	1.2	$815	$978	$1,000		4 foot dia. x 6' deep, concrete, 027-152-0500
Runoff diversion sump pumps	2	EA	D	1.2	$3,000	$3,600	$7,200		pumped upstream of dam, Flygt quote, Alumax
Bypass diversion piping	1,000	LF	D	1.2	$26	$31	$31,200		24" dia CMP, 027-164-2140
Dewatering sump	1	EA	D	1.2	$815	$978	$1,000		4 foot dia. x 6' deep, concrete, 027-152-0500
Dewatering Pump	2	EA	D	1.2	$3,000	$3,600	$7,200		pumped upstream of dam, Flygt quote, Alumax
Sheet piling		LS	D	1.2	$520,000	$624,000	$624,000		pumped upstream of dam, Flygt quote, Alumax
Silt curtains		LS	D	1.2	$20,000	$24,000	$24,000		pumped upstream of dam, Flygt quote, Alumax
								------------	
								$900,000	
Sediment Excavation									sediments only
Excavation and load sediment	33,000	CY	D	1.2	$8.00	$9.60	$220,800		
Haul to site	36,300	CY	D	1.2	$7.93	$9.52	$345,400		12 CY dump truck, 10 mile heavy traffic round trip, 022-266-0550
Sediment storage pad	1	LS	D	1.2	$55,000	$66,000	$180,000		

								$750,000	
Channel reconstruction									
Grading channel sides	350,000	SY	E	1.0	$0.12	$0.12	$40,000		025-122-3300
Haul and grade excess spoils	110,000	CY	E	1.0	$2.60	$2.60	$290,000		022-266-1600;-6030; +0.5/SY seeding
Erosion control netting	350,000	SY	E	1.0	$0.29	$0.29	$100,000		022-704-0300
Seeding	350,000	SY	E	1.0	$0.36	$0.36	$130,000		
Place cobble/rubble	500	CY	E	1.0	$26.00	$26.00	$13,000		2.5in-10in dia cobble/rubble; 022-712-0100
Place gravel	1,300	CY	E	1.0	$20.00	$20.00	$26,000		0.1-2.5 in dia gravel; 022-262-1100
Place rip-rap	900	CY	E	1.0	$25.00	$25.00	$22,500		6" riprap; 0227120400

								$620,000	

TABLE I-11. ALTERNATIVE 6
REMOVE AND INCINERATE SEDIMENTS AND 10E-06 SOIL

DESCRIPTION	QUANTITY	UNIT	WORK LEVEL	LABOR FACTOR	CONVENTIONAL LABOR UNIT PRICE (DOLLARS)	SITE LABOR UNIT RATE (DOLLARS)	COST	SUBTOTAL	ASSUMPTIONS
Soil excavation (for treatment)									
Excavation and stockpile soil	156,000	CY	D	1.2	$6.85	$8.22	$1,282,300		200 Hp bulldozer, 300 foot haul, 022-242-4440
Dewatering		LS	D	1.2	$50,000	$60,000	$60,000		

								$1,300,000	
Incineration System									
Transfer Sediment to system	36,300	CY	D	1.2	$1.00	$1.20	$43,600		2.5 CY FE Loader, from stockpile to system, 022-238-1600
Transfer soil to system	156,000	CY	D	1.2	$1.00	$1.20	$187,200		2.5 CY FE Loader, from stockpile to system, 022-238-1600
Treatment Costs	1	LS	E	1.0	$45,000,000	$45,000,000	$45,000,000		CORA

								$45,000,000	
Transport Residue to Containment Area									
Load residue in dump truck	150,000	CY	D	1.2	$1.00	$1.20	$180,000		2.5 CY FE Loader, from stockpile to dump truck, 022-238-1600
Haul residue to area	150,000	CY	E	1.0	$3.16	$3.16	$470,000		6 CY dump truck, 1 mile trip, 022-266-0040
Grading	150,000	CY	E	1.0	$6.85	$6.85	$1,000,000		200 Hp bulldozer, 300 foot haul, 022-242-4440

								$1,650,000	
Transport Oversize to SW Landfill									
Load in dump truck	3,000	CY	D	1.2	$1.50	$1.80	$10,000		
Hauling cost	3,000	CY	E	1.0	$15.00	$15.00	$50,000		
Disposal cost	3,000	CY	E	1.0	$30.00	$30.00	$100,000		

								$160,000	
Final Cover									for 10-6 contaminated soils
Cover Soil	44,000	CY	D	1.2	$10.00	$12.00	$528,000		Bob Lawson/RDD - Merrideth-Baxter Cost Estimate
Top Soil	11,000	CY	E	1.0	$18.00	$18.00	$198,000		3 ", Furnish and place, 022-286-0700
Seeding	600	MSF	E	1.0	$40.00	$40.00	$24,000		hydraulic seeding, 029-308-1300

								$800,000	
Access Road revegetation									
Top Soil	9,000	CY	E	1.0	$3.46	$3.46	$31,100		Spread from piles, 6", FE loader, 022-286-0400
Tree planting	2,100	EA	E	1.0	$100.00	$100.00	$210,000		Dogwood, willow
Brush planting	2,100	EA	E	1.0	$40.00	$40.00	$84,000		bush, 029-528-0500
Seeding	600	MSF	E	1.0	$40.00	$40.00	$24,000		hydraulic seeding, 029-308-1300
Oat Straw	600	MSF	E	1.0	$29.00	$29.00	$17,400		1" deep w/ large mulcher, 029-516-0700
Remoce access road gravel	7,800	CY	E	1.0	$1.25	$1.25	$9,800		2.5 CY FE loader, load onto truck, 022-238-1600
Haul access road gravel	7,800	CY	E	1.0	$6.10	$6.10	$47,600		12 CY truck, 5 mile round trip, 022-266-0540

								$420,000	

TABLE I-11. ALTERNATIVE 6
REMOVE AND INCINERATE SEDIMENTS AND 10E-06 SOIL

DESCRIPTION	QUANTITY	UNIT	WORK LEVEL	LABOR FACTOR	CONVENTIONAL LABOR UNIT PRICE (DOLLARS)	SITE LABOR UNIT RATE (DOLLARS)	COST	SUBTOTAL	ASSUMPTIONS
Traffic Control								$50,000	
Security								$50,000	
Decon facilities								$160,000	
Verification Sampling	1	LS	D	1.2	$300,000	$360,000	$360,000		

								$360,000	
Allowances									
Mobilize/Demobilize (5%)							$2,670,000		Mobilization/demobilization: bond and insurance: temporary facilit
Field Detail Allowance (5%)							$2,670,000		Accounts for known items not quantified (eg. wasted soil, etc.)

								$5,300,000	

CONSTRUCTION SUBTOTAL								$59,000,000	
Contingencies									
Bid (10%)							$5,900,000		
Scope (20%)							$11,800,000		

								$18,000,000	

CONSTRUCTION TOTAL								$77,000,000	
Other									
Administrative (5%)							$3,850,000		Services to comply with substantive requirements
Permitting and legal (2%)							$1,540,000		
Services During Construction (7%)							$5,400,000		

								$10,790,000	

TOTAL IMPLEMENTATION COST								$88,000,000	
Engineering Design Cost							$500,000		

								$500,000	
TOTAL CAPITAL COST DURING OPERATION								$89,000,000	

TABLE I-12. ALTERNATIVE 6 - ONSITE INCINERATION OF SEDIMENT AND SOIL

DESCRIPTIONS	QUANTITY	UNIT	UNIT PRICE (DOLLARS)	COST	PRESENT WORTH 3%	5%	10%	ASSUMPTIONS
OPERATION AND MAINTENANCE COST					PW OF COSTS OVER 30 YEARS			
Years of operation	30							
GROUNDWATER SAMPLING	12	EA	$1,500	18,000 /YR	$353,000	$277,000	$170,000	
SUBTOTAL				$18,000 /YR	$353,000	$277,000	$170,000	
TOTAL O & M COST				$18,000 /YR	$353,000	$277,000	$170,000	

ALTERNATIVE 6 -- COST ESTIMATE SUMMARY

DESCRIPTION	PRESENT WORTH @ 30 YRS 3%	5%	10%
TOTAL CAPITAL COST DURING OPERATION	$89,000,000	$89,000,000	$89,000,000
OPERATION & MAINTENANCE COSTS	$353,000	$277,000	$170,000
TOTAL PRESENT WORTH	$89,400,000	$89,300,000	$89,200,000

Appendix J
BACKGROUND SEDIMENT SAMPLING

Appendix J
BACKGROUND SEDIMENT SAMPLING

INTRODUCTION

Sediment samples were collected from the Little Menomonee River, Menomonee River, and Beaver Creek on October 3 and 4, 1989, to determine background concentrations of polynuclear aromatic hydrocarbons (PAHs), metals, and dioxins. Three samples were also collected from the Menomonee River downstream of its confluence with the Little Menomonee River to determine if creosote compounds may have migrated from the Little Menomonee River into the Menomonee River. Each sample was analyzed for semivolatile compounds, low-level PAHs, metals, and dioxins. This appendix summarizes the collection procedures and the results of the sampling effort.

Samples were collected by CH2M HILL at the sample locations shown in Figure J-1. Samples were collected using a clamshell type posthole digger. The samples were placed in a stainless steel mixing bowl, thoroughly mixed with a stainless steel spoon, and placed in 8-ounce, wide mouth, glass sample jars. All sampling equipment was decontaminated initially and after each sample was taken by washing with soap and water, rinsing with water, rinsing with methanol, and final rinsing with distilled water. At the end of each day, the samples collected that day were packaged and prepared for shipment.

FIELD OBSERVATIONS

Six samples were taken north of the site between Brown Deer Road and County Line Road from the east and west sides of the Little Menomonee River. The location is a wetland with cattail marsh on both sides of the river. The sediment was dark grey silt. Samples SD01-02 (east side) and SD01-03 (west side) were collected about 1/2 mile north of Brown Deer Road. Samples SD02-02 (east side) and SD02-03 (west side) were collected about 1/3 mile north of Brown Deer Road. Samples SD03-02 (east side) and SD03-03 (west side) were collected 150 yards north of Brown Deer Road.

Three samples were taken from tributaries to the Little Menomonee River downstream of the site. Sample SD04 was taken at the discharge of a large culvert 125 feet west of 91st Street (labeled "inlet O" in the RI report, Appendix B). A slight oil sheen was observed on the sediment. Sample SD05 was taken from a concrete-lined stream bed in a residential area just west of 91st Street and about 75 feet south of Denver Street. The sediment was sand. Sample SD06 was from a dry stream bed (inlet "AM") in a wooded area of the Little Menomonee River Parkway. The soil was brown silt loam with some roots.

Three samples were taken from the ½-mile reach of the Menomonee River immediately below the mouth of the Little Menomonee River. The sediment present in that stretch of river is generally coarse sand and gravel. The finer sediments, when found, were sampled because they were more likely than the coarser material to contain PAH contaminants. Sample SD07 was taken 200 feet south of the Hampton Road bridge in the center of the river channel. Sample SD08 was taken 400 feet south of the bridge from the center of the river. Sample SD09 was taken ½-mile south of Hampton Road near the east bank of the river.

Four samples were taken from the Menomonee River upstream of its confluence with the Little Menomonee River. Sample SD10 was collected from the main river channel just east of the 124th Street bridge. The sediment was silty sand. Sample SD11 was from the main river channel several hundred feet downstream from the railroad bridge east of 124th Street. The sediment was silty sand, and an oil sheen was visible on the sediment sample. Sample SD12 was collected from the main channel of the Menomonee River 40 feet south of Silver Spring Road. The sediment was silty clay. Sample SD13 was dark grey sandy silt from the confluence of a small stream and the Menomonee River. The drainage area for the small stream consists of roadways (Fond du Lac Avenue, I-45) and some residential buildings.

One sample, SD14, was collected from the Milwaukee River watershed east of the Little Menomonee River. The watershed development is comparable to the Little Menomonee River downstream of the site. The sample was taken from Beaver Creek, immediately north of the Brown Deer Road bridge, in an area consisting of retail stores. Two inches of water and about eight inches of soft sediment were present in the creek. The sediment was silty sand.

ANALYTICAL RESULTS

Analytical results for the PAHs, semivolatile compounds, inorganic analytes, and dioxins are provided in Attachment 1. SAS analyses for low level PAH concentrations were determined to be unacceptable for use. The results of the RAS semivolatile compound analysis better met the project objectives than the SAS analyses and are recommended for the following reasons:

- The surrogate recoveries were low in virtually all samples from the SAS analyses.
- Surrogate recoveries for the RAS analyses were also low but were higher than those of the SAS samples.
- Based on the low surrogate recoveries for the SAS analyses, the actual quantification limit achieved may be higher than reported.

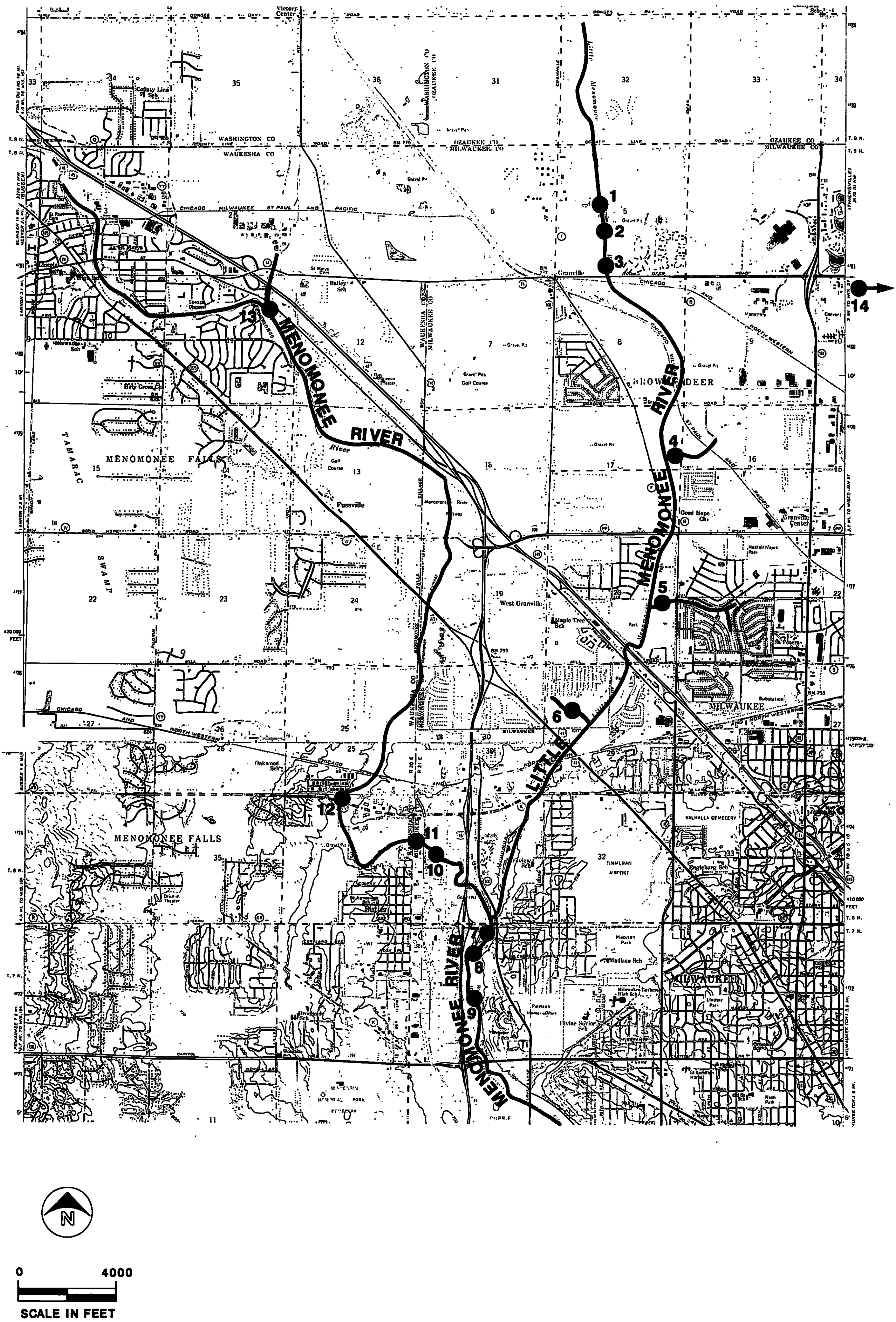

FIGURE J-1
SEDIMENT SAMPLE LOCATIONS
MOSS-AMERICAN FS

- A larger number of different PAHs were detected in the RAS analyses than in the SAS analyses.

- Where PAHs were detected, the levels were generally higher in the RAS samples than in the corresponding SAS samples.

Analytical results for dioxin and metals were acceptable for use with qualifications noted in the data tables.

Mean (arithmetic) and maximum probable background concentrations have been calculated for the inorganic analytes and for carcinogenic and noncarcinogenic PAHs. The arithmetic mean was calculated using half the quantification limit for results reported as not detected. The maximum probable background concentration is the value such that 95 percent of the background values are lower than it. It is defined as 1.645 standard deviations above mean. Any concentration less than the maximum probable background is considered background.

The background sediment data have been grouped together in different ways as described below. Specific samples included in groups are listed in Table J-1. The mean and maximum probable background concentration have been calculated for each group and are listed in Tables J-2 and J-3.

Group 1 contains only samples collected in the Little Menomonee River upstream from Brown Deer Road. The maximum probable background concentration was calculated to be 14,000 µg/kg for total PAHs and 6,900 µg/kg for carcinogenic PAHs for this group of samples. The maximum probable concentration of PAHs used by the Wisconsin DNR in developing sediment quality criteria for the Little Menomonee River was calculated to be 8,100 µg/kg.

Group 2 contains samples collected in the Little Menomonee River upstream from Brown Deer Road and from tributaries to the Little Menomonee River. By adding the tributary samples to those from Group 1, background concentrations for total PAHs increased from 14,000 µg/kg to 47,000 µg/kg, carcinogenic PAHs increased from 6,900 µg/kg to 18,000 µg/kg, and PAHs used in calculating sediment quality criteria increased from 8,100 µg/kg to 29,000 µg/kg. The maximum probable background concentrations were 78,000 µg/kg for total PAHs and 29,000 µg/g for carcinogenic PAHs in the tributary samples.

Group 3 contains all samples except those taken from the Menomonee River.

Group 4 contains only the samples taken from the Menomonee River upstream of the mouth of the Little Menomonee River. The background level of carcinogenic PAHs for this group of samples was calculated to be 34,000 µg/g.

Group 5 contains only the samples taken from the Menomonee River downstream of the mouth of the Little Menomonee River. The background level of carcinogenic PAHs for this group of samples was calculated to be 25,000 μg/kg.

Group 6 contains all samples.

Group 2 probably best represents the background PAH concentrations for the Little Menomonee River since it is an estimate of concentrations entering the river along the reach from the site to the Menomonee River. Group 1, on the other hand, includes only samples from upstream of the site and disregards the increasing urbanization down river from the site. The statistics for Group 2 differ little from Groups 3 through 6, also suggesting these values are typical of background in the area. Should background levels be used as cleanup criteria for the Little Menomonee River, then a more in-depth evaluation of appropriate background levels should be conducted during the predesign.

The maximum probable background concentration is preferred over the mean to determine whether a value is above background. Any value less than the maximum probable background concentration cannot be distinguished from background.

GLT938/096.51

Table J-1
BACKGROUND SEDIMENT SAMPLING
SAMPLE GROUPS

Sample Location	Group 1	2	3	4	5	6
SD01-02	X	X	X			X
SD01-03	X	X	X			X
SD02-02	X	X	X			X
SD02-03	X	X	X			X
SD03-02	X	X	X			X
SD03-02 (REP)	X	X	X			X
SD03-03	X	X	X			X
SD04-02		X	X			X
SD05-02		X	X			X
SD06-02		X	X			X
SD07-02					X	X
SD08-02					X	X
SD09-02					X	X
SD09-02 (REP)					X	X
SD10-02				X		X
SD11-02				X		X
SD12-02				X		X
SD13-02				X		X
SD14-02			X			X

Table J-2
POLYAROMATIC HYDROCARBONS
(Concentrations in ug/Kg) (a)

Parameter		Group 1 MEAN	Group 1 (b) MPBC	Group 2 MEAN	Group 2 MPBC	Group 3 MEAN	Group 3 MPBC	Group 4 MEAN	Group 4 MPBC	Group 5 MEAN	Group 5 MPBC	Group 6 MEAN	Group 6 MPBC
NONCARCINOGENIC PAHs													
NAPHTHALENE	(c)	710	860	690	950	670	940	450	530	470	520	590	860
2-METHYLNAPHTHALENE	(c)	710	860	690	950	670	940	380	650	470	520	570	890
ACENAPHTHYLENE	(c)	710	860	690	950	670	940	430	560	470	520	580	860
ACENAPHTHENE		710	860	670	1100	660	1000	450	690	650	1200	620	1000
FLUORENE		710	860	730	1200	670	1200	590	1100	850	1900	700	1400
PHENANTHRENE *		630	860	1900	7500	1900	7200	2500	6600	2500	8200	2200	7600
ANTHRACENE		650	970	880	2100	830	2000	850	2100	1000	2700	900	2300
FLUORANTHENE		810	1200	2300	8800	2300	8500	3300	7900	1700	4600	2500	8100
PYRENE *		670	1000	1700	6300	1700	6100	3000	7600	1600	4400	2100	6400
CARCINOGENIC PAHs													
BENZO(A)ANTHRACENE *		670	930	1100	3000	1100	2900	1600	4100	1000	2600	1200	3200
CHRYSENE *		630	850	1100	3200	1100	3100	1900	4300	1000	2600	1300	3400
BENZO(B)FLUORANTHENE *		600	870	1000	3000	1000	2900	1500	3700	750	1800	1100	3000
BENZO(K)FLUORANTHENE *		570	890	1000	3200	1000	3100	1900	4900	1000	2600	1300	3600
BENZO(A)PYRENE		630	900	1100	3000	1100	2900	1600	3800	900	2300	1200	3100
INDENO(1,2,3-CD)PYRENE *		660	960	680	1000	660	1000	740	1300	650	1200	690	1100
DIBENZO(A,H)ANTHRACENE *	(c)	710	860	690	950	670	940	540	760	520	700	620	880
BENZO(GHI)PERYLENE *		710	860	700	940	690	920	690	1100	650	1200	690	1100
TOTAL NON-CARCINOGENIC PAHs		6300	7200	10000	29000	10000	28000	12000	26000	9700	24000	11000	28000
TOTAL CARCINOGENIC PAHs		5200	6900	7400	18000	7300	17000	11000	24000	6500	15000	8000	19000
TOTAL PAHs FOR SQC *		--	8100	--	29000	--	27000	--	34000	--	25000	--	30000

(a) -- Concentrations have been rounded to 2 significant digits.
(b) -- Maximum Probable Background Concentration
(c) -- Fewer than 5 detects out of 19 samples.
* -- These PAHs are used by the Wisconsin DNR in developing sediment quality criteria for the Little Menomonee River.

Table J-3
INORGANIC ANALYTES
(Concentrations in ug/Kg) (1)

Parameter		Group 1 MEAN	Group 1 (2) MPBC	Group 2 MEAN	Group 2 MPBC	Group 3 MEAN	Group 3 MPBC	Group 4 MEAN	Group 4 MPBC	Group 5 MEAN	Group 5 MPBC	Group 6 MEAN	Group 6 MPBC
ALUMINUM		11000	17000	9800	16000	9600	16000	5800	11000	7100	14000	8300	15000
ANTIMONY	(3)	3.8	5.2	3.5	4.9	3.5	4.9	3.3	4.1	3.2	4.5	3.4	4.7
ARSENIC		4.4	7.4	4.4	7.5	4.3	7.3	3.4	4.7	3.8	6.5	4.0	6.9
BARIUM		110	160	95	160	93	150	57	99	62	120	79	140
BERYLLIUM	(3)	0.23	0.42	0.20	0.37	0.20	0.37	0.17	0.20	0.16	0.22	0.19	0.32
CADMIUM	(3)	0.99	1.70	0.83	1.60	0.80	1.50	0.50	0.61	0.59	0.89	0.69	1.30
CALCIUM		62000	110000	68000	120000	68000	120000	91000	110000	79000	100000	75000	120000
CHROMIUM		44	110	37	97	35	93	15	23	22	41	28	76
COBALT		9.5	13.0	9.0	13.0	8.9	12.0	5.8	9.6	7.0	13.0	7.8	13.0
COPPER		31	41	27	40	27	39	23	35	44	100	30	62
IRON		23000	34000	21000	33000	21000	32000	11000	18000	15000	25000	18000	30000
LEAD		56	130	47	110	49	110	54	99	41	63	48	100
MAGNESIUM		25000	45000	29000	51000	28000	49000	38000	46000	37000	46000	32000	50000
MANGANESE		450	700	590	1200	560	1100	410	580	480	750	510	980
MERCURY	(3)	0.12	0.27	0.10	0.24	0.10	0.23	0.07	0.08	0.11	0.24	0.10	0.22
NICKEL		24	32	23	32	22	31	14	22	20	32	20	32
POTASSIUM		1400	2400	1300	2300	1300	2200	800	1600	1000	2200	1100	2200
SELENIUM	(3)	0.52	0.95	0.45	0.85	0.45	0.83	0.33	0.41	0.32	0.45	0.40	0.72
SILVER	(3)	0.9	1.0	0.9	1.0	0.9	1.0	0.8	1.0	1.0	2.0	0.9	1.0
SODIUM		260	570	250	510	240	490	220	270	190	220	220	420
THALLIUM		0.84	1.30	0.82	1.30	0.78	1.30	0.54	0.98	0.50	0.99	0.67	1.20
VANADIUM		28	37	26	37	25	36	18	28	21	34	23	36
ZINC		260	620	220	540	210	520	120	180	120	200	170	430

NOTES: 1 -- Concentrations have been rounded to 2 significant digits.
2 -- Maximum Probable Background Concentration
3 -- Fewer than 5 detects out of 19 samples.

Attachment 1
ANALYTICAL RESULTS

SEDIMENT CONCENTRATION (ug/Kg)

TR NUMBER	166	167	168	169	170	183	171	172
SAMPLE LOCATION	SD01-02	SD01-03	SD02-02	SD02-03	SD03-02	RPSD03-02	SD03-03	SD04-02
PARAMETER								
PHENOL	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
BIS(2-CHLOROETHYL) ETHER	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
2-CHLOROPHENOL	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
1,3-DICHLOROBENZENE	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
1,4-DICHLOROBENZENE	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
BENZYL ALCOHOL	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
1,2-DICHLOROBENZENE	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
2-METHYLPHENOL	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
BIS(2-CHLOROISOPROPYL)ETHER	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
4-METHYLPHENOL	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
N-NITORSO-DIPROPYLAMINE	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
HEXACHLOROETHANE	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
NITROBENZENE	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
ISOPHORONE	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
2-NITROPHENOL	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
2,4-DIMETHYLPHENOL	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
BENZOIC ACID	8000 U	8000 U	6400 U	6000 U	6800 U	6000 U	7300 U	9500 U
BIS(2-CHLOROETHOXY) METHANE	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
2,4-DICHLOROPHENOL	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
1,2,4-TRICHLOROBENZENE	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
NAPHTHALENE	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
4-CHLOROANILINE	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
HEXACHLOROBUTADIENE	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
4-CHLORO-3-METHYLPHENOL	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
2-METHYLNAPHTHALENE	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
HEXACHLOROCYCLOPENTADIENE	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
2,4,6-TRICHLOROPHENOL	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
2,4,5-TRICHLOROPHENOL	8000 U	8000 U	6400 U	6000 U	6800 U	6000 U	7300 U	9500 U
2-CHLORONAPHTHALENE	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
2-NITROANILINE	8000 U	8000 U	6400 U	6000 U	6800 U	6000 U	7300 U	9500 U
DIMETHYLPHTHALATE	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
ACENAPHTHYLENE	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
2,6-DINITROTOLUENE	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
3-NITROANILINE	8000 U	8000 U	6400 U	6000 U	6800 U	6000 U	7300 U	9500 U
ACENAPHTHENE	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	1100 J
2,4-DINITROPHENOL	8000 U	8000 U	6400 U	6000 U	6800 U	6000 U	7300 U	9500 U
4-NITROPHENOL	8000 U	8000 U	6400 U	6000 U	6800 U	6000 U	7300 U	9500 U
DIBENZOFURAN	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	710 J
2,4-DINITROTOLUENE	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
DIETHYLPHTHALATE	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
4-CHLOROPHENYL PHENYL ETHER	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
FLUORENE	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	1500 J
4-NITROANILINE	8000 U	8000 U	6400 U	6000 U	6800 U	6000 U	7300 U	9500 U
4,6-DINITRO-2-METHYLPHENOL	8000 U	8000 U	6400 U	6000 U	6800 U	6000 U	7300 U	9500 U
N-NITROSODIPHENYLAMINE	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
4-BROMOPHENYL PHENYL ETHER	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
HEXACHLOROBENZENE	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
PENTACHLOROPHENOL	8000 U	8000 U	6400 U	6000 U	6800 U	6000 U	7300 U	9500 U
PHENANTHRENE	1600 U	780 J	1300 U	1200 U	490 J	700 J	390 J	12000
ANTHRACENE	1600 U	1700 U	1300 U	1200 U	1400 U	230 J	1500 U	3100
DI-N-BUTYL PHTHALATE	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
FLUORANTHENE	510 J	610 J	1300 U	1200 U	1000 J	1100 J	1200 J	14000
PYRENE	370 J	450 J	1300 U	1200 U	750 J	1000 J	870 J	9900
BUTYL BENZYL PHTHALATE	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
3,3-DICHLOROBENZIDINE	3300 U	3300 U	2600 U	2500 U	2800 U	2500 U	3000 U	3900 U
BENZO(A)ANTHRACENE	1600 U	1700 U	1300 U	1200 U	1400 U	340 J	1500 U	4500
CHRYSENE	1600 U	1700 U	1300 U	1200 U	480 J	510 J	540 J	4800
BIS(2-ETHYLHEXYL)PHTHALATE	1600 U	1700 U	1300 U	1200 U	760 J	760 J	1500 U	3100
DI-N-OCTYL PHTHALATE	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
BENZO(B)FLUORANTHENE	1600 U	1700 U	1300 U	1200 U	460 J	390 J	430 J	4600
BENZO(K)FLUORANTHENE	1600 U	1700 U	1300 U	1200 U	350 J	330 J	390 J	4900
BENZO(A)PYRENE	1600 U	1700 U	1300 U	1200 U	1400 U	410 J	390 J	4500
INDENO(1,2,3-CD)PYRENE	1600 U	1700 U	1300 U	1200 U	1400 U	240 J	1500 U	1100 J
DIBENZO(A,H)ANTHRACENE	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U
BENZO(GHI)PERYLENE	1600 U	1700 U	1300 U	1200 U	1400 U	1200 U	1500 U	2000 U

SEDIMENT CONCENTRATION (ug/Kg)

TR NUMBER	173	174	175	176	177	184	178
SAMPLE LOCATION	SD05-02	SD06-02	SD07-02	SD08-02	SD09-02	RPSD09-02	SD10-02
PARAMETER							
PHENOL	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
BIS(2-CHLOROETHYL) ETHER	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
2-CHLOROPHENOL	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
1,3-DICHLOROBENZENE	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
1,4-DICHLOROBENZENE	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
BENZYL ALCOHOL	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
1,2-DICHLOROBENZENE	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
2-METHYLPHENOL	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
BIS(2-CHLOROISOPROPYL)ETHER	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
4-METHYLPHENOL	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
N-NITORSO-DIPROPYLAMINE	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
HEXACHLOROETHANE	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
NITROBENZENE	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
ISOPHORONE	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
2-NITROPHENOL	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
2,4-DIMETHYLPHENOL	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
BENZOIC ACID	4000 U	5100 U	4700 U	4600 U	5000 U	4000 U	4000 U
BIS(2-CHLOROETHOXY) METHANE	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
2,4-DICHLOROPHENOL	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
1,2,4-TRICHLOROBENZENE	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
NAPHTHALENE	820 U	1100 UJ	980 U	950 U	1000 U	840 U	820 U
4-CHLOROANILINE	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
HEXACHLOROBUTADIENE	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
4-CHLORO-3-METHYLPHENOL	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
2-METHYLNAPHTHALENE	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
HEXACHLOROCYCLOPENTADIENE	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
2,4,6-TRICHLOROPHENOL	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
2,4,5-TRICHLOROPHENOL	4000 U	5100 U	4700 U	4600 U	5000 U	4000 U	4000 U
2-CHLORONAPHTHALENE	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
2-NITROANILINE	4000 U	5100 U	4700 U	4600 U	5000 U	4000 U	4000 U
DIMETHYLPHTHALATE	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
ACENAPHTHYLENE	820 U	1100 UJ	980 U	950 U	1000 U	840 U	820 U
2,6-DINITROTOLUENE	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
3-NITROANILINE	4000 U	5100 U	4700 U	4600 U	5000 U	4000 U	4000 U
ACENAPHTHENE	140 J	1100 UJ	1200	950 U	1000 U	840 U	200 J
2,4-DINITROPHENOL	4000 U	5100 U	4700 U	4600 U	5000 U	4000 U	4000 U
4-NITROPHENOL	4000 U	5100 U	4700 U	4600 U	5000 U	4000 U	4000 U
DIBENZOFURAN	120 J	1100 U	960 J	950 U	1000 U	840 U	120 J
2,4-DINITROTOLUENE	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
DIETHYLPHTHALATE	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
4-CHLOROPHENYL PHENYL ETHER	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
FLUORENE	270 J	1100 UJ	2000	950 U	1000 U	840 U	280 J
4-NITROANILINE	4000 U	5100 U	4700 U	4600 U	5000 U	4000 U	4000 U
4,6-DINITRO-2-METHYLPHENOL	4000 U	5100 U	4700 U	4600 U	5000 U	4000 U	4000 U
N-NITROSODIPHENYLAMINE	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
4-BROMOPHENYL PHENYL ETHER	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
HEXACHLOROBENZENE	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
PENTACHLOROPHENOL	4000 U	5100 U	4700 U	4600 U	5000 U	4000 U	4000 U
PHENANTHRENE	2400	1100 UJ	8500	950 U	500 J	360 J	2200
ANTHRACENE	550 J	1100 UJ	2800	950 U	1000 U	840 U	670 J
DI-N-BUTYL PHTHALATE	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
FLUORANTHENE	3100	480 J	4700	950 U	910 J	850	3300
PYRENE	2200	350 J	4500	950 U	720 J	590 J	2900
BUTYL BENZYL PHTHALATE	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
3,3-DICHLOROBENZIDINE	1600 U	2100 U	2000 U	1900 U	2000 U	1700 U	1600 U
BENZO(A)ANTHRACENE	1100	1100 UJ	2700	950 U	1000 U	310 J	1500
CHRYSENE	1300	1100 UJ	2700	950 U	430 J	430 J	1800
BIS(2-ETHYLHEXYL)PHTHALATE	600 J	1100 U	980 U	300 J	470 J	250 J	410 J
DI-N-OCTYL PHTHALATE	820 U	1100 U	980 U	950 U	1000 U	840 U	820 U
BENZO(B)FLUORANTHENE	1100	220 J	1800	950 U	360 J	370 J	1400
BENZO(K)FLUORANTHENE	1200	270 J	2700	950 U	380 J	430 J	1800
BENZO(A)PYRENE	1200	1100 UJ	2400	950 U	340 J	370 J	1600
INDENO(1,2,3-CD)PYRENE	550 J	1100 UJ	1200	950 U	1000 U	840 U	780 J
DIBENZO(A,H)ANTHRACENE	820 U	1100 UJ	700 J	950 U	1000 U	840 U	410 J
BENZO(GHI)PERYLENE	520 J	1100 UJ	1200	950 U	1000 U	840 U	740 J

SEDIMENT CONCENTRATION (ug/Kg)

TR NUMBER	179		180		181		182	
SAMPLE LOCATION	SD11-02		SD12-02		SD13-02		SD14-02	
PARAMETER								
PHENOL	810	U	990	U	1000	U	1000	U
BIS(2-CHLOROETHYL) ETHER	810	U	990	U	1000	U	1000	U
2-CHLOROPHENOL	810	U	990	U	1000	U	1000	U
1,3-DICHLOROBENZENE	810	U	990	U	1000	U	1000	U
1,4-DICHLOROBENZENE	810	U	990	U	1000	U	1000	U
BENZYL ALCOHOL	810	U	990	U	1000	U	1000	U
1,2-DICHLOROBENZENE	810	U	990	U	1000	U	1000	U
2-METHYLPHENOL	810	U	990	U	1000	U	1000	U
BIS(2-CHLOROISOPROPYL)ETHER	810	U	990	U	1000	U	1000	U
4-METHYLPHENOL	810	U	990	U	1000	U	1000	U
N-NITORSO-DIPROPYLAMINE	810	U	990	U	1000	U	1000	U
HEXACHLOROETHANE	810	U	990	U	1000	U	1000	U
NITROBENZENE	810	U	990	U	1000	U	1000	U
ISOPHORONE	810	U	990	U	1000	U	1000	U
2-NITROPHENOL	810	U	990	U	1000	U	1000	U
2,4-DIMETHYLPHENOL	810	U	990	U	1000	U	1000	U
BENZOIC ACID	3900	U	4800	U	5000	U	5100	U
BIS(2-CHLOROETHOXY) METHANE	810	U	990	U	1000	U	1000	U
2,4-DICHLOROPHENOL	810	U	990	U	1000	U	1000	U
1,2,4-TRICHLOROBENZENE	810	U	990	U	1000	U	1000	U
NAPHTHALENE	810	U	990	U	1000	U	1000	U
4-CHLOROANILINE	810	U	990	U	1000	U	1000	U
HEXACHLOROBUTADIENE	810	U	990	U	1000	U	1000	U
4-CHLORO-3-METHYLPHENOL	810	U	990	U	1000	U	1000	U
2-METHYLNAPHTHALENE	97	J	990	U	1000	U	1000	U
HEXACHLOROCYCLOPENTADIENE	810	U	990	U	1000	U	1000	U
2,4,6-TRICHLOROPHENOL	810	U	990	U	1000	U	1000	U
2,4,5-TRICHLOROPHENOL	3900	U	4800	U	5000	U	5100	U
2-CHLORONAPHTHALENE	810	U	990	U	1000	U	1000	U
2-NITROANILINE	3900	U	4800	U	5000	U	5100	U
DIMETHYLPHTHALATE	810	U	990	U	180	J	1000	U
ACENAPHTHYLENE	300	J	990	U	1000	U	1000	U
2,6-DINITROTOLUENE	810	U	990	U	1000	U	1000	U
3-NITROANILINE	3900	U	4800	U	5000	U	5100	U
ACENAPHTHENE	600	J	990	U	1000	U	1000	U
2,4-DINITROPHENOL	3900	U	4800	U	5000	U	5100	U
4-NITROPHENOL	3900	U	4800	U	5000	U	5100	U
DIBENZOFURAN	510	J	990	U	1000	U	1000	U
2,4-DINITROTOLUENE	810	U	990	U	1000	U	1000	U
DIETHYLPHTHALATE	810	U	990	U	1000	U	1000	U
4-CHLOROPHENYL PHENYL ETHER	810	U	990	U	1000	U	1000	U
FLUORENE	1100		990	U	1000	U	130	J
4-NITROANILINE	3900	U	4800	U	5000	U	5100	U
4,6-DINITRO-2-METHYLPHENOL	3900	U	4800	U	5000	U	5100	U
N-NITROSODIPHENYLAMINE	810	U	990	U	1000	U	1000	U
4-BROMOPHENYL PHENYL ETHER	810	U	990	U	1000	U	1000	U
HEXACHLOROBENZENE	810	U	990	U	1000	U	1000	U
PENTACHLOROPHENOL	3900	U	4800	U	5000	U	5100	U
PHENANTHRENE	6600		140	J	980	J	1500	
ANTHRACENE	2100		990	U	150	J	310	J
DI-N-BUTYL PHTHALATE	810	U	990	U	1000	U	1000	U
FLUORANTHENE	7800		300	J	1800		2400	
PYRENE	7600		240	J	1400		1900	
BUTYL BENZYL PHTHALATE	400	J	990	U	760	J	1000	U
3,3-DICHLOROBENZIDINE	1600	U	2000	U	2100	U	2100	U
BENZO(A)ANTHRACENE	4100		990	U	460	J	790	J
CHRYSENE	4300		990	U	810	J	1000	J
BIS(2-ETHYLHEXYL)PHTHALATE	1100		380	J	1500		510	J
DI-N-OCTYL PHTHALATE	810	U	990	U	1000	U	1000	U
BENZO(B)FLUORANTHENE	3700		100	J	720	J	1000	J
BENZO(K)FLUORANTHENE	4900		140	J	820	J	860	J
BENZO(A)PYRENE	3800		990	U	670	J	960	J
INDENO(1,2,3-CD)PYRENE	1300		990	U	400	J	500	J
DIBENZO(A,H)ANTHRACENE	760	J	990	U	1000	U	1000	U
BENZO(GHI)PERYLENE	1100		990	U	420	J	530	J

SEDIMENT CONCENTRATION
(ug/Kg)

SAS NUMBER	4963E-01	4963E-02	4963E-03	4963E-04	4963E-05
SAMPLE LOCATION	SD01-02	SD01-03	SD02-02	SD02-03	SD03-02
PARAMETER					
NAPHTHALENE	240 U	R	190 U	200 U	190 U
ACENAPHTHYLENE	240 U	R	190 U	200 U	190 U
ACENAPHTHENE	240 U	R	190 U	200 U	190 U
FLUORENE	240 U	R	190 U	200 U	190 U
PHENANTHRENE	240 U	R	190 U	200 U	190 U
ANTHRACENE	240 U	R	190 U	200 U	190 U
FLUORANTHENE	830	R	190 U	200 U	190 U
PYRENE	240 U	R	190 U	200 U	190 U
BENZO(A)ANTHRACENE	240 U	R	190 U	200 U	190 U
CHRYSENE	240 U	R	190 U	200 U	190 U
BENZO(B)FLUORANTHENE	240 U	R	190 U	200 U	190 U
BENZO(K)FLUORANTHENE	240 U	R	190 U	200 U	190 U
BENZO(A)PYRENE	240 U	R	190 U	200 U	190 U
INDENO(1,2,3-CD)PYRENE	240 U	R	190 U	200 U	190 U
DIBENZO(A,H)ANTHRACENE	240 U	R	190 U	200 U	190 U
BENZO(GHI)PERYLENE	240 U	R	190 U	200 U	190 U

SEDIMENT CONCENTRATION
(ug/Kg)

SAS NUMBER	4963E-18		4963E-06		4963E-07		4963E-08		4963E-09	
SAMPLE LOCATION	RPSD03-02 REPLICATE		SD03-03		SD04-02		SD05-02		SD06-02	
PARAMETER										
NAPHTHALENE	130	U	220	U	150	U	120	U	140	U
ACENAPHTHYLENE	130	U	220	U	150	U	120	U	140	U
ACENAPHTHENE	130	U	220	U	580		120	U	140	U
FLUORENE	130	U	220	U	1100		120	U	140	U
PHENANTHRENE	130	U	220	U	7800		610		140	U
ANTHRACENE	130	U	220	U	1800		120	U	140	U
FLUORANTHENE	760		860		12000		1400		1200	
PYRENE	420		220	U	7900		810		520	
BENZO(A)ANTHRACENE	130	U	220	U	3200		120	U	140	U
CHRYSENE	130	U	220	U	4000		450		140	U
BENZO(B)FLUORANTHENE	130	U	220	U	3200		1400		140	U
BENZO(K)FLUORANTHENE	130	U	220	U	2800		120	U	140	U
BENZO(A)PYRENE	130	U	220	U	3400		120	U	140	U
INDENO(1,2,3-CD)PYRENE	130	U	220	U	3400		120	U	140	U
DIBENZO(A,H)ANTHRACENE	130	U	220	U	150	U	120	U	140	U
BENZO(GHI)PERYLENE	130	U	220	U	3000		120	U	140	U

SEDIMENT CONCENTRATION
(ug/Kg)

SAS NUMBER	4963E-10		4963E-11		4963E-12		4963E-19		4963E-13	
SAMPLE LOCATION	SD07-02		SD08-02		SD09-02		RPSD09-02 REPLICATE		SD10-02	
PARAMETER										
NAPHTHALENE	140	U	140	U	150	U	200	U	120	U
ACENAPHTHYLENE	140	U	140	U	150	U	200	U	120	U
ACENAPHTHENE	140	U	140	U	150	U	200	U	120	U
FLUORENE	140	U	140	U	150	U	200	U	120	U
PHENANTHRENE	540		140	U	150	U	200	U	2900	
ANTHRACENE	140	U	140	U	150	U	200	U	610	
FLUORANTHENE	1200		3200		1500		1400		4700	
PYRENE	740		140	U	710		940		3900	
BENZO(A)ANTHRACENE	140	U	140	U	150	U	200	U	1400	
CHRYSENE	140	U	140	U	150	U	200	U	1500	
BENZO(B)FLUORANTHENE	140	U	140	U	150	U	200	U	120	U
BENZO(K)FLUORANTHENE	140	U	140	U	150	U	200	U	120	U
BENZO(A)PYRENE	140	U	140	U	150	U	200	U	120	U
INDENO(1,2,3-CD)PYRENE	140	U	140	U	150	U	200	U	120	U
DIBENZO(A,H)ANTHRACENE	140	U	140	U	150	U	200	U	120	U
BENZO(GHI)PERYLENE	140	U	140	U	150	U	200	U	120	U

SEDIMENT CONCENTRATION
(ug/Kg)

SAS NUMBER	4963E-14		4963E-15		4963E-16		4963E-17	
SAMPLE LOCATION	SD11-02		SD12-02		SD13-02		SD14-02	
PARAMETER								
NAPHTHALENE	120	U	140	U	150	U	150	U
ACENAPHTHYLENE	120	U	140	U	150	U	150	U
ACENAPHTHENE	120	U	140	U	150	U	150	U
FLUORENE	720		140	U	150	U	150	U
PHENANTHRENE	6000		140	U	150	U	1600	
ANTHRACENE	1300		140	U	150	U	150	U
FLUORANTHENE	8100		1500		150	U	3700	
PYRENE	6600		500		150	U	2700	
BENZO(A)ANTHRACENE	2100		140	U	150	U	1100	
CHRYSENE	2200		140	U	150	U	1500	
BENZO(B)FLUORANTHENE	120	U	140	U	150	U	3200	
BENZO(K)FLUORANTHENE	1300		140	U	150	U	150	U
BENZO(A)PYRENE	1500		140	U	150	U	150	U
INDENO(1,2,3-CD)PYRENE	120	U	140	U	150	U	150	U
DIBENZO(A,H)ANTHRACENE	120	U	140	U	150	U	150	U
BENZO(GHI)PERYLENE	120	U	140	U	150	U	150	U

CONCENTRATION (ug/Kg)

TR NUMBER	MECW00		MECW01		MECW02		MECW39		MECW40	
SAMPLE LOCATION	SD01-02		SD01-03		SD02-02		SD02-03		SD03-02	
Parameter										
ALUMINUM	10300		9310		14300		9290		2920	
ANTIMONY	9.7	UJ	10.1	UJ	7.6	UJ	6.1	UJ	4.9	UJ
ARSENIC	5.4		4.2	J	3.6	J	4.1		2.9	
BARIUM	130		119		125		94.2		29.1	J
BERYLLIUM	0.48	U	0.50	U	0.38	U	0.30	U	0.24	U
CADMIUM	1.5	U	1.5	U	1.1	U	1.3	J	1.1	J
CALCIUM	92100		77500		29600		85400		94500	
CHROMIUM	21		17.6		25.9		145		39.5	
COBALT	10.5	J	9.3	J	10	J	9.2	J	4.7	J
COPPER	26.0		25.7		31.4		37.8		41.8	
IRON	20800		17500		21200		18000		37700	
LEAD	42.9		21.4		20.7		87.9		63.5	
MAGNESIUM	23100		21700		14100		40000		46800	
MANGANESE	463		384		274		664		410	
MERCURY	0.34		0.24	U	0.17	U	0.15	U	0.10	U
NICKEL	26.2		18.7	J	28.9		21.9		18.9	
POTASSIUM	1200	J	1230	J	1770	J	1360	J	183	J
SELENIUM	0.97	UJ	1.0	UJ	0.95	J	0.61	UJ	0.49	UJ
SILVER	2.4	U	2.5	U	1.9	U	1.5	U	1.2	U
SODIUM	165	J	157	J	119	J	276	J	280	J
THALLIUM	1.2	J	1.0	U	0.76	U	0.85	J	1.1	J
VANADIUM	26.4		22.2	J	33.8		24.6		19.0	
ZINC	119	J	111	J	109	J	584	J	185	J

CONCENTRATION (ug/Kg)

TR NUMBER	MET985		MECW41		MECW42		MECW43		MECW44	
SAMPLE LOCATION	RPSD03-02 REPLICATE		SD03-03		SD04-02		SD05-02		SD06-02	
Parameter										
ALUMINUM	16600		12300		8760		10500		3320	
ANTIMONY	7.9	UJ	6.2	UJ	5.8	UJ	5.2	UJ	6.5	UJ
ARSENIC	2.1	J	8.2		3.5		7.3		2.4	J
BARIUM	137		107		61.5		110		33.9	J
BERYLLIUM	0.49	J	0.31	U	0.29	U	0.26	U	0.32	U
CADMIUM	1.2	U	1.9	J	0.86	U	0.79	U	0.97	U
CALCIUM	33200		18500		95800		51300		103000	
CHROMIUM	28.7		26.9		19.9		20.6		20	
COBALT	11.6	J	11.2	J	7.8	J	10.2	J	5.2	J
COPPER	27.2		27.8		20.7		16.6		15.1	
IRON	24500		22600		16500		24700		10500	
LEAD	16.3		140		40.6		13.4		24.2	
MAGNESIUM	14500		12200		38700		29300		49500	
MANGANESE	282		666		569		1550		611	
MERCURY	0.16	U	0.14	U	0.12	U	0.13	U	0.14	U
NICKEL	31.4		24.2		21.3		25.9		11.2	J
POTASSIUM	2550		1270	J	1520	J	1120	J	410	J
SELENIUM	0.87	J	0.62	UJ	0.58	UJ	0.52	UJ	0.65	UJ
SILVER	2.0	U	1.6	U	1.4	U	1.3	U	1.6	U
SODIUM	149	J	696	J	221	J	172	J	224	J
THALLIUM	0.98	J	0.90	J	0.78	J	1.2	J	0.65	U
VANADIUM	36.6		30.3		23.7		28.7		12.2	J
ZINC	118	J	619	J	103	J	88.0	J	130	J

CONCENTRATION (ug/Kg)

TR NUMBER	MECW45		MECW46		MECW47		MET986		MECW48	
SAMPLE LOCATION	SD07-02		SD08-02		SD09-02		RPSD09-02 REPLICATE		SD10-02	
Parameter										
ALUMINUM	2320		2780		12100		11000		7330	
ANTIMONY	5.3	UJ	5.2	UJ	5.8	UJ	9.1	UJ	6.6	UJ
ARSENIC	2.1	J	2.3	J	4.5		6.1		2.8	J
BARIUM	20.8	J	37	J	93.2		98.8		79.3	
BERYLLIUM	0.27	U	0.26	U	0.29	U	0.45	U	0.33	U
CADMIUM	0.8	U	0.83	J	0.86	U	1.4	U	0.99	U
CALCIUM	88900		82600		54600		89100		96700	
CHROMIUM	8.2		16.5		40.3		21.4		18.9	
COBALT	3.7	J	3.2	J	10.8	J	10.2	J	7	J
COPPER	9.8		104.0		30.5		30.3		32.7	
IRON	8550		9020		22600		19700		13700	
LEAD	21.5		36.9		45.5		58.5		90.7	
MAGNESIUM	43500		40200		29100		34400		36600	
MANGANESE	493		280		726		437		546	
MERCURY	0.11	U	0.12	U	0.25		0.17	U	0.14	U
NICKEL	8.2	J	18.7		25.8		26.8		16.3	
POTASSIUM	233	J	390	J	1750	J	1710	J	832	J
SELENIUM	0.53	UJ	0.52	UJ	0.58	UJ	0.91	UJ	0.66	UJ
SILVER	1.3	U	1.3	U	2.1	J	2.3	U	1.7	U
SODIUM	220	J	165	J	179	J	192	J	212	J
THALLIUM	0.53	U	0.52	U	1.0	J	0.91	U	0.66	J
VANADIUM	13.9		10.7	J	28.2		29.3		21.2	
ZINC	54.7	J	85.1	J	194	J	137	J	171	J

CONCENTRATION (ug/Kg)

TR NUMBER	MECW49		MECW50		MECW51		MET979	
SAMPLE LOCATION	SD11-02		SD12-02		SD13-02		SD14-02	
Parameter								
ALUMINUM	2950		9820		3140		7710	
ANTIMONY	5.4	UJ	8.0	UJ	6.3	UJ	7.6	UJ
ARSENIC	2.3	J	3.9	J	4.4		3.6	J
BARIUM	25.8	J	84.6		39.6	J	81	
BERYLLIUM	0.27	U	0.40	U	0.32	U	0.38	U
CADMIUM	0.82	U	1.2	U	0.95	U	1.1	U
CALCIUM	103000		82100		81900		71500	
CHROMIUM	6.8		19.6		14.5		17.3	
COBALT	3.5	J	9	J	3.6	J	8.4	J
COPPER	16.9		26.9		14.6		24.7	
IRON	6100		16600		9010		14800	
LEAD	29.3		70.1		25.0		64.9	
MAGNESIUM	45700		32500		37000		21300	
MANGANESE	263		387		448		324	
MERCURY	0.12	U	0.16	U	0.12	U	0.15	U
NICKEL	8.3	J	21.1		9.4	J	18.7	
POTASSIUM	262	J	1570	J	532	J	1330	J
SELENIUM	0.54	UJ	0.80	UJ	0.63	UJ	0.76	UJ
SILVER	1.4	U	2.0	U	1.6	U	1.9	U
SODIUM	254	J	182	J	251	J	150	J
THALLIUM	0.54	U	0.92	J	0.63	U	0.76	U
VANADIUM	11.9	J	26.7		10.9	J	21.0	
ZINC	131	J	121	J	69.1	J	127	J

CONCENTRATION (ng/Kg)

SAS NUMBER	4963E-22		4963E-23		4963E-24		4963E-25		4963E-26	
SAMPLE LOCATION	SD01-02		SD01-03		SD02-02		SD02-03		SD03-02	
Parameter										
2,3,7,8-TCDD	2.3	U	2.4	U	37.2	U	27.5	U	2.3	U
TETRA-CCD	2.3	U	2.4	U	37.2	U	27.5	U	2.3	U
PENTA-CCD	4.0	U	6.5	U	35.6	U	35.0	U	3.0	U
HEXA-CCD	6.6	U	9.7	U	50.4	U	36.3	U	3.8	U
HEPTA-CDD	14.4	U	11.9	U	149.5	U	712		8.0	U
OCTA-CDD	11.4	U	9.2	U	4116		3488		7.9	U
2,3,7,8-TCDF	1.1	U	3.2	U	22.1	U	7.7	U	0.9	U
TETRA-CCF	1.1	U	3.2	U	22.1	U	7.7	U	0.9	U
PENTA-CCF	2.4	U	1.8	U	25.1	U	13.7	U	0.8	U
HEXA-CCF	2.1	U	3.1	U	25.3	U	15.5	U	3.2	U
HEPTA-CDF	10.9	U	15.4	U	65.5	U	29.4	U	2.4	U
OCTA-CDF	10.8	U	7.5	U	74.0	U	40.7	U	6.2	U

CONCENTRATION (ng/Kg)

SAS NUMBER	4963E-21		4963E-27		4963E-28		4963E-29		4963E-30	
SAMPLE LOCATION	RPSD03-02 REPLICATE		SD03-03		SD04-02		SD05-02		SD06-02	
Parameter										
2,3,7,8-TCDD	3.5	U	23.6	U	2.0	U	0.9	U	1.0	U
TETRA-CCD	3.5	U	23.6	U	2.0	U	0.9	U	1.0	U
PENTA-CCD	4.4	U	30.3	U	3.3	U	2.5	U	2.9	U
HEXA-CCD	4.5	U	30.1	U	2.4	U	1.8	U	2.8	U
HEPTA-CDD	6.7	U	52.4	U	4.0	U	5.0	U	3.4	U
OCTA-CDD	9.0	U	3614		5.1	U	5.3	U	5.3	U
2,3,7,8-TCDF	2.1	U	28.6	U	1.5	U	0.9	U	0.9	U
TETRA-CCF	2.1	U	28.6	U	1.5	U	0.9	U	0.9	U
PENTA-CCF	2.3	U	9.7	U	1.5	U	0.8	U	1.0	U
HEXA-CCF	2.7	U	20.1	U	2.2	U	1.1	U	1.1	U
HEPTA-CDF	4.0	U	130.4	U	5.1	U	2.1	U	3.1	U
OCTA-CDF	7.0	U	113.4	U	5.5	U	2.7	U	4.2	U

CONCENTRATION (ng/Kg)

SAS NUMBER	4963E-31		4963E-32		4963E-33		4963E-20		4963E-34	
SAMPLE LOCATION	SD07-02		SD08-02		SD09-02		RPSD09-02 REPLICATE		SD10-02	
Parameter										
2,3,7,8-TCDD	13.8	U	1.9	U	2.4	U	12.8	U	3.7	U
TETRA-CCD	13.8	U	1.9	U	2.4	U	12.8	U	3.7	U
PENTA-CCD	20.5	U	3.9	U	2.3	U	15.0	U	3.4	U
HEXA-CCD	25.4	U	2.4	U	5.6	U	23.4	U	4.8	U
HEPTA-CDD	69.1	U	3.8	U	3.5	U	51.0	U	127	
OCTA-CDD	1616		3.9	U	108		1195		784	
2,3,7,8-TCDF	7.1	U	0.7	U	1.3	U	5.9	U	3.6	U
TETRA-CCF	7.1	U	0.7	U	1.3	U	5.9	U	3.6	U
PENTA-CCF	7.5	U	1.5	U	1.3	U	6.0	U	2.9	U
HEXA-CCF	15.6	U	1.3	U	1.0	U	11.0	U	6.3	U
HEPTA-CDF	65.9	U	2.3	U	4.3	U	42.4	U	13.4	U
OCTA-CDF	96.1	U	7.3	U	5.3	U	49.5	U	17.1	U

CONCENTRATION (ng/Kg)

SAS NUMBER	4963E-35		4963E-36		4963E-37		4963E-38	
SAMPLE LOCATION	SD11-02		SD13-02		SD13-02		SD14-02	
Parameter								
2,3,7,8-TCDD	2.0	U	1.3	U	1.9	U	2.0	U
TETRA-CCD	2.0	U	1.3	U	1.9	U	2.0	U
PENTA-CCD	3.8	U	3.6	U	3.9	U	5.1	U
HEXA-CCD	1.9	U	4.3	U	6.1	U	4.5	U
HEPTA-CDD	1081	J	6.8	U	11.9	U	741	
OCTA-CDD	3540	J	10.0	U	403.0		3807	
2,3,7,8-TCDF	3.5	U	1.1	U	2.8	U	0.8	U
TETRA-CCF	3.5	U	1.1	U	2.8	U	0.8	U
PENTA-CCF	11.3	U	1.3	U	2.7	U	39.6	
HEXA-CCF	11.5	U	2.0	U	4.5	U	66.7	
HEPTA-CDF	23.1	U	5.8	U	8.9	U	792	
OCTA-CDF	12.9	U	4.6	U	9.1	U	27.0	

Appendix K
RESULTS OF BIOTREATABILITY STUDY

Appendix K
RESULTS OF BIOTREATABILITY STUDY

This appendix summarizes the results of a treatability study performed by the CH2M HILL laboratory in Corvallis, Oregon, on contaminated soil and sediment from the Moss-American site.

OBJECTIVES

The goal of the treatability study was to evaluate the potential effectiveness of slurry bioreactor treatment and solid phase treatment for reducing PAH concentrations in Moss-American site soil and sediment. This information will be used by the U.S. EPA to support the development of feasible, permanent alternatives to reduce toxicity, mobility, or volume of contaminated media. The specific study objectives were:

- To determine if 4- and 5-ring PAHs in contaminated soils from the site can be biodegraded by native microorganisms in soil and sediment
- To determine biodegradation rates for PAHs, particularly 4- and 5-ring PAHs
- To compare removal rates achieved by the two bioremediation methods studied
- To provide information that will serve as a basis for evaluating the feasibility of bioremediation and for performing a comparative analysis of the two bioremediation technologies

The experimental design of this study comprised three tasks:

1. Soil acquisition and initial characterization
2. Soil respiration screening experiments
3. Bioremediation treatability testing

SUMMARY OF RESULTS

Respiration rates (O_2 consumption/CO_2 production) are indicative of the microbial activity present in the waste being treated. Respiration rates observed during the study indicated that both sediment and soil contain a viable microbial community that would actively metabolize organic compounds present (presumably including organic contaminants) under the proper conditions.

For both sediment and soil, respiration rates were lowest in nonamended systems, intermediate in nutrient-amended systems, and highest in nutrient- and manure-amended systems. The increase in respiration rate caused by adding nutrients to the sediment sample was slight, but might be expected to become greater over a longer test period as indigenous nutrients become depleted.

In Task 3, slurry bioreactor treatment and solid phase treatment of contaminated soil and sediment was modeled by slurry flask and solid phase pan treatability studies, respectively. Half-lives for PAHs measured in the study are summarized in Table K-1. PAH treatment in slurry flasks yielded half-lives less than 60 days for virtually all compounds, while many half-lives were 20 days or less. Half-lives of all 2- and 3-ring PAHs in soil pans and all compounds except benzo[a]pyrene in sediment pans were less than 100 days. Removal of 4- and 5-ring PAHs in soil pans was conspicuously slow.

METHODS

SOIL ACQUISITION AND INITIAL CHARACTERIZATION

Contaminated soils from the site and sediment samples taken from the Little Menomonee River between Brown Deer Road and Bradley Road were used in the study. The soil samples were combined from three locations around the site where previous work had indicated PAH contamination was present. The sample locations were the northeast landfill and two locations in the treated storage area. Soil samples were collected after first removing the top 6 inches of soil. Composite samples were mixed in the field and shipped to the laboratory.

In the laboratory the samples were sieved to remove objects larger than ½ inch, and homogenized and analyzed for moisture content, pH, exchangeable ammonia nitrogen (NH_3-N), and water-soluble orthophosphate phosphorus (Ortho-P).

SOIL RESPIRATION SCREENING

The objectives of the soil respiration studies were:

- To determine if a metabolically active microbial community was present in the soil and sediment
- To evaluate rates at which organic compounds may be oxidized
- To identify amendments and modifications that might enhance microbial activity

Amendments that were evaluated include exchangeable ammonia nitrogen, water-soluble Ortho-p and manure.

Respiration, measured as oxygen consumption and carbon dioxide production, was rapid in all systems indicating the presence of active microbial communities. Respiration rates slowed after 96 hours but this may have been due to the reduction of oxygen concentrations in the closed systems used for the test. Results suggest nutrient addition may speed up respiration in soils, but the respiration rates in the sediment samples were not significantly affected.

BIOREMEDIATION TREATABILITY TESTING

Two treatability tests were performed as part of the study. One test evaluated the biodegradation PAHs using a slurry treatment. This test evaluated the efficacy of a slurry bioreactor. The other test evaluated biodegradation in solid phase soils and was used to evaluate land treatment.

Slurry Flask Study

The slurry treatment was performed using slurry flasks. A slurry was formed by adding water to the soil and mixing vigorously until a 30 percent (by weight) moisture content was reached. Nutrients (NH_3-N and Ortho-P) were added to obtain 40 mg/l nitrogen and 10 mg/l phosphorus. Aliquots of the slurry were transferred to a sufficient number of flasks to allow sacrificial sampling during the study. Flasks were kept on a shaker table with the agitation speed set to maintain solids in suspension. Flasks were sampled at the beginning of the study and on days 7, 14, 28, and 56 for analysis of PAHs, NH_3-N, Ortho-P and pH.

Solid Phase Pan Study

The solid phase treatment study was performed using a layer of soil spread in aluminum baking pans. Soils were prepared by mixing in nutrients (NH_3-N and Ortho-P) and spreading to a depth of 5 centimeters in each of 4 pans. Additional nutrients were added after 56 days. Twice a week during the survey, pans were tilled to break up and aerate the soil. Water was added, avoiding leaching or ponding. Pans were sampled at the beginning of the study and after 28, 56, and 84 days for analysis of PAHs, NH_3-N, Ortho-P, and pH. Samples were prepared by collecting cores from several random locations around the pan and combining them into a single sample for analysis.

PRESENTATION OF RESULTS

Removal efficiency, first order reaction rate constant and coefficient of correlation have been calculated for each compound for each test to describe decay of PAHs.

Removal efficiency (RE) is calculated as:

$$RE = (C_o - C_t)/C_o \quad \text{(K-1)}$$

where

C_o = initial concentration

C_t = concentration at time, t (t = 56 days for the flask study and 84 days for the pan study)

Organic contaminant biodegradation in soil is frequently described using the zero order (Equation K-2) or first order (Equation K-3) rate models:

$$dC/dt = -k \quad \text{(K-2)}$$
$$dC/dt = -kC \quad \text{(K-3)}$$

where

C = contaminant concentration
k = reaction rate constant

These models are used because of their simplicity and their ability to describe observed data reasonably well, and because they facilitate data presentation and comparison.

Kinetic data presented throughout this report are computed using the first order rate model because it consistently fits the observed data better than the zero order model. The first order reaction rate constant (k) is determined graphically as the slope of the best-fit line through the data plotted according to the integrated form of the first order equation:

$$\ln(C_t/C_o) = -kt \quad \text{(K-4)}$$

The first order half-life ($t_{1/2}$)—the time required for a contaminant concentration to be reduced by 50 percent—is determined as:

$$t_{1/2} = \ln 2/k \quad \text{(K-5)}$$

An analysis of variance was performed on the raw PAH data to test whether there was a reasonable probability (i.e., a probability greater than the selected significance level of 0.05) that the measured slope, k, could have come from sampling a population with a slope equal to zero (Zar 1974). Rejection of this hypothesis indicates that the degradation rate constant is significantly different from (greater than) zero at the 5 percent level of significance.

Because the chromatographic responses of benzo[b]fluoranthene and benzo[k]fluoranthene were not always distinguishable, the approximate combined concentration of those two compounds is presented as benzo[b]fluoranthene + benzo[k]fluoranthene.

SLURRY FLASK STUDY

The solid phase and liquid phase of the slurry samples were separated and analyzed individually. The liquid phase contained generally less than 1 percent of the total mass of constituent PAH compounds and is considered negligible. The following discussion focuses on solid phase concentrations.

PAH Removal in Soil Flasks

Table K-2 lists the average PAH concentrations measured in the solid phase of the soil flask over time. Figure K-1 illustrates the degradation of total PAH concentrations and total carcinogenic PAHs from the soil flask study.

Slurry flask treatment of contaminated soil significantly reduced the concentration of every measurable PAH. In the soil flasks, total PAHs were reduced by 92 percent over 56 days. Removal efficiency for 4- and 5-ring PAHs ranged from 54 percent for chrysene to 92 percent for pyrene.

Table K-3 presents the estimated degradation coefficient according to a first-order decay model. The coefficient of correlation (r^2) provides an indication of how well the first order model fits the analytical data, with 1.00 being a perfect fit. The model fit well with the exceptions of naphthalene, phenanthrene, and chrysene, which deviated from the first order pattern. The longest half-life measured in the soil flasks was 48 days for chrysene. Half-lives of all other PAHs were less than or equal to 40 days. The half-life reported for naphthalene is probably overestimated because of the poor fit of the first order model (r^2 = 0.43). Table K-2 shows that the naphthalene concentration was reduced by nearly 70 percent over the first 7 days of treatment.

Examination of Table K-2 reveals differences in the pattern of degradation for certain PAHs. The first six compounds listed were degraded more rapidly during the first 14 days of treatment compared to the next six compounds. Degradation of the latter group (fluoranthene through benzopyrene excluding chrysene) tended to occur slowly for 14 days and more rapidly thereafter. Lag phases in the biotransformation of recalcitrant organic compounds are well documented in the literature. Lag phases can have several explanations, but they probably are most often caused by the time required for a microbial culture to develop a population of organisms capable of significantly degrading the compound of interest. The practical significance of this observation is that the higher degradation rates may be sustainable by maintaining the acclimated population once it is developed.

Table K-2
PAH CONCENTRATIONS IN SOIL FLASKS
(mg/dry kg)

Compound	Initial		7 Days		14 Days		28 Days		56 Days	
	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
NAPHTHALENE	140	10.0	46	11.0	45	3.2	34	2.7	37	a
ACENAPHTHYLENE	27	0.4	19	1.9	22	1.5	11	1.3	9	a
ACENAPHTHENE	1300	26.0	970	64.0	520	26.0	84	30.0	19	a
FLUORENE	850	28.0	200	45.0	62	12.0	36	10.0	14	a
PHENANTHRENE	2100	72.0	160	63.0	95	20.0	73	17.0	53	a
ANTHRACENE	450	49.0	160	13.0	100	31.0	73	19.0	49	a
FLUORANTHENE	1100	15.0	1000	80.0	1000	54.0	210	65.0	82	a
PYRENE	830	9.0	770	58.0	760	43.0	170	41.0	69	a
BENZO(a)ANTHRACENE	220	7.8	210	16.0	210	15.0	71	14.0	29	a
CHRYSENE	310	18.0	220	16.0	220	16.0	140	52.0	150	a
B(b)F + B(k)F	200	17.0	200	8.6	170	27.0	130	15.0	79	a
BENZO(a)PYRENE	110	2.1	87	3.0	110	3.6	48	5.7	38	a
IDENO PYRENE	51	5.7	N 40		N 40		N 40		N 40	a
DIBENZO ANTHRA	N 40		N 40		N 40		N 40		N 40	a
BENZO PERYLENE	N 40		N 40		N 40		N 40		N 40	a

SD = Standard deviation
N = Not detectable at the given detection limit
< = Below detection limit in one or two samples
A = Average of two samples

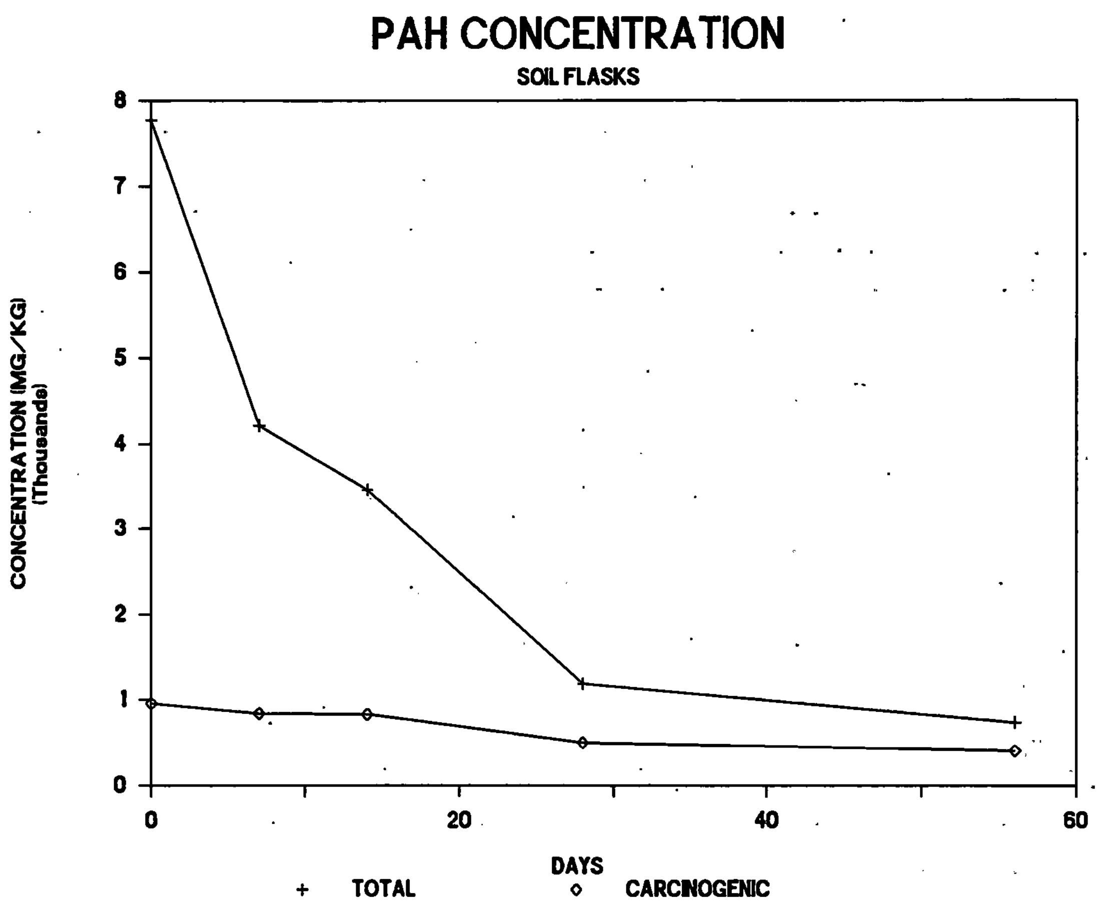

FIGURE K-1
TOTAL PAH CONCENTRATION
SOIL FLASKS
MOSS-AMERICAN FS

Table K-3
PAH DEGRADATION KINETICS IN SOIL FLASKS

Compound	Co (mg/kg)	RE (%)	k (1/day)	r^2	n	HALF LIFE (days)	STAT SIG (5%)
NAPHTHALENE	140	75	0.0197	0.41	14	35	*
ACENAPHTHYLENE	27	66	0.0201	0.78	14	34	*
ACENAPHTHENE	1300	99	0.0820	0.95	14	8	*
FLUORENE	850	98	0.0693	0.79	14	10	*
PHENANTHRENE	2100	98	0.0526	0.49	14	13	*
ANTHRACENE	450	89	0.0358	0.69	14	19	*
FLUORANTHENE	1100	93	0.0526	0.88	14	13	*
PYRENE	830	92	0.0502	0.89	14	14	*
BENZO(a)ANTHRACENE	220	87	0.0400	0.92	14	17	*
CHRYSENE	310	54	0.0145	0.55	14	48	*
B(b)F + B(k)F	200	60	0.0173	0.92	14	40	*
BENZO(a)PYRENE	110	64	0.0203	0.80	14	34	*
IDENO(1,2,3-cd)PYRENE	51	>21	0.0332	0.77	6	21	*
DIBENZO(a,h)ANTHRACENE	ND	-	-	-	-	-	-
BENZO(g,h,i)PERYLENE	ND	-	-	-	-	-	-

Co = Initial concentration
RE = Removal efficiency over 56 days
k = First order reaction rate constant
r^2 = Coefficient of correlation
n = Number of data included in the regression;
Half-Life = Assumes first order kinetics
ND = Not detectable
* = PAH removal rate is statistically significant

PAH Removal in Sediment Flasks

Table K-4 lists the average PAH concentrations measured in the solid phase of the sediment flask over time. Figure K-2 illustrates the degradation of total PAH concentrations and total carcinogenic PAHs from the sediment flask study.

The sediment sample contained lower contaminant levels than the soil sample. Nevertheless, removal efficiency in sediment flasks over 56 days was high for all measured contaminants (Table K-5). Total PAHs were reduced by at least 94 percent over 56 days. The removal efficiency for five individual PAHs exceeded 90 percent, and was greater than 70 percent for all measurable compounds (with the exception of naphthalene which was only 31 percent higher than the detection limit in the initial sample). Removal of 4- and 5-ring PAHs varied from 74 percent for chrysene to 90 percent for pyrene.

The kinetic models did not apply well to the sediment flask data because the initial contaminant concentrations were rapidly reduced to levels near or below the analytical detection limits. Degradation rates may also have been inhibited by insufficient substrate to supply enough energy for metabolic maintenance.

Keeping in mind the stated limitations of the first order model for describing the observed sediment flask data, the longest half-life was 53 days for chrysene (Table K-5). All other PAH half-lives were less than 30 days. As mentioned above, PAH removal was virtually complete within 7 days, with the exceptions of benzo[b]fluoranthene + benzo[k]fluoranthene and benzopyrene; consequently, the reported half-lives are probably overestimated for phenanthrene, fluoranthene, pyrene, and chrysene.

Nutrients in Slurry Flasks

Based on the rate of oxygen demand exertion measured in the preliminary soil respiration experiments (Task 2) and a typical nutrient requirement ratio of BOD:N:P = 100:5:1, the amount of N and P added to the slurry flasks initially and on day 14 exceeded the estimated requirements by approximately 25-fold. These nutrients should not have limited contaminant degradation.

SOLID PHASE PAN STUDY

PAH Removal in Soil Pans

Tables K-6 and K-7 list average PAH concentrations measured in soil pans P1 and P2, respectively, over time. Figures K-3 and K-4 illustrate the degradation of total PAH and carcinogenic PAH concentrations over time.

Tables K-8 and K-9 list removal efficiencies and other measures of removal kinetics for P1 and P2. Treatment was very similar in these similar systems (differing only in

Table K-4
PAH CONCENTRATIONS IN SEDIMENT FLASKS
(mg/dry kg)

Compound	Initial MEAN	Initial SD	7 Days MEAN	7 Days SD	14 Days MEAN	14 Days SD	28 Days MEAN	28 Days SD	56 Days MEAN	56 Days SD
NAPHTHALENE	6.0	1.3	< 4.4	a	6.0	1.7	< 4.0	a	N 4.0	
ACENAPHTHYLENE	N 4.0		N 4.0	a	N 4.0		N 4.0	a	N 4.0	
ACENAPHTHENE	50.0	1.0	N 4.0	a	< 4.6	1.1	N 4.0	a	N 4.0	
FLUORENE	47.0	0.9	N 4.0	a	N 4.0		N 4.0	a	N 4.0	
PHENANTHRENE	120.0	1.7	6.1	a	7.4	0.7	8.0	a	6.1	0.1
ANTHRACENE	28.0	0.5	N 4.0	a	N 4.0		< 4.1	a	N 4.0	
FLUORANTHENE	110.0	1.0	6.8	a	11.0	3.7	9.4	a	5.1	0.4
PYRENE	74.0	2.5	5.4	a	8.4	3.2	6.9	a	7.4	0.4
BENZO(a)ANTHRA	21.0	0.3	N 4.0	a	< 4.3	0.5	N 4.0	a	N 4.0	
CHRYSENE	29.0	0.3	5.4	a	5.4	0.7	4.6	a	7.6	0.1
B(b)F + B(k)F	22.0	0.7	16.0	a	10.0	1.0	6.4	a	N 4.0	
BENZO(a)PYRENE	19.0	1.8	6.7	a	< 6.7	2.3	4.5	a	< 4.2	0.3
IDENO PYRENE	N 4.0		N 4.0	a	N 4.0		N 4.0	a	N 38.0	
DIBENZO ANTHRA	N 40.0		N 4.0	a	N 4.0		N 4.0	a	N 38.0	
BENZO PERYLENE	N 4.0		N 4.0	a	N 4.0		N 4.0	a	N 38.0	

SD = Standard deviation
N = Not detectable at the given detection limit
< = Below detection limit in one or two samples
A = Average of two samples

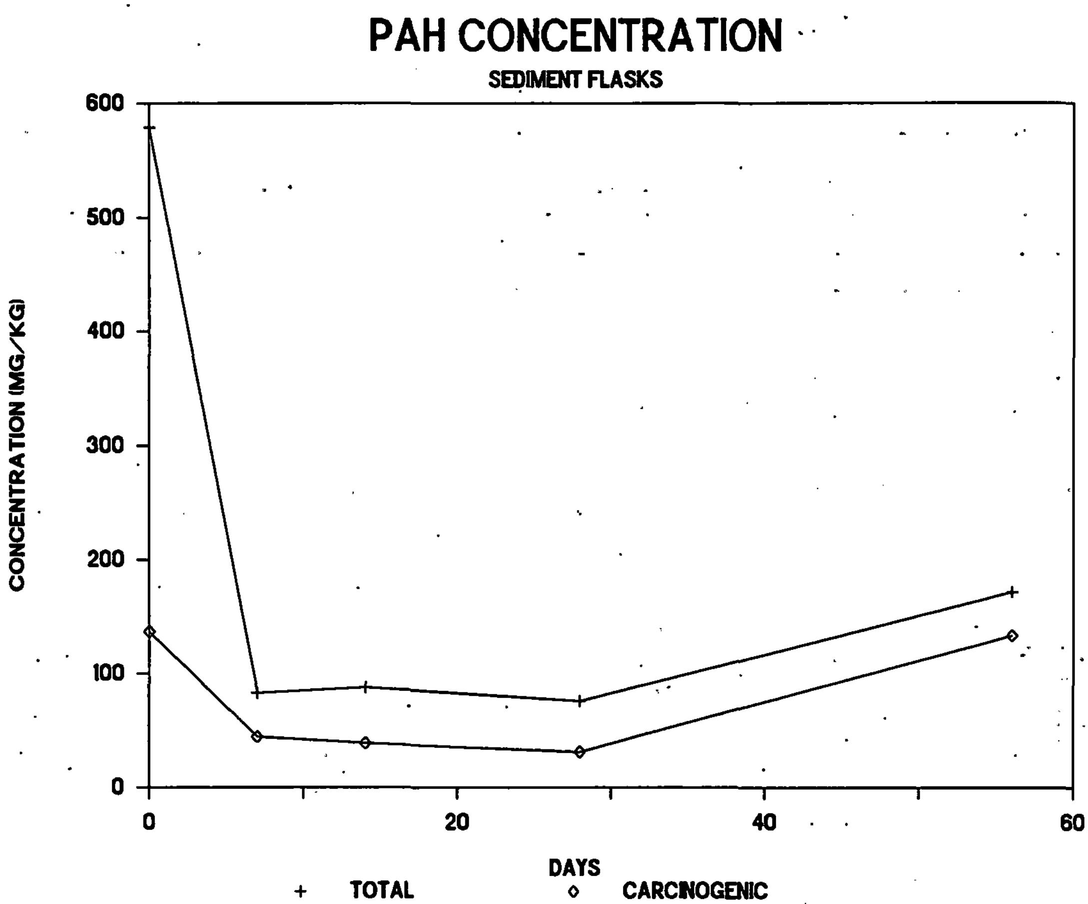

FIGURE K-2
TOTAL PAH CONCENTRATION
SEDIMENT FLASKS
MOSS-AMERICAN FS

Table K-5
PAH DEGRADATION KINETICS IN SEDIMENT FLASKS

Compound	Co (mg/kg)	RE (%)	k (1/day)	r^2	n	HALF LIFE (days)	STAT SIG (5%)
NAPHTHALENE	5.8	>31	0.0391	0.43	5	18	
ACENAPHTHYLENE	ND	-	-	-	-	-	-
ACENAPHTHENE	49.6	>92	0.3597	1.00	5	2	*
FLUORENE	47.2	>92	0.3525	1.00	5	2	*
PHENANTHRENE	124	95	0.0338	0.32	13	21	*
ANTHRACENE	28.4	>86	0.2800	1.00	5	2	*
FLUORANTHENE	109	95	0.0383	0.47	13	18	*
PYRENE	73.8	90	0.0253	0.27	13	27	*
BENZO(a)ANTHRACENE	20.6	>81	0.2341	1.00	5	3	*
CHRYSENE	28.7	74	0.0132	0.16	13	53	
B(b)F + B(k)F	21.7	>82	0.0453	0.96	10	15	*
BENZO(a)PYRENE	18.6	>77	0.0481	0.69	10	14	*
IDENO(1,2,3-cd)PYRENE	ND	-	-	-	-	-	-
DIBENZO(a,h)ANTHRACENE	ND	-	-	-	-	-	-
BENZO(g,h,i)PERYLENE	ND	-	-	-	-	-	-

Co = Initial concentration
RE = Removal efficiency over 56 days
k = First order reaction rate constant
r^2 = Coefficient of correlation
n = Number of data included in the regression;
Half-Life = Assumes first order kinetics
ND = Not detectable
* = PAH removal rate is statistically significant

Table K-6
PAH CONCENTRATIONS IN SOIL PAN P1
(mg/dry kg)

Compound	Initial MEAN	Initial SD	28 Days MEAN	28 Days SD	56 Days MEAN	56 Days SD	84 Days MEAN	84 Days SD
NAPHTHALENE	250	63	36	4	< 44	5.1	23	0.9
ACENAPHTHYLENE	< 20	4	N 27		N 41		N 19	
ACENAPHTHENE	1000	210	630	61	170	15.0	80	17.0
FLUORENE	650	120	220	29	76	5.7	45	13.0
PHENANTHRENE	1600	160	470	51	230	16.0	140	24.0
ANTHRACENE	460	68	190	25	95	9.2	85	27.0
FLUORANTHENE	920	170	1100	85	790	8.3	550	36.0
PYRENE	720	130	810	61	660	5.5	640	62.0
BENZO(a)ANTHRACENE	160	24	230	19	180	4.9	140	8.4
CHRYSENE	270	35	230	19	270	3.4	260	13.0
B(b)F + B(k)F	150	35	170	14	160	2.4	180	5.6
BENZO(a)PYRENE	98	18	74	12	73	3.5	84	4.7
IDENO(1,2,3-cd)PYRENE	N 25		N 27		N 41		N 38	
DIBENZO(a,h)ANTHRACENE	N 25		N 27		N 41		N 38	
BENZO(g,h,i)PERYLENE	N 25		N 27		N 41		N 38	

SD = Standard Deviation
N = Not detectable at the given detection limit
< = Below detection limit in one or two samples

Table K-7
PAH CONCENTRATIONS IN SOIL PAN P2
(mg/dry kg)

	Initial		28 Days		56 Days		84 Days	
Compound	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
NAPHTHALENE	290	59	42	1.5	< 41	0.9	31	6.5
ACENAPHTHYLENE	N 25		N 27		N 40		N 18	
ACENAPHTHENE	1100	170	610	7.6	140	13.0	40	8.3
FLUORENE	680	130	210	4.9	70	0.7	27	3.7
PHENANTHRENE	1500	170	460	15.0	210	16.0	110	13.0
ANTHRACENE	380	100	180	21.0	89	12.0	76	8.4
FLUORANTHENE	940	100	1100	14.0	690	23.0	410	49.0
PYRENE	660	88	810	11.0	610	22.0	510	52.0
BENZO(a)ANTHRACENE	170	21	230	2.7	170	7.1	120	12.0
CHRYSENE	280	11	230	4.2	250	3.9	230	16.0
B(b)F + B(k)F	170	20	230	30.0	170	6.4	170	14.0
BENZO(a)PYRENE	71	17	83	2.4	110	5.6	87	7.2
IDENO(1,2,3-cd)PYRENE	N 25		N 27		N 40		N 36	
DIBENZO(a,h)ANTHRACENE	< 30	7	N 27		N 40		N 18	
BENZO(g,h,i)PERYLENE	N 25		N 27		N 40		N 36	

SD = Standard Deviation
N = Not detectable at the given detection limit
< = Below detection limit in one or two samples

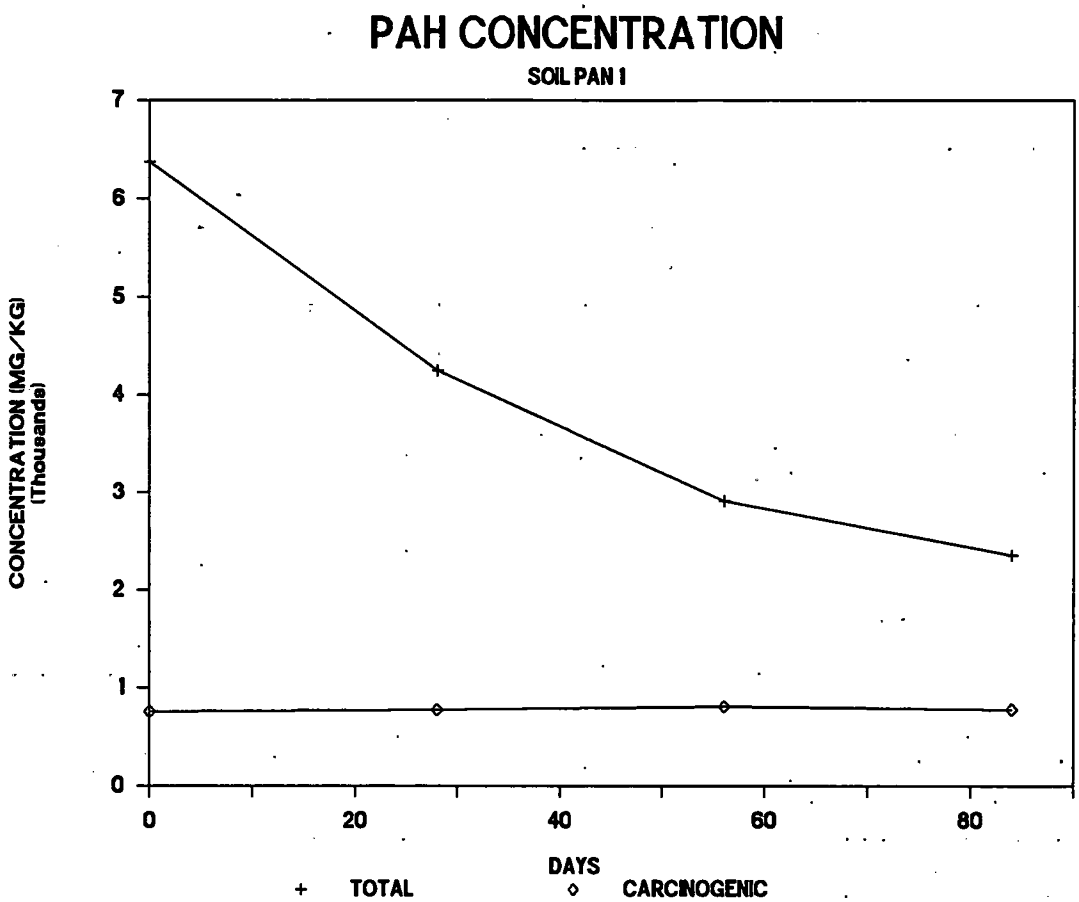

FIGURE K-3
TOTAL PAH CONCENTRATION
SOIL PAN 1
MOSS-AMERICAN FS

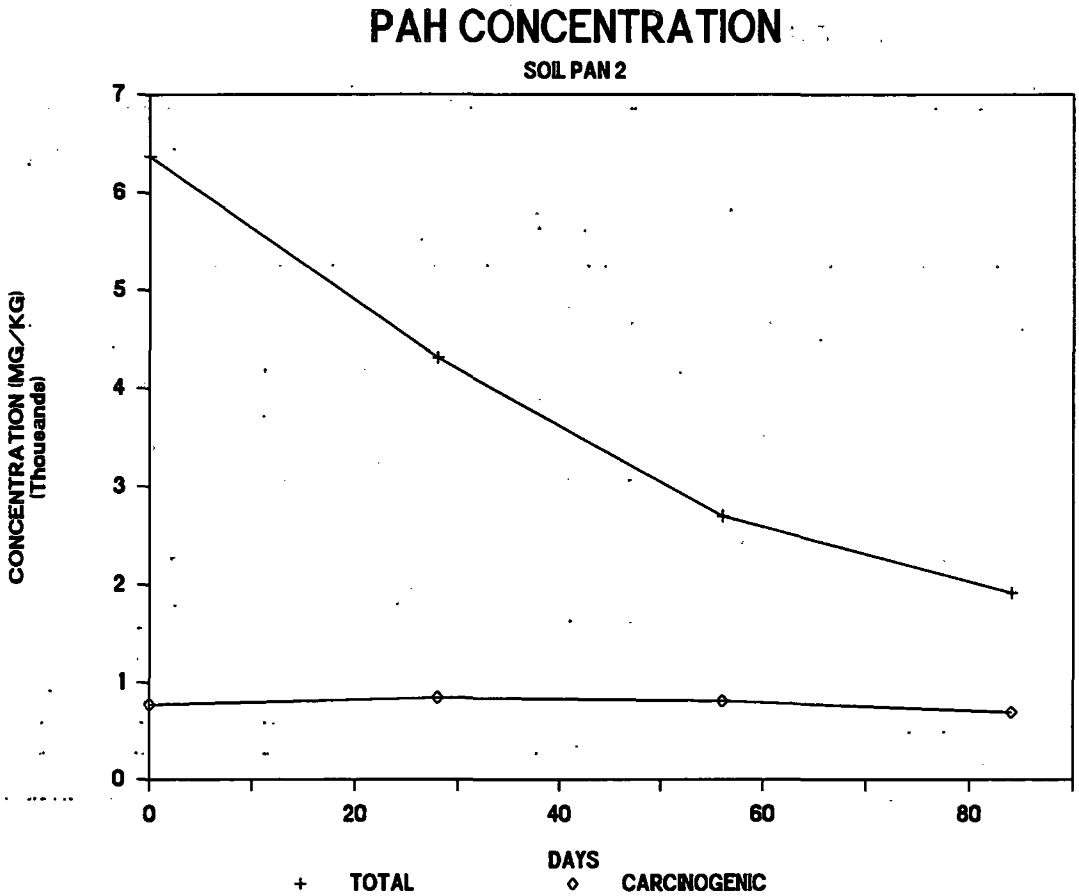

FIGURE K-4
TOTAL PAH CONCENTRATION
SOIL PAN 2
MOSS-AMERICAN FS

Table K-8
PAH DEGRADATION KINETICS IN SOIL PAN P1

Compound	Co (mg/kg)	RE (%)	k (1/day)	r^2	n	HALF LIFE (days)	STAT SIG (5%)
NAPHTHALENE	250	91	0.0245	0.71	10	28	*
ACENAPHTHYLENE	20	-	-	-	-	-	-
ACENAPHTHENE	1000	92	0.0319	0.96	12	22	*
FLUORENE	650	93	0.0325	0.96	12	21	*
PHENANTHRENE	1600	91	0.0289	0.95	12	24	*
ANTHRACENE	460	82	0.0208	0.87	12	33	*
FLUORANTHENE	920	40	0.0067	0.60	12	100	*
PYRENE	720	11	0.0020	0.24	12	340	
BENZO(a)ANTHRACENE	160	12	0.0021	0.13	12	330	
CHRYSENE	270	4	0.0002	0.04	12	3500	
B(b)F + B(k)F	150	0	0.0000	-	12	-	
BENZO(a)PYRENE	98	14	0.0016	0.11	12	430	
IDENO(1,2,3-cd)PYRENE	ND	-	-	-	-	-	-
DIBENZO(a,h)ANTHRACENE	ND	-	-	-	-	-	-
BENZO(g,h,i)PERYLENE	ND	-	-	-	-	-	-

Co = Initial concentration
RE = Removal efficiency over 84 days
k = First order reaction rate constant
r^2 = Coefficient of correlation
n = Number of data included in the regression;
Half-Life = Assumes first order kinetics
ND = Not detectable
* = PAH removal rate is statistically significant at the 5% level

Table K-9
PAH DEGRADATION KINETICS IN SOIL PAN P2

Compound	Co (mg/kg)	RE (%)	k (1/day)	r^2	n	HALF LIFE (days)	STAT SIG (5%)
NAPHTHALENE	290	89	0.0236	0.69	10	29	*
ACENAPHTHYLENE	ND	-	-	-	-	-	-
ACENAPHTHENE	1100	96	0.0406	0.97	12	17	*
FLUORENE	690	96	0.0422	0.90	12	16	*
PHENANTHRENE	1500	93	0.0314	0.98	12	22	*
ANTHRACENE	380	80	0.0195	0.90	12	36	*
FLUORANTHENE	940	56	0.0107	0.73	12	65	*
PYRENE	660	23	0.0038	0.42	12	180	*
BENZO(a)ANTHRACENE	170	29	0.0047	0.43	12	150	*
CHRYSENE	280	18	0.0018	0.37	12	380	*
B(b)F + B(k)F	170	2	0.0014	0.08	12	500	
BENZO(a)PYRENE	71	0	0.0000	-	12	-	
IDENO(1,2,3-cd)PYRENE	ND	-	-	-	-	-	-
DIBENZO(a,h)ANTHRACENE	30	40	-	-	-	-	-
BENZO(g,h,i)PERYLENE	ND	-	-	-	-	-	-

Co = Initial concentration
RE = Removal efficiency over 84 days
k = First order reaction rate constant
r^2 = Coefficient of correlation
n = Number of data included in the regression
Half-Life = Assumes first order kinetics
ND = Not detectable
* = PAH removal rate is statistically significant

the addition of manure to P2). Consequently, the results of these two soil pan treatment systems can be discussed together. Contaminant removal was relatively rapid for 2- and 3-ring PAHs, except for fluoranthene, with 84-day removal efficiencies in the 80 to 95 percent range. Fluoranthene removal was less efficient, at around 50 percent. The measurable 4- and 5-ring PAHs (including benzo[a]anthracene, chrysene, benzo[b]fluoranthene + benzo[k]fluoranthene, and benzopyrene) were removed slowly or not at all (indeno[1,2,3-cd]pyrene, dibenzo[a,h]anthracene, and benzo[g,h,i]perylene were generally not detectable). Total PAH concentrations were reduced by approximately 65 to 70 percent.

The first order kinetic parameters can be grouped similarly (Tables K-8 and K-9). The 2- and 3-ring PAHs generally followed first order kinetics ($r^2 > 0.80$) and had short half-lives of 16 to 36 days. Fluoranthene fit the first order model less well ($r^2 \sim 0.65$) and was somewhat more resistant to degradation ($t_{1/2}$ = 65 to 103 days). The 4- and 5-ring PAHs generally were not accurately modelled by first order kinetics ($r^2 < 0.50$) and were refractory, with half-lives ranging from approximately 150 days to nearly 9 years or longer.

PAH Removal in Sediment Pans

Tables K-10 and K-11 list average PAH concentrations and Tables K-12 and K-13 provide a kinetic analysis of data for sediment pans P3 and P4, respectively. P3 and P4 treatments differed only in that P4 was amended with manure, and PAH removal characteristics were similar for the two systems. Figure K-5 and K-6, illustrate the reduction of PAH concentration over time. The measurable naphthalene removal efficiency of approximately 70 percent was probably constrained by analytical detection limits. Removal of all other 2- and 3-ring PAHs over 84 days exceeded 90 percent. The removal efficiencies of 4- and 5-ring PAHs from sediment pans (P3 and P4) were considerably higher than from soil pans. Only benzopyrene in P3 was not substantially reduced (RE = 23%) in the sediment pan systems. Total PAHs were reduced by 87 percent.

With a few exceptions, PAH removal in the sediment pans was described very well by the first order rate model. Measured half-lives ranged from 10 days (for 2-ring PAHs) to approximately 50 days for 5-ring PAHs.

Comparison of Solid Phase Pan Treatments

The difference in treatments for a given sample type was the addition of manure (pans P2 and P4). Inorganic nutrients (N and P) were added to all solid phase pans. Manure can provide both organic and inorganic nutrients, enhance water holding capacity, and improve soil texture. The latter two properties, while being fairly insignificant in a laboratory-scale study, can be particularly important in full-scale treatment. The Moss-American soil and sediment samples consisted of sticky clays with a strong tendency to form stubborn clumps; therefore, it is likely that manure or

Table K-10
PAH CONCENTRATIONS IN SEDIMENT PAN P3
(mg/dry kg)

Compound	Initial		28 Days		56 Days		84 Days	
	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
NAPHTHALENE	7.3	1.1	3.9	0.3	N 3.7		2.2	a
ACENAPHTHYLENE	N 2.9		N 2.7		N 3.7		N 1.8	a
ACENAPHTHENE	44.0	5.2	6.5	1.1	N 3.7		N 1.8	a
FLUORENE	42.0	4.6	5.5	0.8	N 3.7		N 1.8	a
PHENANTHRENE	140.0	13.0	18.0	2.6	7.6	1.7	5.5	a
ANTHRACENE	48.0	4.0	7.0	0.6	< 4.1	0.6	2.7	a
FLUORANTHENE	89.0	9.8	41.0	2.9	15.0	5.6	8.1	a
PYRENE	80.0	7.4	35.0	2.0	14.0	4.4	12.0	a
BENZO(a)ANTHRACENE	21.0	1.8	13.0	0.2	7.0	1.4	4.5	a
CHRYSENE	30.0	2.1	15.0	0.5	11.0	5.9	13.0	a
B(b)F + B(k)F	18.0	1.3	21.0	2.2	15.0	2.7	9.8	a
BENZO(a)PYRENE	7.6	2.0	8.7	0.8	12.0	0.9	5.9	a
IDENO(1,2,3-cd)PYRENE	N 2.9		N 5.3		N 3.7		N 4.9	a
DIBENZO(a,h)ANTHRACENE	N 29.0		N 2.7		N 3.7		N 1.8	a
BENZO(g,h,i)PERYLENE	N 2.9		N 2.7		N 3.7		N 4.9	a

SD = Standard Deviation
N = Not detectable at the given detection limit
< = Below detection limit in one or two samples
a = Average of two samples

Table K-11
PAH CONCENTRATIONS IN SEDIMENT PAN P4
(mg/dry kg)

Compound	Initial MEAN	Initial SD	28 Days MEAN	28 Days SD	56 Days MEAN	56 Days SD	84 Days MEAN	84 Days SD
NAPHTHALENE	8.3	2.1	4.5	0.2	< 4.0	0.2	N 2.0	
ACENAPHTHYLENE	N 2.8		N 2.6		N 3.9		N 2.0	
ACENAPHTHENE	56.0	4.3	6.5	0.7	N 3.9		N 2.0	
FLUORENE	54.0	9.0	5.8	0.5	N 3.9		N 2.0	
PHENANTHRENE	115.0	22.0	21.0	1.5	7.9	1.1	6.1	0.9
ANTHRACENE	37.0	8.5	7.3	0.2	N 3.9		3.3	1.6
FLUORANTHENE	106.0	6.3	51.0	0.9	19.0	3.4	10.0	0.3
PYRENE	76.0	4.4	43.0	0.9	19.0	3.6	13.0	2.7
BENZO(a)ANTHRACENE	23.0	3.1	16.0	0.3	8.1	1.0	5.2	0.2
CHRYSENE	30.0	4.6	18.0	0.8	16.0	0.8	13.0	0.7
B(b)F + B(k)F	22.0	5.1	21.0	0.8	14.0	1.2	13.0	1.9
BENZO(a)PYRENE	14.0	3.3	16.0	1.3	13.0	0.6	5.6	1.5
IDENO(1,2,3-cd)PYRENE	N 5.6		N 5.3		N 3.9		N 5.1	
DIBENZO(a,h)ANTHRACENE	N 28.0		N 2.6		N 3.9		N 2.0	
BENZO(g,h,i)PERYLENE	N 2.8		N 2.6		N 3.9		N 3.8	

SD = Standard Deviation
N = Not detectable at the given detection limit
< = Below detection limit in one or two samples

Table K-12
PAH DEGRADATION KINETICS IN SEDIMENT PAN P3

Compound	Co (mg/kg)	RE (%)	k (1/day)	r^2	n	HALF LIFE (days)	STAT SIG (5%)
NAPHTHALENE	7	70	0.0141	0.89	8	49	*
ACENAPHTHYLENE	ND	-	-	-	-	-	-
ACENAPHTHENE	44	>96	0.0680	0.99	6	10	*
FLUORENE	42	>96	0.0723	0.99	6	10	*
PHENANTHRENE	140	96	0.0397	0.87	11	17	*
ANTHRACENE	48	94	0.0333	0.84	9	21	*
FLUORANTHENE	89	91	0.0296	0.96	11	23	*
PYRENE	80	85	0.0247	0.90	11	28	*
BENZO(a)ANTHRACENE	21	78	0.0188	0.97	11	37	*
CHRYSENE	30	57	0.0118	0.53	11	59	*
B(b)F +B(k)F	18	47	0.0074	0.64	11	94	*
BENZO(a)PYRENE	8	23	0.0000	-	11	-	-
IDENO(1,2,3-cd)PYRENE	ND	-	-	-	-	-	-
DIBENZO(a,h)ANTHRACENE	ND	-	-	-	-	-	-
BENZO(g,h,i)PERYLENE	ND	-	-	-	-	-	-

Co = Initial concentration
RE = Removal efficiency over 84 days
k = First order reaction rate constant
r^2 = Coefficient of correlation
n = Number of data included in the regression;
Half-Life = Assumes first order kinetics
ND = Not detectable
* = PAH removal rate is statistically significant

Table K-13
PAH DEGRADATION KINETICS IN SEDIMENT PAN P4

Compound	Co (mg/kg)	RE (%)	k (1/day)	r^2	n	HALF LIFE (days)	STAT SIG (5%)
NAPHTHALENE	8	>76	0.0159	0.93	10	44	*
ACENAPHTHYLENE	ND	-	-	-	-	-	-
ACENAPHTHENE	56	>96	0.0769	1.00	6	9	*
FLUORENE	54	>96	0.0795	0.99	6	9	*
PHENANTHRENE	120	95	0.0476	0.97	9	15	*
ANTHRACENE	37	91	0.0274	0.83	9	25	*
FLUORANTHENE	110	90	0.0283	0.99	12	24	*
PYRENE	76	82	0.0218	0.95	12	32	*
BENZO(a)ANTHRACENE	23	78	0.0184	0.97	12	38	*
CHRYSENE	30	56	0.0090	0.84	12	77	*
B(b)F + B(k)F	22	42	0.0071	0.71	12	98	*
BENZO(a)PYRENE	14	61	0.0108	0.58	12	64	*
IDENO(1,2,3-cd)PYRENE	ND	-	-	-	-	-	-
DIBENZO(a,h)ANTHRACENE	ND	-	-	-	-	-	-
BENZO(g,h,i)PERYLENE	ND	-	-	-	-	-	-

Co = Initial concentration
RE = Removal efficiency over 84 days
k = First order reaction rate constant
r^2 = Coefficient of correlation
n = Number of data included in the regression;
Half-Life = Assumes first order kinetics
ND = Not detectable
* = PAH removal rate is statistically significant

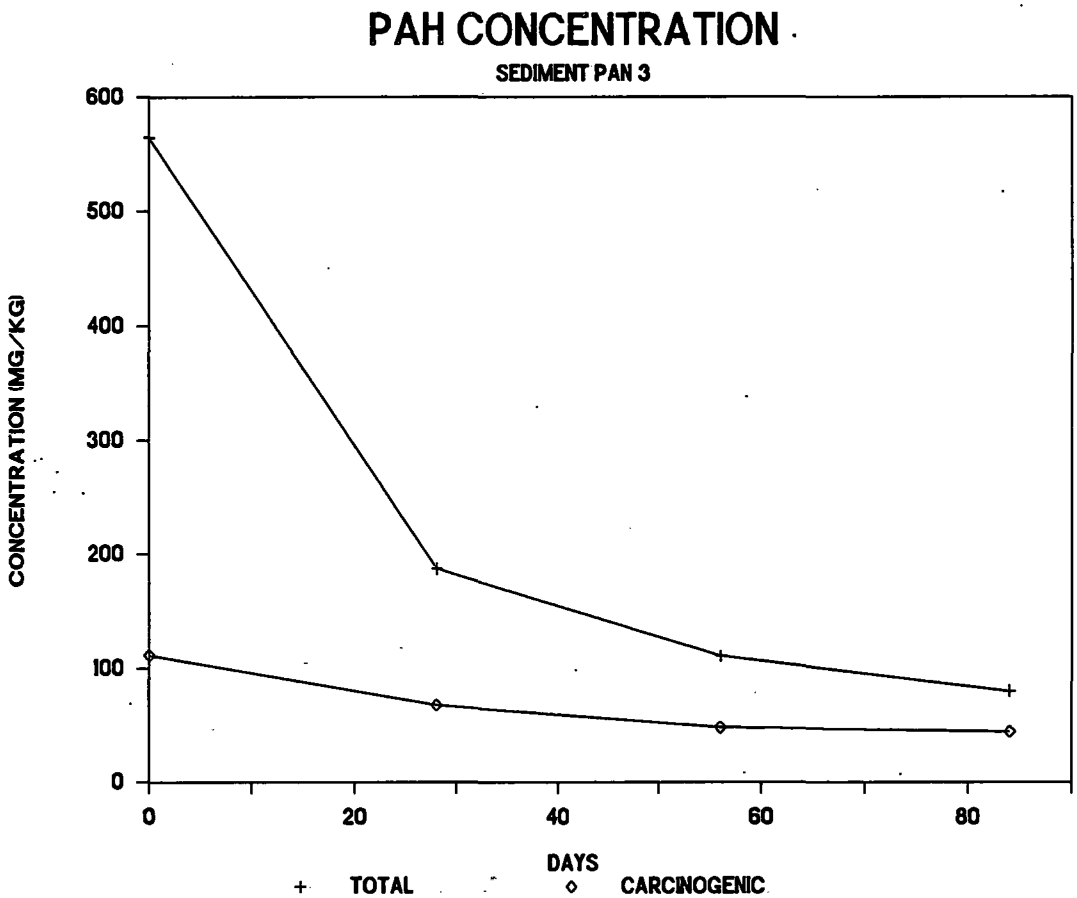

FIGURE K-5
TOTAL PAH CONCENTRATION
SEDIMENT PAN 3
MOSS-AMERICAN FS

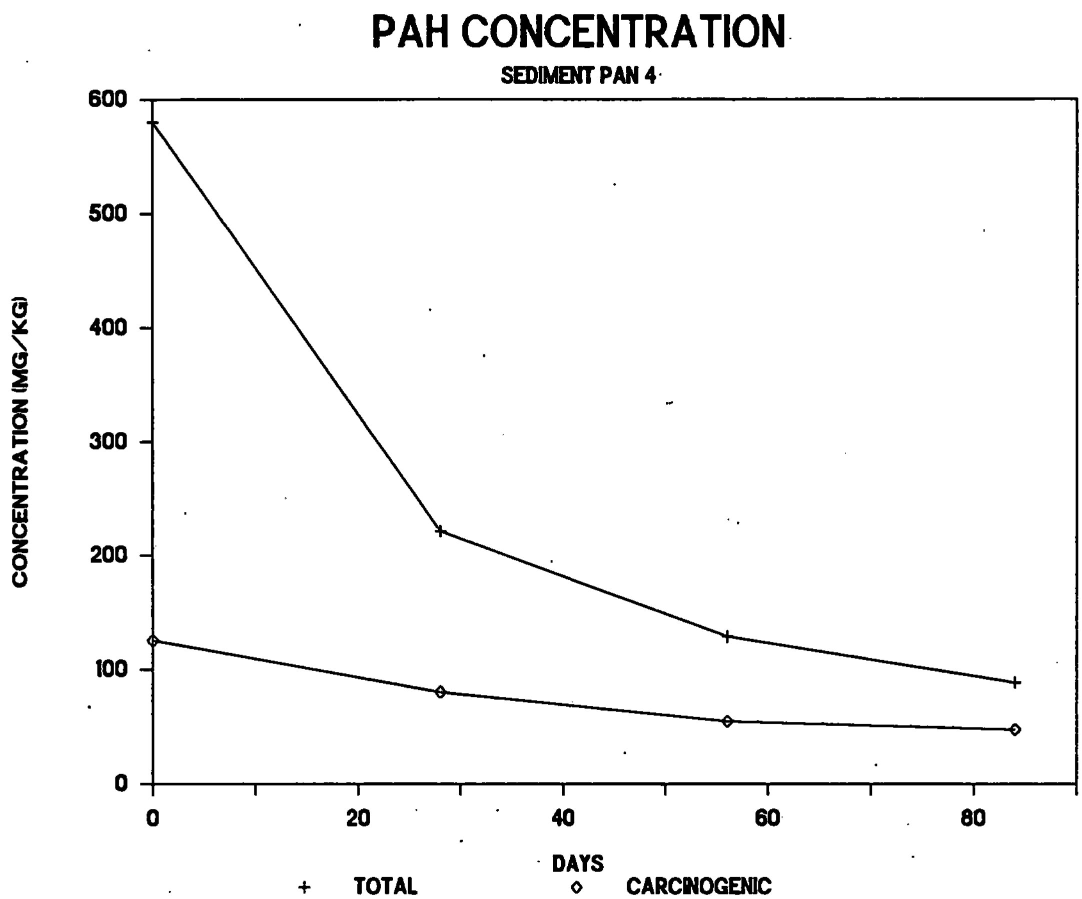

FIGURE K-6
TOTAL PAH CONCENTRATION
SEDIMENT PAN 4
MOSS-AMERICAN FS

some other bulking agent would be added to improve its character if solid phase treatment were conducted at the site.

Results of the soil respiration study (Task 2) indicated that addition of manure increased overall respiration rates of soil and sediment samples but that respiration of organic contaminants in those samples may have actually been lower than in nonmanure-amended samples (the additional O_2 uptake being due to metabolism of manure-organic compounds). Therefore, the purpose of evaluating the effect of manure addition was not only to determine if PAH degradation would be accelerated (since moisture and tilling could be kept uniform on the lab-scale), but to determine if PAH degradation would be decelerated (since manure addition would probably be employed in full-scale solid phase treatment).

Comparisons of Tables K-8 to K-9 and K-12 to K-13 show addition of manure to solid phase pans had very little effect on PAH removal. Treatment was virtually the same in manure-amended and nonmanure-amended systems containing the same sample type.

Nutrients in Solid Phase Pans

As was observed in the slurry flask study, only a portion of the added nutrients was measurable by the analytical methods employed. Sufficient nitrogen appeared to remain readily available throughout the study and phosphorus availability should not have limited contaminant degradation.

Treatment Evaluation

This treatability study demonstrated the potential for both slurry bioreactor and land treatment technologies to biologically reduce levels of contaminants in soil and sediment from the Moss-American site. Several observations were similar to those reported in literature regarding treatability of PAHs:

- An acclimated population of microbes is already present in both sol and sediment.
- Degradation half-lives were less in the slurry test than the pan (land treatment) test.
- The instantaneous degradation rate appears to be proportional to the concentration.

The slurry bioreactor technology would appear to achieve the desired level of treatment in a much shorter time than land treatment. Actual degradation rates can differ significantly from bench scale studies, however, should either of these options be pursued for the Moss-American site, then pilot studies should be conducted to develop design-level information.

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