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FEASIBILITY STUDY ADDENDUM REPORT
FOR THE
REMEDIAL INVESTIGATION/FEASIBILITY STUDY
AT THE
NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT
FRIDLEY, MINNESOTA

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EXECUTIVE SUMMARY

The Naval Industrial Reserve Ordnance Plant (NIROP) is located in an industrial area in the northern portion of the Minneapolis/St. Paul Metropolitan Area within the city limits of Fridley, Minnesota. Advanced naval weapons systems are designed and manufactured at the NIROP. The northern portion of the facility is government-owned and operated by a private contractor (FMC Corporation), and the remainder of the facility is owned independently by FMC.

A sequence of remedial investigations and remedial actions have been performed at the NIROP and the abutting FMC-owned property. Investigations began at the NIROP after the initial discovery in March 1981 of a potential hazardous substance release from the facility.

In March 1982, the U.S. Navy implemented the Navy Assessment and Control of Installation Pollutants (NACIP) program to identify and control environmental contamination from past use and disposal of hazardous substances at the NIROP. The NACIP program is designed to conform to the scope and purposes of the National Oil and Hazardous Substances Contingency Plan (NCP), known as the Superfund program, established by the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA), of 1986.

In implementing the NACIP program, the U.S. Navy has agreed to conform to the requirements of the State of Minnesota Environmental Response and Liability Act (MERLA), as authorized by Minnesota Chapter

615B.17 and 115B.18. The MERLA is also designed to conform to the scope and purpose of CERCLA.

Under the authority of MERLA, the Minnesota Pollution Control Agency (MPCA) issued a Request for Response Action (RFRA) on May 22, 1984, to the Navy, for the NIROP site. Requested response actions included both a Remedial Investigation (RI) and a Feasibility Study (FS) as specified in the NCP (40 CFR Subpart 300.68 and Subpart 300.70).

The services of the United States Army Corps of Engineers (USACE) were obtained by the U.S. Navy to manage the initial site investigation and remedial actions, and to complete the RI/FS requested by the MPCA in the RFRA. The USACE retained the services of RMT, Inc., in June 1986 to assist the USACE with completion of the RI/FS. RMT prepared and issued an Interim Report in May 1987, a RI Report in June 1987, and an FS Report in July 1988.

To address the need for further information defining the nature and extent of contamination, RMT prepared and issued a Conceptual Workplan for Additional Investigations in June 1987. Implementation of this Conceptual Workplan, as approved by the U.S. Navy and USACE, was completed by RMT between November 1987 and March 1988. The work consisted of installation and sampling of 16 new ground water monitoring wells, soil pore gas testing using a portable gas chromatograph, installation of two shallow aquifer pumping wells (one for determining aquifer hydraulic properties and one for a contaminant time-series test), and sampling of two storm sewers. The results of these

additional field investigations were included in the addendum to the RI Report, issued in July 1988.

The FS Report, based on the information presented in the RI Report, was issued in July 1988. Following the steps under the CERCLA process, several potentially applicable remedial technologies were identified and screened. Technologies which passed through the screening step were then used to develop an initial list and description of feasible remedial action alternatives. An initial screening of these remedial alternatives was then performed, based on evaluation factors consisting of the relative degree of environmental protection provided, potential adverse environmental effects from implementation of the alternative, technical feasibility, and a rough cost comparison.

Based on the initial screening of the alternatives, three remedial alternatives were recommended for detailed evaluation and comparison. These three alternatives consisted of two source control alternatives and one alternative addressing management of contaminant migration.

The two source control alternatives were directed at remediation near the site of Trench 3 in the former waste disposal area at the north end of the plant. These alternatives involved placing a concrete cap over the Trench 3 area, or installation of an in-situ vacuum extraction system in this same general area.

The management of migration alternative which was recommended for detailed evaluation involved a ground water pumping, treatment, and disposal system. Under this alternative, five ground water extraction wells would be installed across the site. All extracted ground water would be treated in a new treatment system at the NIROP, then disposed

by discharge to either a storm sewer or to a leaching field constructed above and upgradient to the former Trench 3 area.

To incorporate the findings and conclusions of the RI Addendum Report, RMT has prepared this FS Addendum Report. This FS Addendum Report also addresses the ongoing changes in the policy of the Minnesota Pollution Control Agency (MPCA) in the areas of surface water and air quality.

The alternatives presented in this FS Addendum Report are modified versions of those in the FS Report. Sections 2 and 3 of the FS Addendum Report supplement the corresponding sections of the FS Report, while Section 5 in this report replaces Section 5 of the FS Report.

Findings from the RI Addendum Report have affected the development and evaluation of the remedial actions in the following areas:

- The pumpout system of Alternative F (revised geological and ground water flow data).
- The pretreatment necessary for the air stripping treatment system of Alternative F (bench-scale testing).
- The size of the applicable area of the source control alternative (soil pore gas survey).

MPCA policies are undergoing major changes in the standards for surface water quality and air quality. No new alternatives were considered necessary in response to these policy changes. However, components and the scheduling of the implementation of Alternative F, the management of migration alternative, were revisited in order to develop an appropriate alternative with the flexibility to respond to these ongoing changes. The primary revisions to Alternative F resulting from the modified MPCA policy are as follows:

- A phased approach has been introduced into the implementation of Alternative F, consisting of an assemblage of pumping and disposal technologies in the first phase, and three options for pumping, treatment, and disposal technologies in the second phase.

- Technologies that were screened out in the FS Report have been re-evaluated. The sanitary sewer disposal technology has been incorporated into Phase 1 of Alternative F. It was formerly part of Alternative E and was screened out in the FS Report.

- Granular activated carbon (GAC) is evaluated as one of two treatment technologies for Phase 2 of Alternative F. It was screened out as a technology in the FS Report based on cost. It is assumed that the nondegradation policy for disposal to surface water will require a greater level of treatment before surface water disposal is permitted. GAC becomes more cost effective when higher levels of treatment are needed.

- Air stripping treatment has been modified from a single air stripper to a two-stage air stripper system, potentially requiring vapor-phase GAC treatment for the air emissions.

- The in-situ vacuum extraction source control alternative potentially will require vapor-phase GAC treatment, based on the results of a preliminary screening model run by the MPCA. Further evaluation is needed to determine whether vapor-phase treatment is actually required for either air stripping or in-situ vacuum extraction.

The findings of the RI Addendum Report identified additional areas of shallow soil contamination in the northern portion of the NIROP. However, shallow soil source areas were not identified in the eastern portion, although high levels of ground water contamination were identified at depths greater than 50 feet below grade. In order to respond to the uncertainty over the source of the ground water contamination in the eastern portion of the site and to more fully explore the northern portion, it is recommended in this report that the source control alternatives not be implemented until the source areas are more well defined. Toward this end, three additional upgradient

monitoring wells are proposed for the monitoring program of the remediation. Additionally, the source area evaluation could be performed during the Phase 1 implementation of Alternative F. Alternative F includes the installation of one additional source control well (AT-4), which would operate along with source control well AT-1 (previously installed) during Phase 1 operation, which could be used to provide information regarding the extent of the ground water contamination in the source areas.

Preliminary cost estimates were revisited for this FS Addendum Report. The costs for all alternatives were shown to be minimally sensitive to operating life and interest rate. As in the FS Report, the no-action and source control alternatives are estimated to have 30-year present work values in the range of $1 million, including monitoring.

The three pumping options are estimated to have 30-year present worth values in the range of $4 to $6 million, including monitoring. Option 1, air stripping with vapor-phase GAC, is estimated to be marginally cheaper than the other two options, although the cost difference would increase if vapor-phase GAC were not needed. Option 3, direct discharge to the sanitary sewer for all 30 years, is estimated to be the most expensive of the three. There is additional variability in this option as the cost for sanitary disposal is subject to the pricing decisions of the city of Fridley and the Metropolitan Waste Control Commission. However, the absence of treatment minimizes the potential for system failures. The difference among the costs estimated for the Alternative F options is within the range of accuracy of the estimates. Thus, although Option 1 is estimated to be the least

expensive of the three, Options 2 and 3 cannot be eliminated solely on the basis of cost.

1. INTRODUCTION

1.1 Background

RMT, Inc., has been retained by the Omaha District of the U.S. Army Corps of Engineers (USACE) to complete a Feasibility Study (FS) Report for the Naval Industrial Reserve Ordnance Plant (NIROP) located in Fridley, Minnesota.

A draft FS Report was issued in December 1987, based on the findings and conclusions of the Remedial Investigation (RI) Report issued by RMT in June 1987. Following receipt of review comments on the draft report from the USACE, U.S. Navy, and the Minnesota Pollution Control Agency (MPCA), a final FS Report was prepared and issued in July 1988 (RMT, 1988b).

Remedial action alternatives were developed and evaluated in the FS Report based on the information presented in the RI Report. The selection of alternatives for detailed evaluation was also based on the Minnesota Pollution Control Agency policy that was in effect at the time of the development of the alternatives.

An RI Addendum Report, issued in July 1988, presented revised findings and conclusions concerning the geology and ground water flow conditions in the vicinity of the NIROP. Revised findings and conclusions were also presented concerning the extent of ground water contamination and contaminant source areas.

MPCA policy is currently in a transition in areas that directly affect the evaluation of remedial action alternatives. The two main areas are the management of surface water quality and air quality.

Environmental standards are evolving that represent a policy shift away from technology limitations and toward a risk-based approach.

This FS Addendum Report has been prepared to present a re-evaluation of the remedial action alternatives developed in the FS Report. This re-evaluation incorporates the findings and conclusions of the RI Addendum Report and the evolving environmental standards of the MPCA.

1.2 Purpose and Scope

July 1988 FS Report

The purpose of the FS Report was to develop and evaluate remedial action alternatives (RAA) for the NIROP site in Fridley, Minnesota. The alternatives were evaluated to permit the USACE to recommend the most appropriate remedial action to mitigate the release or threatened release of hazardous substances from the NIROP site.

The scope of the FS Report consisted of the development and screening of remedial action technologies and alternatives, and the performance of a detailed evaluation of selected alternatives.

FS Addendum Report

The purpose of this FS Addendum Report is to revisit the remedial action alternatives (RAA) that were presented in the FS Report, using the findings and conclusions of the RI Addendum Report and incorporating the current MPCA policies.

The scope of the report consists of the following tasks:

- Revisions to the goals of the remedial action, based on current MPCA policy.

- Revisions to the screening of alternatives and the development of alternatives for detailed evaluation, based on a re-evaluation of the assumptions used in the FS Report.

- Updating the evaluation of the revised RAA.

1.3 Overview of Report

This FS Addendum generally follows the format of the July 1988 FS Report. The alternatives presented in Section 4 of the FS Addendum Report have been substantially revised from the alternatives presented in the FS Report. The description of the revised alternatives, presented in Section 4 and the evaluation of the alternatives, presented in Section 5, replace the description and evaluation of alternatives presented in the FS Report. However, the FS Report is referenced in these sections of the FS Addendum Report to highlight similarities and differences in the alternatives presented in the two reports. Information presented in Sections 2 (Introduction) and 3 (Screening) of the FS Addendum supplement the information presented in the corresponding sections of the FS Report.

2. FEASIBILITY STUDY INTRODUCTION

2.1 Overview

The primary objective of this section of the Feasibility Study (FS) Addendum Report is to summarize the key findings and conclusions of the Remedial Investigation (RI) Addendum Report that may affect the evaluation of the alternatives. This section also presents findings regarding additional applicable or relevant and appropriate requirements (ARARs) identified in 1988, along with findings regarding potential contaminant receptors. The RI Addendum Report supports the following key findings and conclusions of the RI Report:

- TCE was still found to be the best indicator for evaluating remedial alternatives.
- The general direction of ground water flow is still to the southwest.
- On-site source areas were found to be generally the same as those identified in the RI Report, with some modifications and expansions discussed in Section 2.3.4 of this report.

The RI Addendum Report made the following modifications to key findings and conclusions of the RI Report:

- The geology of the local unconsolidated aquifer was re-interpreted, and ground water flow parameters were modified.
- Benzene was not detected at any of the 52 wells monitored.

The basis for the RI Addendum Report was the additional remedial investigation field work completed between November 1987 and March 1988. This field work included soil pore gas sampling to evaluate several potential source areas of VOC contamination. Eighteen (18)

wells were installed and sampled, along with existing wells, to further define the magnitude and direction of ground water flow and the lateral and vertical extent of ground water contamination. Aquifer pumping tests were conducted in the southeast and southwest corners of the NIROP site. The pumping test to the southwest was performed to evaluate hydraulic properties of the aquifer. Results of this test were used to evaluate the rate of contaminated ground water flow through the site, and to better estimate the effectiveness of wells proposed for management of contaminant migration. The pumping test to the southeast was performed to evaluate whether ground water contamination identified in the area of well 9-S in the RI Report was due to on-site or off-site sources. The results of this work are presented in the RI Addendum Report submitted in July 1988.

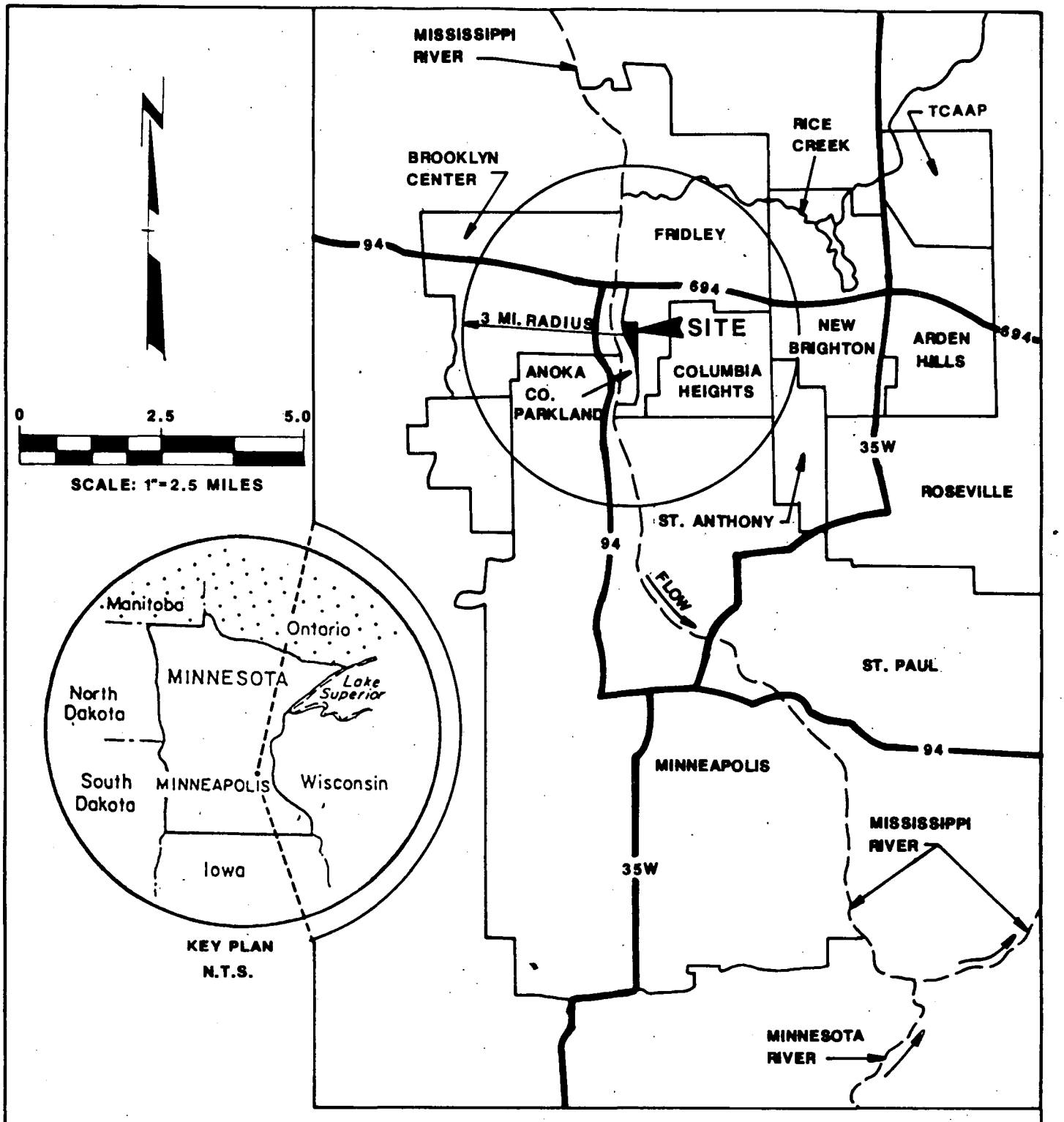
2.2 Site Background Information

A site location map is included as Figure 2-1.

2.2.1 Regional and Local Features

Regional Features

The Twin Cities Army Ammunition Plant (TCAAP), discussed in the FS Report and RI Addendum Report and shown on Figure 2-1, is a potential source of ground water contamination upgradient of the NIROP. As presented in the New Brighton/Arden Hills/St. Anthony (Alternate Water Supply) Superfund Record of Decision (ROD), a plume of trichloroethylene (TCE) and other volatile organic compounds (VOCs) had migrated over half



NOTE: USEPA SUPERFUND SITES ARE IDENTIFIED AT THE TCAAP AND AT NEW BRIGHTON/ ST. ANTHONY/ARDEN HILLS.

LOCATION MAP

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AUG 26 1988 FIGURE 2-1

the 5-mile distance between the vicinity of the TCAAP and the NIROP in the Prairie du Chien - Jordan (PCJ) aquifer, as of May 1985 (USEPA, 1986a). The USEPA identified TCE as the most appropriate indicator chemical for the ground water studies as it was the most prevalent compound with the highest concentrations.

Local Features

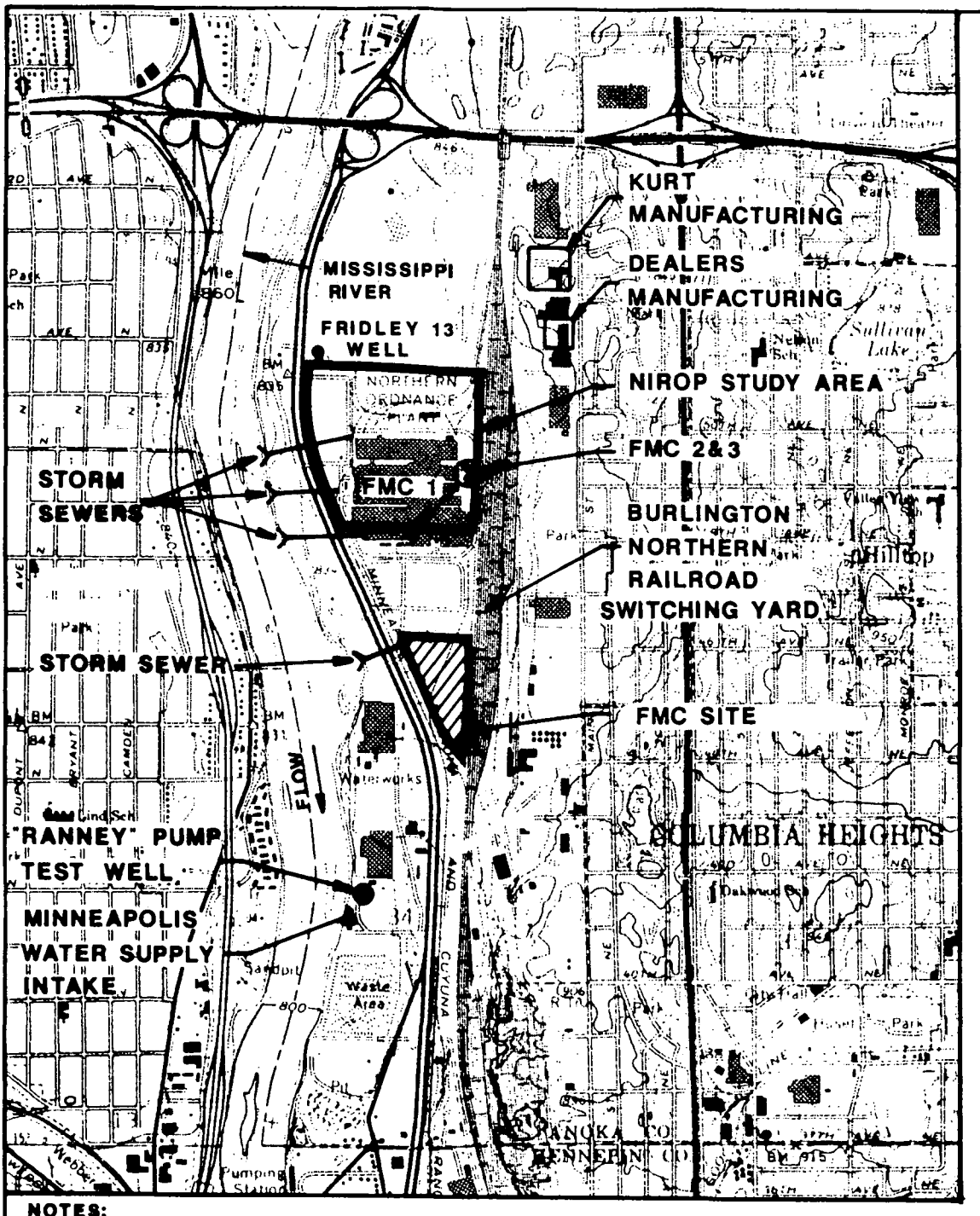
Local features in the vicinity of the NIROP are shown on Figure 2-2. No additional local features were identified in the RI Addendum Report. However, it was reported that ground water extraction wells at the Kurt Manufacturing Company are currently operational. In addition, the Dealer's Manufacturing site is in the preliminary assessment stage of investigation.

The RI Addendum Report found that ground water quality data collected to date is inconclusive regarding whether these two sites are currently contributing to ground water contamination at the NIROP.

2.2.2 Chronology of Remedial Work and Investigations

From November 1987 through February 1988, RMT, Inc., conducted additional investigations at the NIROP. These investigations included the following major work elements:

- A soil pore-gas survey.
- Installation of 16 new ground water monitoring wells.
- Installation of two (2) new pumping/monitoring wells and performance of two aquifer pumping tests and in-situ permeability tests.



NOTES:

(1) KURT MFG. AND THE FMC SITE ARE U.S. EPA SUPERFUND SITES.

(2) DEALERS MFG. IS A SITE WITH SUSPECTED DISPOSAL OF NUMEROUS DRUMS OF TCE INTO SOIL.

SOURCE:
USGS MINNEAPOLIS NORTH QUADRANGLE 1967; PHOTO-REVISED 1972 AND 1980.

REGIONAL SITE MAP

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FIGURE 2-2

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- A comprehensive ground water sampling round including the 52 monitoring wells on and adjacent to the NIROP property, with water level measurements at all the wells.

- Sampling of two storm sewers which receive flow from the NIROP.

- Analysis of soil samples from the borings installed for monitoring well construction for physical properties of the soils.

- Bench-scale tests of ground water samples collected during the aquifer pumping tests to evaluate chemical characteristics of the ground water.

2.2.3 Historical Description

A private airfield was located north of the existing NIROP property. It was abandoned sometime in the 1970's.

2.2.4 Conflicting or Missing Information

Several information deficiencies identified in the June 1987 RI Report have been corrected, as noted in Section 2.1.4 of the RI Addendum Report.

2.2.5 Regional Physiography

(No changes to the July 1988 FS Report).

2.2.6 Hydrogeology

This section highlights the key modifications to the hydrogeologic data presented in the RI Addendum Report.

Geology

The following two conclusions of the RI Addendum Report regarding the unconsolidated soil deposits were incorporated into the evaluation of the ground water pumpout alternative.

- A silty to clayey sand glacial till appears to be present beneath much of the NIROP between approximate elevations of 760 to 780 feet (approximate ground elevation around the NIROP is 835 feet).

- This till layer may impede vertical migration of contaminants in the areas where it is present, such as in the vicinity of well 7-D and in the vicinity of the eastern edge of the plant where ground water contamination has been found.

Ground Water Flow

Ground water flow data were modified in the RI Addendum Report based on ground water measurements at 52 wells located in the vicinity of the NIROP, in-situ permeability measurements at seven (7) new wells in the unconsolidated aquifer, and a pumping test at well AT-2. Fifteen (15) new monitoring wells were installed in the unconsolidated aquifer, along with two (2) new production test wells (AT-1 and AT-2). The modifications are discussed in Section 5.3.2 of the RI Addendum Report.

The ground water flow data are used in the re-evaluation of the ground water capture zones developed for the ground water pumpout system design of Section 4.3.5. Median values and ranges of values substantially different from the values presented in the June 1987 RI Report were presented in the RI Addendum Report for in-situ permeability, the horizontal ground water gradient, and the ground water velocity for both the shallow and deep layers of the unconsolidated aquifer. These values are presented and used in Appendix C to

recalculate capture zones and radii of influence for the proposed pumpout systems. The pumping test results for production well AT-2 were also used in the Appendix C calculations for the evaluation of the radius of influence of the pumpout system at well AT-2. The results are presented in the A-E Quality Control Summary Report (QCSR) for Aquifer Tests (RMT, 1988b).

2.3 Nature and Extent of Problem

2.3.1 General

Based on the findings and conclusions of the RI Addendum Report, TCE continues to be the best indicator of the occurrence and migration of ground water contamination at the NIROP.

2.3.2 NIROP Activities Involving Hazardous Substances

A finding of the RI Addendum Report is that the use of TCE at the NIROP was discontinued in the first quarter of 1987 (FMC, 1988). The above-ground solvent storage tank located on the east side of the plant, formerly containing TCE, now stores 1,1,1-trichloroethane.

2.3.3 Potential On- and Off-site Sources of Contamination

Results of investigations to identify potential soil, ground water, and surface water source areas are discussed in Section 2.3.4, 2.3.5, and 2.3.7, respectively. Potential off-site sources were discussed in Section 2.2.1.

A potential off-site source of VOC contamination to the Mississippi River not discussed in the RI Addendum Report is the FMC site abutting

the NIROP to the south. The FMC site has had four ground water extraction wells in operation since December 1987, pumping at a total rate of 100 gallons per minute (gpm) (Lahtinen, 1988).

2.3.4 Soil Contamination

The feasibility study evaluated source control remedial alternatives based on limited soil sampling conducted through November 1985. The focus of the evaluation was trench 3 in the former trench disposal area north of the NIROP building. The extent of the contaminated area was estimated in the FS Report to be approximately 1,200 square feet.

The RI Addendum Report included findings and conclusions of a soil pore gas analysis of three suspected areas of shallow VOC-contaminated soil. The findings and conclusions are useful for re-evaluating the extent of the area where source control remediation may result in reduced VOC contamination of the ground water. No significant levels of TCE or other VOCs were detected in the former TCE tank area west of the plant, or in the existing TCA tank area east of the plant. These findings indicate that high levels of TCE detected in the ground water in these areas are not the result of VOCs leaching from the shallow soils.

The findings of the soil pore gas survey also indicate that a larger portion of the former trench disposal area north of the plant has elevated VOC concentrations in the shallow soils than assumed in the FS Report evaluation for the source control remediation. The areas with the highest VOC concentrations were in the vicinity of trench 3, as

previously found, and near the decontamination pad. The findings are used to re-evaluate the area of potential source control remediation. The calculations for the re-evaluation are presented in Appendix A, for use in Section 4, Remedial Action Alternatives.

The findings do not indicate the current vertical distribution of VOCs in the shallow soils. However, they do indicate areas where VOC concentrations are likely to exceed 1 mg/kg in the soil. These areas are shown on Figure 4-1.

2.3.5 Ground Water Contamination

Updated evaluations of constituents of concern and the extent of contamination in the ground water are based on ground water samples collected between January 25 and February 18, 1988. The samples were analyzed for 4 inorganic and 15 organic compounds.

Constituents of Concern

The RI Addendum Report identified the continuing presence of selenium in well 9-S. The report concluded that this constituent may be an indicator of a possible off-site, upgradient, contaminant source east of the NIROP property.

Four organic compounds were identified in the feasibility study as potential constituents of concern. Of these, benzene is removed from this category. It was not detected in any of the 52 wells monitored in the 1988 sampling program and only in well 17-S in November 1986 at a concentration slightly above the detection limit of 0.005 mg/l (0.0065 mg/l).

The findings of Section 5.3.4 of the RI Addendum Report indicate that TCE is still the primary constituent of concern. Both TCE and 1,2-cis-DCE were found at concentrations comparable to previous results and in ten or more wells. The RI Addendum Report identified 1,1,1-trichloroethane (TCA), 1,1-dichloroethane (DCA), and 1,1-dichloroethylene (DCE) as potential constituents of concern, especially in the vicinity of the existing TCA tank area. Both 1,1-DCA, and 1,1-DCE exceeded the maximum contaminant level (MCL) in the TCA tank area. Only 1,1-DCE slightly exceeded the MCL at a downgradient well (18-S). A pumpout remedial action alternative that addresses TCE would also address the lower concentrations of these other VOCs.

Extent of Contamination

The extent of contamination of the unconsolidated aquifer with TCE and related compounds in the vicinity of the NIROP is discussed at length in Section 5.3.5 of the RI Addendum Report. Six areas shown on Figures 5-8 through 5-10 of the RI Addendum Report have been identified with TCE-contaminated ground water.

The major findings of the RI Addendum Report, regarding the extent of ground water contamination, are essentially unchanged from those of the RI Report as they pertain to remediation alternatives. The unchanged findings are as follows:

- TCE continues to be the best indicator of the occurrence and migration of ground water contamination at the NIROP.

- Wells 18-S and 8-D continue to have the highest levels of TCE contamination of any of the downgradient wells. The concentration of TCE in well 18-S has increased from 1.53 mg/l in November 1986 to 12.7 mg/l in January 1988. The 8.1 mg/l concentration of TCE in well 4-I, located near wells 18-S and

8-D and installed since the November 1986 sampling round, indicates that high levels of TCE are present throughout the aquifer in this area.

- Ground water source areas are still identified in the north former pit/trench disposal area and in the TCA storage tank area in the southeast portion of the NIROP.

The ground water contamination areas, discussed above, were accounted for in developing the feasibility study ground water pumpout alternative (Alternative F).

The RI Addendum Report further expanded the identification of the extent of ground water contamination as follows:

- An area downgradient of Hazardous Waste Storage Area C was identified with contamination by TCE and other VOCs.

- The contamination in the TCA storage tank area was found to be higher than anticipated from the ground water quality data presented in the RI Report.

- The findings indicate the need for further evaluation of whether ground water contamination originates from on-site or off-site sources in both the north and east areas of the NIROP property. This information needs to be incorporated in the development of the long-term ground water monitoring program.

- Selenium has been identified as an indicator of an off-site contribution to ground water contamination in the southeast portion of the NIROP.

2.3.6 Trends in TCE Contamination of Ground Water

Levels of TCE contamination in monitoring wells 8-S, 3-S, and FMC-33 are slightly decreased from the November 1986 levels. TCE was detected at 0.4 mg/l in well 21-S, downgradient of Hazardous Waste Storage Area C. The highest levels of TCE contamination on-site were found in the southeast corner of the NIROP, especially at wells AT-1 (11.3 mg/l) and 5-I (7.1 mg/l). However, the concentration of TCE in

well 9-S (1.32 mg/l) has been declining since the January 1986 sampling round.

2.3.7 Surface Water Contamination

The January 1988 analyses of storm sewer samples from two locations suggest that the sources of water discharged to the storm sewers during regular plant operations in winter weather conditions do not currently create a potential for release of significant levels of hazardous constituents to the shallow ground water flow system beneath the NIROP or to the Mississippi River.

2.3.8 Summary of Constituents, Media, and Contaminant Sources

The key modifications to the data presented in this section of the FS Report are as follows:

- Benzene is no longer considered a constituent of concern in the ground water based on information presented in Section 2.3.5, Ground Water Contamination.
- The area with shallow VOC-contaminated soils in the northern portion of the NIROP has been expanded from the assumed area with residual soil contamination evaluated in the FS Report.
- VOC contamination was not identified in the RI Addendum Report in two potential on-site contaminant source areas: the shallow soils at the southwest edge of the NIROP and the storm sewers discharging from the main NIROP building to the Mississippi River.

2.4 Objectives of Remedial Action

2.4.1 General Purpose

The primary purpose of the remedial action alternatives proposed in the FS Addendum Report is still the minimization of off-site contaminant

migration in the ground water. The second general objective remains the control of on-site sources of VOC contamination including ground water, saturated soils, and shallow unsaturated soils. These objectives are to be met by a cost-effective and technically justifiable remedial alternative that protects human health and the environment in the vicinity of the site.

2.4.2 Background

(No changes to the July 1988 FS Report.)

2.4.3 General Goals

(No changes to the July 1988 FS Report.)

2.4.4 Specific Goals

(No changes to the July 1988 FS Report.)

2.4.5 Environmental Criteria and Standards

In the FS Report, the Safe Drinking Water Act (SDWA) maximum contaminant level (MCL) was listed as the only federal standard considered as an applicable or relevant and appropriate requirement (ARAR). The MCL is applicable to "public water systems" at the point of use (the tap). Of the three constituents of concern at the NIROP (TCE, PCE, 1,2-DCE) only TCE has an assigned MCL (5 ug/l).

The Minneapolis Water Supply System (MWSS) does not treat the intake water specifically for VOCs. Thus, significant VOC removal cannot be expected between the intake and the point of use.

Consequently, the point of application for the MCL or other guidances to be considered as ARARs at the NIROP is at the intake to the MWSS, where water enters the Minneapolis Water Treatment Plant. This is approximately one mile downstream from the NIROP.

A potential point of application of the MCL and other guidance concentrations is the set of unconsolidated and bedrock aquifer systems downgradient from the NIROP. These systems are not currently used for pumping drinking water; however, there is the potential for either the public or private use of these aquifers for drinking water. In any case, the point of application for ground water pumpout for drinking water would still be at the tap.

Another potential ARAR is the Resource Conservation and Recovery Act (RCRA) ground water protection standard (40 CFR Section 264.94). The RCRA ground water protection standard is applicable for RCRA corrective actions. It has been considered relevant and appropriate at other hazardous waste remedial action sites.

The point of application for RCRA corrective action standards is generally considered to be within the downgradient boundary of the facility property. One of the following three clean-up standards may be used: a background level of a given constituent in the ground water; a limited list of constituents for which an MCL is specified; or an alternate concentration limit (ACL) which is developed from a set of hydrogeologic and health risk-based conditions. When an ACL is specified, the remediation is required to continue until the ACL is achieved at the property boundary for a period of at least three years.

If ground water is to be developed as a drinking water source downgradient of the NIROP, then either the MCL or the State of Minnesota Recommended Allowable Limits (RAL) would probably be considered reasonable health-based values for the ACL at the site boundary. However, if ground water downgradient of the NIROP is not developed for drinking water use, then it is reasonable to evaluate the only existing drinking water receptor, the Minneapolis Water Treatment Plant intake, in order to develop a health-based value for the ACL for ground water remediation.

Different ACLs may be developed for the protection of the existing (surface water) and potential future (ground water) drinking water supply. Until more definite plans for the development of a ground water supply downgradient of the NIROP are considered, the ACL for the existing surface water supply (the Minneapolis Water Treatment Plant intake) should be used to determine the required level of ground water remediation. A risk calculation for the intake is presented in Section 5.1.4, which is useful for establishing a risk-based ACL. In accordance with the RCRA corrective action requirements, remediation should continue for three years following achievement of the ACL. If at some point in the future, ground water development is called for and the ground water protection ACL is not achieved, then the remedial alternatives should be re-evaluated at that time. A comparison should be made between continued remediation with the system that will have been instituted and a point of use treatment system for the proposed drinking water well system.

In addition to the ambient or chemical-specific requirements discussed above, significant changes have been made in action-specific requirements established by the MPCA. These changes concern the various disposal alternatives evaluated for Alternative F and air emissions requirements for air stripping and vacuum extraction treatment technologies. The essential change is that the MPCA is undergoing a transition from performance-based requirements to health-based requirements in their permitting processes. The change affects the National Pollutant Discharge Elimination System (NPDES) discharge permit to the storm sewer system, the State Disposal System (SDS) disposal permit for leaching fields, and the state air quality discharge permit for air emissions from the proposed air stripping and vacuum extraction systems. The modifications to the NPDES permitting process are based on an EPA-driven policy of nondegradation of surface waters similar to the policy that has been incorporated for ground water in the State of Minnesota. A more comprehensive discussion of these issues is presented in Section 5.1.3, Institutional Requirements.

3. SCREENING OF REMEDIAL TECHNOLOGIES AND REMEDIAL ALTERNATIVES

3.1 General

No additional technologies were screened for this FS Addendum Report. However, the leaching field, presented as a disposal option for Remedial Action Alternative F, is revisited in Section 3.4.

3.2 Potential Remedial Technologies

(No changes to the July 1988 FS Report.)

3.3 Development of Remedial Action Technologies

(No changes to the July 1988 FS Report.)

3.4 Screening of Remedial Technologies

The leaching field was re-evaluated as a technology for disposing of treated ground water, in order to incorporate the potential for bacterial fouling of the leaching field infiltration beds. Bacterial fouling could result from the growth of bacteria on the air stripper column packing, the GAC in the carbon vessel, or on the leaching field infiltration beds in the presence of sufficient nutrients. Conventional practice involves operation of parallel leaching fields, running alternately, which has been found to minimize fouling problems.

The leaching field system proposed in the FS Report was based on a hydraulic loading rate of 2 minutes per inch. Conservative design in the absence of percolation tests calls for an assumed 12 minutes-per-inch hydraulic loading rate (Metcalf and Eddy, 1979). Incorporating a conservative hydraulic loading rate (12 min/in) and redundant leaching

field systems results in the need for parallel leaching fields, each with a surface area of approximately 135,000 square feet.

Based on the above design revisions, the leaching field system is removed from consideration as a disposal technology based on cost and feasibility considerations. Capital costs for the leaching field system would exceed $800,000 based on an approximate $3 per-square-foot cost of installation. The cost for installing either the on-site or off-site storm sewer disposal systems discussed in Section 4 ranges between $25,000-$75,000 for the same disposal capacity. This is an order of magnitude lower than the approximate cost for the leaching field.

The area required for the leaching field, which exceeds six acres, also becomes a major impediment. The north parking lot is the primary location where extensive disturbance to the railroad tracks and underground utilities would be avoided. However, if installation were to occur beneath the parking area, aeration holes through the pavement would be needed to prevent the growth of anaerobic bacteria in the leaching field.

Moving the leaching field to the parking lot removes the advantage of flushing either the saturated or unsaturated VOC-contaminated soils to the east of the parking area, unless a third (smaller) leaching field would be constructed in this area.

Using the leaching fields for ground water disposal would require a State Disposal System Permit. The permit would require treatment of the contaminated ground water to the Maximum Contaminant Level or a level determined by MPCA. Even with redundant leaching field systems, due to the potential for failure of a leaching field, the typical lifetime is estimated at 20 years.

Spray aeration as a treatment technology for VOC-contaminated ground water is screened from consideration based on the same factors as discussed above for the leaching field. Spray aeration would ultimately require land disposal of the treated ground water with a leaching field with the resulting problems associated with the leaching field. Furthermore, spray aeration would result in the potential for exposure to contaminated air emissions. In addition, spray aeration would require an exposed surface area to receive the aerated water. It would be extremely difficult to operate this system under winter conditions. It would also be difficult to locate the system on-site due to the large amount of land that would not be available for other uses.

4. REMEDIAL ACTION ALTERNATIVES

4.1 General

No new remedial action alternatives are presented in this FS Addendum Report. However, the alternatives presented in the FS Report have been re-evaluated. The assumptions used for the detailed evaluation of the alternatives have been modified based on the data collected in the field program performed for the RI Addendum Report.

Alternative F, Ground Water Pumpout, Treatment and Disposal, has been extensively revised. The revisions are based on the RI Addendum field program data and on major changes in MPCA policy regarding disposal of pumped, contaminated ground water and contaminated air emissions. The main revision is the introduction of a phased approach to implementation of the alternative.

The intent of the phased approach is to provide a period of from one to three years when off-site contaminant migration is minimized and time is provided for the following:

- MPCA policy to proceed toward implementing rules for ground water disposal and air emissions.

- Additional investigation of potential on-site and off-site contaminant source areas.

- Collection of additional ground water data to facilitate treatment system design and optimize system operation.

4.2 General Assumptions

Assumptions concerning key site parameters that were listed in this section of the FS Report are revised as follows:

Description	Assumptions: FS Addendum Report	Assumptions: FS Report
Area of shallow soil contamination:		
. Location	Vicinity of trench 3 and decon. pad	Trench 3
. Area	6,000 sq. ft.*	1,250 sq. ft.
. Thickness	5-15 feet	15 feet
. In-place volume	1,800 cubic yards	700 cubic yards
. Depth to contaminated soil	0-5 feet	5 feet
Approximate depth to water table:	20-25 feet	20 feet
Aquifer properties:		
. Effective porosity	0.2-0.3**	0.3
. Radius of influence for 200 gpm pumping well	500 feet (AT-3 and AT-5)**	400 feet
. Ground water velocity	500 feet/year**	1,200 feet/year
Average contaminant concentrations in contaminated soil:		
. Total VOCs	70-160 mg/kg*	830 mg/kg
. TCE	60-140 mg/kg*	670 mg/kg
Mass of contaminants identified in contaminated soil:		
. Total VOCs	460 lb.*	1,600 lb.
. TCE	400 lb.*	1,300 lb.

*Based on soil pore gas survey.
**Based on aquifer pumping tests.

The calculations supporting the revised shallow soil contamination assumptions are presented in Appendix A. The calculations supporting the revised aquifer assumptions are presented in Appendix C.

4.3 Description of Remedial Action Alternatives

The program for the remedial action alternatives involves a two-phased approach. Phase 1 involves a period ranging from one to three years following the start of implementation of the remedial action. No remediation for the shallow VOC-contaminated soils is proposed in Phase 1. Instead, this approach uses the Phase 1 period to evaluate the areas where either high levels of VOC contamination have been detected in the ground water and/or soil pore gas analysis has indicated potentially high levels of shallow VOC-contaminated soil.

The evaluation would consist of two parts. The first part is the addition of several soil borings with soil samples analyzed for VOCs. Additional ground water monitoring wells are proposed upgradient of the NIROP to the east and to the north of the NIROP as the second part. Quarterly sampling of these wells is proposed to quantify contamination from potential upgradient source areas.

The Phase 1 ground water remediation approach includes ground water pumpout for both source control and contaminant migration management. As shown on Figure 4-1, pumpout wells AT-3 and AT-5 are proposed to supplement existing pumpout well AT-2 to minimize the downgradient off-site migration of contaminants from the NIROP. It is also proposed that existing production well AT-1 be supplemented by a well in the northern portion of the NIROP, AT-4, for contaminant removal from areas of high VOC concentration in the ground water. The locations shown for AT-3, AT-4, and AT-5 are preliminary and would be determined by the plume locations and additional hydrogeologic information.

BURLINGTON NORTHERN RAILROAD (BNR)

AT-1

SS

APPROXIMATE AREA WITH IDENTIFIED SOIL CONTAMINATION

DECONTAMINATION PAD

GROUND WATER FLOW (FEB., 1988)

IN-SITU VACUUM EXTRACTION STAGING AREA (ALT. D)

APPROXIMATE AREA WITH IDENTIFIED SOIL CONTAMINATION

AREA AROUND TRENCHES 3 & 6

NIROP FACILITY

AT-4

SS

GRAVITY STORM SEWER (ALT. A)

EXISTING BUILDING (APPROX.)

FLOW/SAMPLE CONTROLS (TYP)

AT-2

MH

LEACHING FIELDS (UNDERNEATH PARKING AREA)

GROUND WATER TREATMENT AREA (ALT. F)

42" STORM SEWER NPDES 20100

72" STORM SEWER NPDES 20200

48" STORM SEWER NPDES 20300

FMC FACILITY

SS

15" SANITARY SEWER

SOIL VAULT

TO MWCC WASTEWATER TREATMENT FACILITY

BNR PROPERTY

ALTERNATIVE OFF-SITE STORM SEWER DISPOSAL

12" STORM SEWER (DISCHARGES APPROX. 80' SOUTH OF PUMP STA. 5 INTAKE)

MH

MINNEAPOLIS WATERWORKS

AT-5

MH

AT-3

SS (APPROX.)

WATER INTAKE APPROXIMATELY 1400'

MISSISSIPPI RIVER

NOTES:

1. LOCATIONS FOR REMEDIAL ACTION ALTERNATIVE FACILITIES ARE APPROXIMATE, AND USED ONLY FOR BASIS OF FEASIBILITY DESIGN. FINAL REMEDIAL FACILITIES MAY DIFFER IN LOCATION AND NUMBER FROM THOSE SHOWN ABOVE.

2. BASE MAP PROVIDED BY CORPS OF ENGINEERS. DATE OF SURVEY AND DATUM UNKNOWN. MONITORING WELL LOCATIONS ARE APPROXIMATE, BASED ON PROXIMITY TO LANDMARKS.

LEGEND

- EXISTING PAVED ROAD
- EXISTING UNPAVED ROAD
- EXISTING BUILDING
- EXISTING FENCE
- 800 EXISTING 5' CONTOUR
- EXISTING 1' CONTOUR
- x 865.1 EXISTING SPOT ELEVATION
- TREES AND / OR BRUSH
- EDGE OF WATER
- WET AREA
- APPROXIMATE NIROP PROPERTY LINE
- APPROXIMATE FMC PROPERTY LINE
- APPROXIMATE BNR PROPERTY LINE
- EXISTING PRODUCTION WELL
- PROPOSED PRODUCTION WELL
- PROPOSED WATER TABLE OBSERVATION WELL
- PROPOSED INTERMEDIATE PIEZOMETER
- MH STORM SEWER MANHOLE
- SS SANITARY SEWER MANHOLE

SCALE: 1" = 200'

0 200 400 600 FEET

NO.	BY	DATE	REVISION	APP'D.
3.				
2.				
1.				

PROJECT:
FEASIBILITY STUDY ADDENDUM
USACE-NIROP FRIDLEY, MINNESOTA

SHEET TITLE:
REMEDIAL ACTION ALTERNATIVES
PRELIMINARY LOCATION PLAN (UPDATED)

DRAWN BY: DRB	SCALE: 1"=200'	PROJ. NO. 1473.10
CHECKED BY: MAW		DRWG. NO.
APPROVED BY:	DATE PRINTED: AUG 26 1988	SHEET FIGURE 4-1
DATE: 8/88		

RMT INC.
Suite 124
1406 East Washington Ave.
Madison, WI 53703
Phone: 608-255-2134

In the Phase 1 period, it is proposed to dispose of all contaminated ground water from the pumpout systems into the sanitary sewer system. The intent is to allow time to evaluate the potential impact of evolving MPCA rules regarding the NPDES permit requirements for disposal of pumped and treated ground water to the storm sewer system. The intent is also to allow time to assess the results of additional contaminant source investigations prior to implementing source control remediations.

A ground water monitoring program is also proposed to begin in the Phase 1 period in order to evaluate pumpout effectiveness and the potential for contamination from upgradient source areas.

Ground water monitoring results from the Phase 1 period would be used to evaluate the effectiveness of the pumpout remedial action. It is proposed that the remedial alternatives be re-evaluated if one or more of the following conditions should arise:

- The identification of significant ground water contamination at the NIROP from upgradient source areas.
- A significant increase or decrease in the concentration of TCE in one or more monitoring and/or production wells.
- Ineffecitve pumpout system for containing the contaminant plume.
- A significant increase in the TCE levels at the Minneapolis Water Treatment Plant intake.
- The persistence of high levels of TCE contamination at source control wells AT-1 or AT-4, and the finding that contamination does not originate from upgradient source areas or from shallow VOC-contaminated soils.

It is proposed that the Phase 2 program be finalized during the Phase 1 period. It is assumed that, in the absence of off-site upgradient sources or an undetected on-site subsurface source area, pumpout at source control wells AT-1 and AT-4 will have had sufficient time to remove a significant portion of contamination in the potential source areas in the vicinity of these wells. Thus, wells AT-1 and AT-4 would not be operating during Phase 2, and the proposed Phase 2 program would consist of continued pumpout at downgradient wells only.

The technologies for the treatment and disposal of the ground water pumpout at downgradient wells AT-2, AT-3, and AT-5 are discussed in detail in Section 4.3.5, Alternative F - Ground Water Pumpout, Treatment, and Disposal. The alternative treatment technologies that are evaluated are air stripping and granular activated carbon (GAC). The alternative disposal technologies that are evaluated include two locations for surface water disposal and continued disposal to the sanitary sewer system.

4.3.1 No-Action Alternative

The No-Action Alternative is retained as the baseline case. Only ground water monitoring would be proposed for this alternative. A monitoring program is proposed for each of the alternatives discussed in Section 4. The monitoring program proposed for the No-Action Alternative is the same as that for the source control alternatives, but differs from that for Alternative F, the management of migration alternative. The actual monitoring program would be developed in coordination with the MPCA, the USACE, and the Navy. However, the

monitoring programs presented below are for order-of-magnitude cost estimates and evaluation purposes.

A typical program for monitoring under the No-Action Alternative would include essentially the same program proposed in Section 4 of the FS Report under Alternative A, Capping of the Area Around Trench 3. However, the program proposed for the No-Action Alternative in this FS Addendum Report includes fewer but more appropriately targeted wells, based on the findings of the RI Addendum Report. The following ten wells are proposed for a ground water monitoring program for the No-Action Alternative:

- Upgradient Wells - Monitoring of two upgradient wells to the north and two upgradient wells to the east of the NIROP is proposed. These wells include existing well 7-S and three wells proposed for installation, as shown on Figure 4-1.

- Downgradient Wells - Existing wells 18-S and 8-D are proposed for the monitoring program based on the high concentration of TCE at these wells.

- On-Site Wells - Two monitoring wells are proposed for long-term monitoring in each of the two identified ground water contaminant source areas. The two wells proposed for the north source area are shallow well 8-S and intermediate-depth well 5-I. The two wells proposed for the southeast source area are shallow well 9-S and intermediate-depth well 3-I.

- Water Level Measurements - In addition to the wells proposed for ground water monitoring, it is also proposed that each of the wells in the unconsolidated aquifer have water level measurements taken as part of the monitoring program, in order to determine contours of ground water flow.

The monitoring program for the No-Action Alternative is still proposed to be done on a quarterly basis. Chemical analyses for VOCs are also still proposed. The duration is assumed to be 30 years for cost estimating purposes.

4.3.2 Alternative B1 - Excavation and Off-Site Disposal

(No changes to the July 1988 FS Report.)

4.3.3 Alternative A - Capping of Contaminated Area

Objective

The objective of capping as a source control alternative is still the reduction of contaminant migration to the ground water from the shallow VOC-contaminated soils. The means of source control is the reduction of mobility of contaminants in the soil due to impeding the infiltration of precipitation. According to SARA, the site would need to be re-evaluated every five years, if this were a Superfund site, since the means of control does not involve removal, detoxification, or destruction of VOCs in the shallow soil.

The extent of source area capping is subject to the uncertainty of the location of the source areas with the highest levels of contamination. The phased remediation approach incorporates a delay in the selection of the source control alternative until additional source area investigations are completed in the first phase of remediation. The source control alternatives should be re-visited upon completion of the investigations.

Key Features

The area evaluated for capping (6,000 square feet) is approximately five times the area evaluated for the FS Report (1,250 square feet). The source area is also separated into two locations, with one in the

vicinity of trench 3 (4,000 square feet) and the other near the decontamination pad (2,000 square feet). Both locations are shown on Figure 4-1. Separate caps would be needed for each of the two source area locations. A single location in trench 3 was the only source area considered in the FS Report.

An extension to the storm sewer system is part of the proposed design, as shown on Figure 4-1. The length of this extension has increased slightly from the 900 feet proposed in the FS Report to 1,100 feet, due to the need to drain both of the capped areas. Installation of the storm sewer extension to a 42-inch storm sewer shown on Figure 4-1 would involve jacking beneath railroad tracks and avoiding underground utilities. A modification to the NPDES permit for the 42-inch storm sewer may be needed for the disposal of storm water runoff from the cap.

Installation Phasing

(No changes to the July 1988 FS Report.)

Operation and Maintenance

In addition to the regular maintenance of the cap and storm sewer extension, cap replacement has been factored into the cost estimate.

Ground Water Monitoring

The same ground water monitoring program proposed for the No-Action Alternative is also proposed for Alternative A.

4.3.4 Alternative D - In-situ Vacuum Extraction

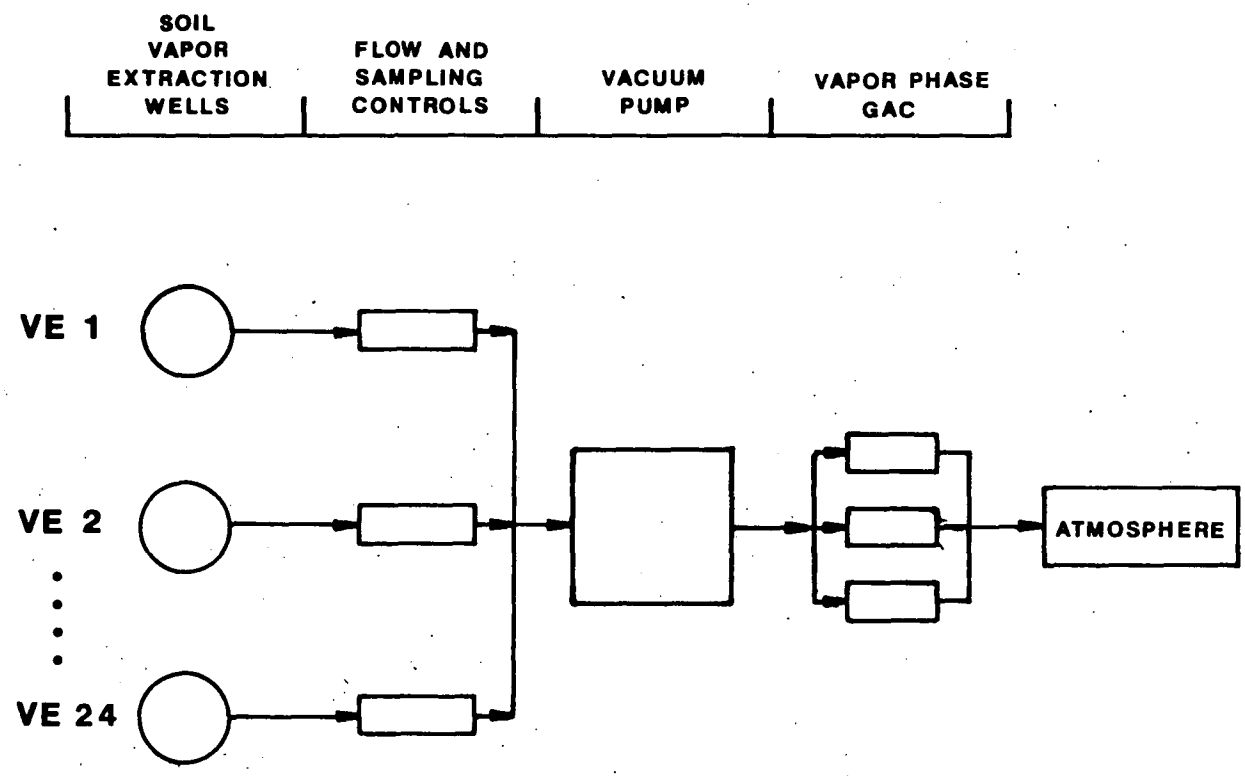
Objective

The objective of this alternative remains to minimize the amount of continuing contamination to the ground water by reducing the level of toxicity of residual soil contamination by volatilizing the contaminants. This system, shown in the process flow diagram on Figure 4-2, has been modified to incorporate a vapor-phase granular activated carbon (GAC) filter for air emissions. As a result, the objective has been expanded to either the reduction or destruction of contaminants. Contaminants will be adsorbed by the GAC, which will be returned to the carbon supplier when spent. The spent carbon would be either landfilled or destroyed. Whether the vapor-phase GAC will actually be used if this system is selected will depend on the results of further evaluation of the need for GAC. Additional air quality modeling is recommended for this evaluation.

Key Features

The main revision to the key features of the in-situ vacuum extraction system proposed in the FS Report is the addition of vapor-phase GAC treatment for contaminated air emissions. The GAC treatment system was added as a result of modified requirements for the MPCA air quality discharge permit for carcinogens such as TCE. A risk-based approach has been adopted by the MPCA. Further details of this revision are discussed in Section 5.1.3, Institutional Requirements.

The second major revision from the system proposed in the FS Report results from the expansion of the identified contaminated area. As a result of the nearly five-fold increase in the area identified for



ALTERNATIVE D:

IN-SITU VACUUM EXTRACTION PROCESS FLOW DIAGRAM

RMT INC

Dwn. by.:	DRB
Date:	8/88
Proj. #:	1473.10

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FIGURE 4-2

source control remediation, the estimated size of the extraction system has been increased substantially from that proposed in the FS Report. These estimates are based on the results of the pore gas sampling. Therefore, the size of the actual vacuum extraction system would be determined after further investigation of site characteristics.

Installation Phasing

A pilot test may be required for this site due to the expanded size of the identified contaminant source area. The pilot test would consist of installing multiple gas extraction wells and measuring the zone of influence under a variety of pumping conditions. The pilot test would be performed prior to equipment design for full-scale operation. The cost for the pilot test is included as part of the system start-up cost.

Operation and Maintenance

The estimated duration of the system operation has been revised from the nine months used in the FS Report to six months. The decreased treatment duration is based on revised estimates of the mass and concentration of the VOCs in the shallow soils, where the mass is estimated to be approximately 30 percent and the concentration is estimated to be in the range of 10-20 percent of the mass concentration estimated in the FS Report. The decreased duration estimate is also based on the proposed increase in the vacuum extraction air flow to a value of approximately eight times the flow rate proposed for the FS Report. The average TCE concentration in the soil pore gas is approximately 170 ppm in the areas identified for source control

remediation, based on the findings of the RI Addendum Report. Assuming an extraction rate of 2,400 scfm, an initial concentration of 170 ppm, and one order of magnitude decrease in TCE concentration per month, TCE concentrations should decrease to an acceptable level within a six-month period, based on the calculations presented in Appendix A. This time estimate is similar to estimates from equipment vendors. The time required to remediate the soil depends on many currently unknown factors, including initial contaminant levels, soil properties, and final clean-up levels. Hence, the actual operating time of a vacuum extraction system could vary considerably.

Operation and maintenance will also be required for the GAC treatment system. This will require monitoring of the air emissions and the replacement of spent carbon when VOC breakthrough is detected.

In the FS Report, soil samples were proposed to evaluate the performance of the vacuum extraction system. Nine (9) soil samples from three (3) soil borings were proposed for analysis on a quarterly basis, beginning with the start of operation. Thirty-two (32) soil samples from twelve (12) borings are proposed for each quarterly sampling round for this expanded system.

Ground Water Monitoring

The same ground water monitoring program as proposed for the No-Action Alternative is also proposed for Alternative D.

4.3.5 Alternative F - Ground Water Pumpout, Treatment, and Disposal

Objectives

One objective of Alternative F is to contain the contaminant plumes originating from the NIROP, within or near to the site boundaries. The second objective of Alternative F has expanded from the air stripping treatment proposed in the FS Report. The second objective is to remove and dispose of contaminated ground water and to treat, if necessary, based on the chosen disposal alternative. Alternative treatments that are evaluated here include air stripping with vapor-phase carbon adsorption and liquid-phase carbon adsorption. Disposal alternatives that are considered here include two locations for disposal to the storm sewer system or disposal to the sanitary sewer system. The use of vapor-phase carbon adsorption with the air stripping alternative would depend on the results of further evaluation of the need for this air emissions treatment system.

Layout of the System

The layout has been substantially modified and simplified from that presented in the FS Report (see Figure 4-1). The treatment area has been relocated much closer to the downgradient pumpout wells, resulting in a reduction in the length of the water distribution system. Treatment will only be used if the sanitary sewer disposal alternative is not chosen. Sanitary sewer hookups will be provided for each of the five pumpout wells. Disposal to the storm sewer system is only provided for the downgradient wells. The leaching field, proposed in the FS

Report as Alternative F, Option 2, has been eliminated from consideration based on the screening in Section 3 of this report, due to the substantially increased size required after re-evaluation of the design assumptions. The leaching field is shown on Figure 4-1 to present a possible location for the revised leaching field, in the event that additional consideration is desired.

Process Flow

Alternative F consists of ground water extraction, distribution, and disposal, with treatment if the storm sewer disposal system is chosen. By comparing disposal of treated ground water to the storm sewer with disposal of untreated ground water to the sanitary sewer, Alternative F incorporates Alternative E, which was previously screened out in the FS Report.

Alternative F consists of two phases. Phase 1 includes pumpout of ground water from AT-1, AT-2, AT-3, AT-4, and AT-5 and disposal of this untreated water to a sanitary sewer for three years. Phase 2 would consist of one of the following options:

- Option 1 - Treatment of ground water pumpout by two-stage air stripping and disposal to an on-site storm sewer. Treatment of air emissions from air stripping columns is provided by vapor-phase GAC.
- Option 2 - Treatment of ground water by liquid phase GAC and disposal to an on-site storm sewer.
- Option 3 - Disposal of untreated ground water to the sanitary sewer system.

The revised process flow diagram (PFD) for Alternative F is shown on Figure 4-3.

The Phase 2 option would be selected and designed during the Phase 1 operating period. It is anticipated that only the downgradient wells, AT-2, AT-3, and AT-5, would be operating during Phase 2.

Extraction

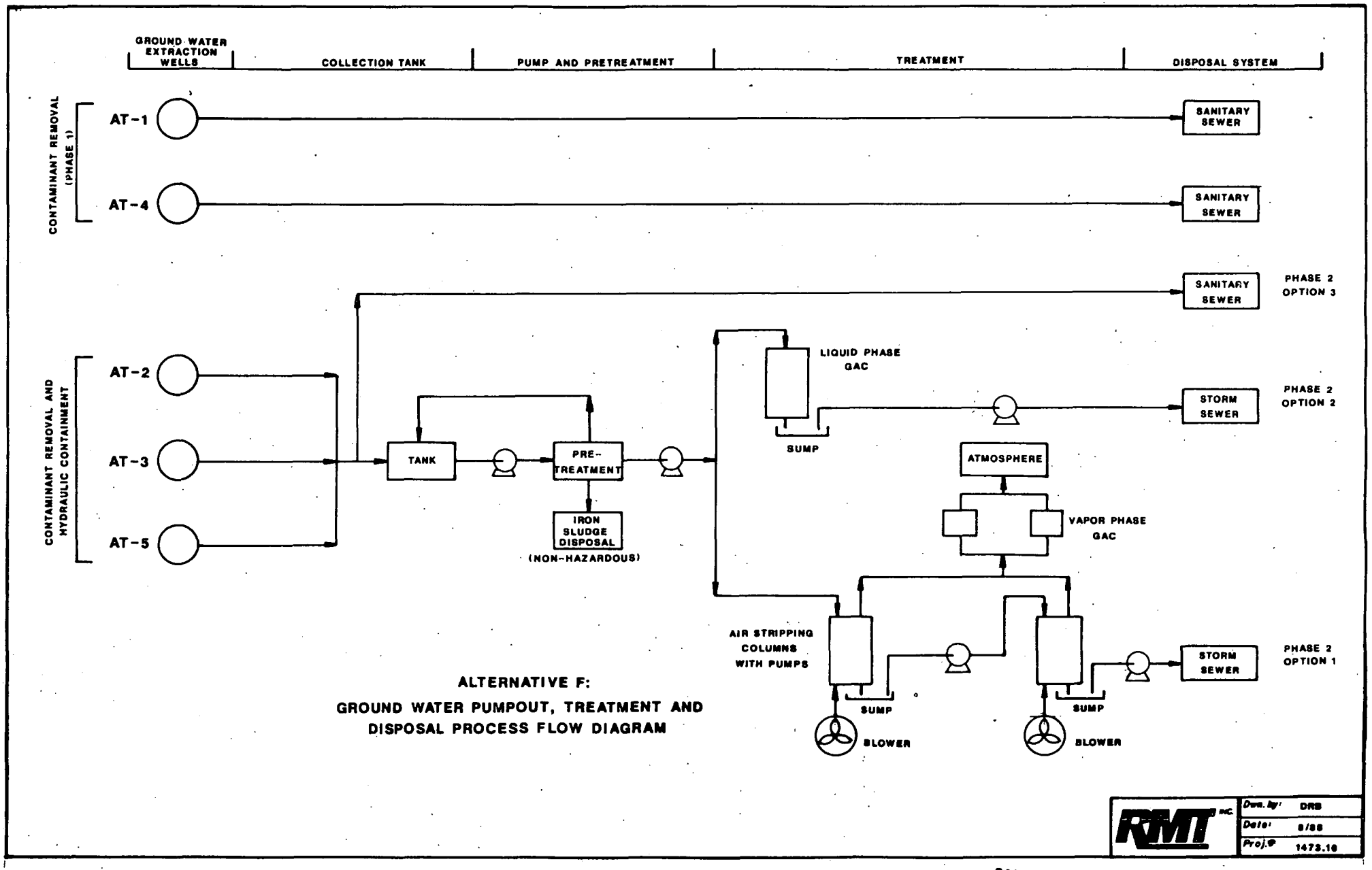
The ground water extraction system has been simplified by the elimination of the collection tanks and above-ground pumps that were proposed to be located near the pumpout wells. This was made possible by the reduced length of the water distribution system and the increased pump horsepower rating for proposed wells AT-1 and AT-4.

The proposed pumpout rates for wells AT-1 and AT-2 have changed based on the findings of the RI Addendum Report. The pumpout rate for AT-1 has increased from 25 gpm to 50 gpm, and the pumpout rate for AT-2 has decreased from 200 gpm to 150 gpm. These rates are based on revised aquifer properties determined by pumping tests conducted during the RI Addendum field program.

The design strategy for the pumping scheme is summarized later in this section. The calculations are presented in Appendix C.

Distribution System

The water distribution system to transport water from the ground water pumpout system to the ground water disposal system is shown on Figure 4-1 for three disposal alternatives. Evaluations of the storm



ALTERNATIVE F:
GROUND WATER PUMPOUT, TREATMENT AND DISPOSAL PROCESS FLOW DIAGRAM

AUG 26 1988

FIGURE 4-3

sewer disposal options are based on assumed on-site disposal. However, institutional constraints may prohibit that option. An alternative off-site disposal system is also shown on Figure 4-1. Discharge of the treated ground water for that system is into the Mississippi River approximately 80 feet downstream of the Minneapolis Water Treatment Plant intake. Each system would be under pressure flow. The approximate pipeline length for each disposal alternative is as follows:

Disposal Alternative	Pipeline Length (ft)
Sanitary Sewer	1,400
On-Site Storm Sewer (with sanitary backup)	1,800
Off-Site Storm Sewer	4,700

Sanitary sewer disposal will remain as a backup option even if on-site storm sewer disposal is chosen for Phase 2 remediation. A large portion of the distribution system is the same for the sanitary sewer and storm sewer disposal systems.

Treatment

The treatment system proposed in the FS Addendum is substantially modified from that proposed in the FS Report. Instead of the single-stage air stripping column proposed in the FS Report, a liquid phase granular activated carbon (GAC) system is compared with a two-stage air stripping system coupled with vapor-phase granular activated carbon. The re-evaluation of the treatment system is based on the increased stringency of the ground water disposal standards that have taken effect since the treatment system was developed for the Feasibility Study.

The Feasibility Study designs for both the air stripping and the liquid phase GAC system were based on the objective of reducing TCE concentrations from an estimated level of 3 mg/l to less than the MCL of 5 ug/l in the ground water.

The pretreatment system was re-evaluated based on the results of the bench-scale testing performed for the RI Addendum Report. It was determined that pretreatment would be necessary for iron and calcium for the air stripping alternative and for calcium for the carbon adsorption alternative. Pretreatment for iron was not proposed for the carbon adsorption system because it was anticipated that the carbon pack would be changed several times a year. However, if clogging of the carbon system with iron precipitate becomes a problem, back flushing or backwashing of the carbon tank is a relatively simple and low cost alternative.

No significant changes were made to the design of the proposed pretreatment system in the FS Addendum. However, the iron level that was measured in untreated ground water samples used in the bench-scale testing (2 mg/l) marginally indicated the need for advanced pretreatment as proposed in this alternative. Additional analysis of iron concentrations in the ground water may indicate that a simpler and less costly alternative for pretreatment may be acceptable for the air stripping alternative.

Vapor-phase treatment may be required for the air stripping option based on existing regulatory information. Additional air quality modeling is recommended to further evaluate the need for vapor-phase treatment. Vapor-phase GAC is the proposed treatment technology.

Disposal of the spent carbon is assumed to be accomplished by regeneration by the carbon supplier. Other vapor-phase carbon adsorption systems are available at a higher cost. One alternative for vapor-phase carbon includes on-site destruction of the adsorbed VOCs. The cost for this system is several hundred thousand dollars more than the cost estimated for the system evaluated.

Disposal

Disposal alternatives for the ground water pumpout system were revised based on the information provided by the MPCA regarding their updated surface and ground water discharge policies. The leaching field disposal alternative was screened out in Section 3 of this report based on revisions indicating a much larger required area than that estimated in the FS Report. The area was revised based on the treatability test results and the concern over potential clogging of the leaching field infiltration trenches.

The disposal alternatives evaluated for the FS Addendum Report include storm sewer disposal and sanitary sewer disposal. Alternative locations are available for both sanitary sewer disposal and storm sewer disposal as shown on Figure 4-1. For the cost comparison, storm sewer disposal was evaluated using the 72-inch on-site storm sewer shown on Figure 4-1. Sanitary sewer disposal was evaluated for an off-site 96-inch interceptor sewer.

One change between the FS Report and the FS Addendum Report is that the disposal alternative is now part of the phased approach. This approach includes an estimated three years of sanitary sewer disposal

for five pumpout wells and additional time for disposal from wells AT-2, AT-3, or AT-5 to either the storm or sanitary sewer system depending on a variety of institutional factors. These factors are discussed in Section 5.

Institutional barriers discussed in Section 5 may also preclude the use of the on-site storm sewer proposed for the Phase 2 disposal of ground water under Option 2 (Figure 4-3). The sanitary sewer disposal option would be available (Option 3). In addition, a downstream 12-inch storm sewer manhole is available on the Minneapolis Water Works property shown on Figure 4-1. If this alternative storm sewer is needed, it would require an additional approximately 3,000 feet of disposal pipeline along the FMC property line and pipe jacking underneath East River Road. Additional pumpout controls would be needed to accommodate concern over the capacity of this sewer to handle the ground water discharge during runoff events. The sewer drains a large portion of the water treatment plant facility, with a capacity estimated at 2 cfs. The ground water discharge would be 1.2 cfs.

Two alternative sanitary sewer disposal manholes are indicated on Figure 4-1. One of the manholes is on FMC property; the other requires pipe jacking beneath East River Road. The latter disposal location is currently proposed for ground water pumpout disposal under Option 3. There is some question as to whether the 12-inch FMC sanitary sewer line has the capacity to receive the approximately 800,000 gallons per day that would be pumped from the downgradient wells.

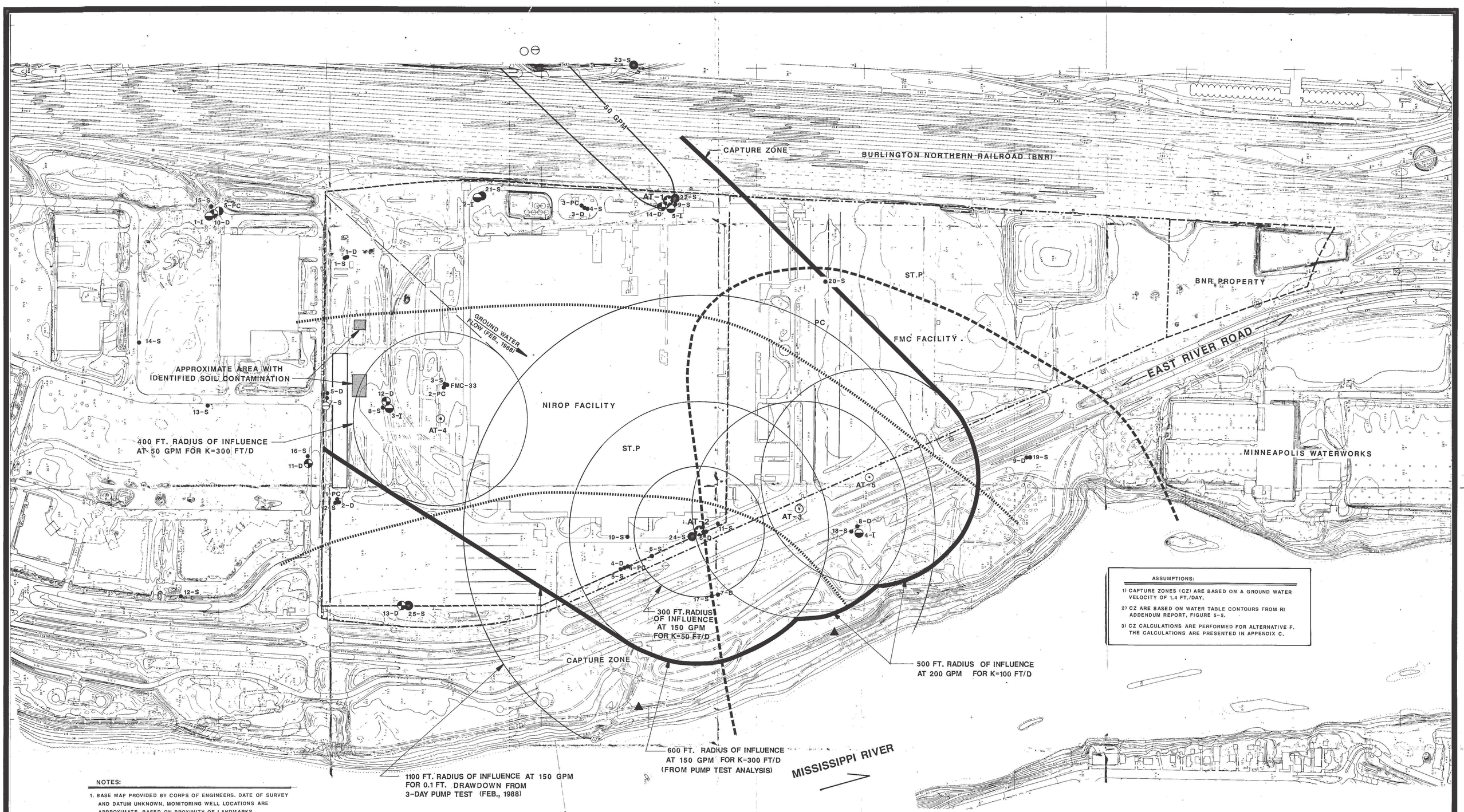
Ground Water Extraction System Design

The design of the ground water extraction system that was proposed in the feasibility study was revisited in the FS Addendum Report. The number of wells, the well locations, and the pumping rate were re-evaluated based on the following:

- Pumping tests at production wells AT-1 and AT-2.
- Borehole permeability measurements at on-site wells.
- Revised ground water contour maps.
- Revised geologic interpretation of the aquifer.

The revised preliminary design for the ground water extraction system is based on calculations presented in Appendix C. The calculations are for the revised capture zones and radii of influence shown on Figure 4-4. The calculations in Appendix C also contain a sensitivity analysis for a range of hydraulic conductivity estimates, pumping rates, and ground water velocities. Only the capture zones associated with the pumping rates used in the cost estimate are shown on Figure 4-4. These capture zones have a considerable amount of overlap, but the system operation would be adjusted to minimize overlap. This conservative preliminary design is intended to demonstrate the technical feasibility of ground water extraction.

The capture zones presented on Figure 4-4 of this FS Addendum Report are substantially different in shape, direction, and capture zone width from those shown on Figure 4-4 of the FS Report. The changes include the following:



ASSUMPTIONS:

1) CAPTURE ZONES (CZ) ARE BASED ON A GROUND WATER VELOCITY OF 1.4 FT./DAY.

2) CZ ARE BASED ON WATER TABLE CONTOURS FROM RI ADDENDUM REPORT, FIGURE 5-5.

3) CZ CALCULATIONS ARE PERFORMED FOR ALTERNATIVE F. THE CALCULATIONS ARE PRESENTED IN APPENDIX C.

NOTES:

1. BASE MAP PROVIDED BY CORPS OF ENGINEERS. DATE OF SURVEY AND DATUM UNKNOWN. MONITORING WELL LOCATIONS ARE APPROXIMATE, BASED ON PROXIMITY OF LANDMARKS.
2. K = HYDRAULIC CONDUCTIVITY.

LEGEND

- EXISTING PAVED ROAD
- EXISTING UNPAVED ROAD
- EXISTING BUILDING
- EXISTING FENCE
- 800 — EXISTING 5' CONTOUR
- EXISTING 1' CONTOUR
- x 865.1 — EXISTING SPOT ELEVATION
- TREES AND / OR BRUSH
- EDGE OF WATER
- WET AREA
- APPROXIMATE NIROP PROPERTY LINE
- APPROXIMATE FMC PROPERTY LINE
- APPROXIMATE BNR PROPERTY LINE
- WATER TABLE OBSERVATION WELL IN UNCONSOLIDATED SEDIMENTS
- INTERMEDIATE DEPTH PIEZOMETER IN UNCONSOLIDATED SEDIMENTS
- DEEP PIEZOMETERS IN UNCONSOLIDATED SEDIMENTS
- BEDROCK PIEZOMETERS
- EXISTING PRODUCTION WELLS
- PROPOSED PRODUCTION WELL
- PROPOSED WATER TABLE OBSERVATION WELL
- PROPOSED INTERMEDIATE DEPTH PIEZOMETER
- CONTACT BETWEEN ST. PETER AND PRAIRIE du CHIEN FORMATIONS
- ST.P — ST. PETER SANDSTONE
- PC — PRAIRIE du CHIEN DOLOMITE
- PRELIMINARY PROJECTED GROUND WATER CAPTURE ZONE
- EXTENT OF MISSING TILL LAYER

SCALE: 1" = 200'
0 200 400 600 FEET

NO.	BY	DATE	REVISION	APPD.
3.				
2.				
1.				

PROJECT :
FEASIBILITY STUDY ADDENDUM
USACE-NIROP FRIDLEY, MINNESOTA

SHEET TITLE :
EXTRACTION WELL CAPTURE ZONES (UPDATED)

DRAWN BY: DRB	SCALE : 1"=200'	PROJ . NO . 1473.10
CHECKED BY:		DRWG . NO .
APPROVED BY:	DATE PRINTED : AUG 26 1988	SHEET FIGURE 4-4
DATE : 8/88		

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- In the FS Report, parallel capture zones were calculated for wells AT-2 and AT-3 in a northeast direction while the capture zone for AT-5 was directed easterly. In the FS Addendum Report, parallel capture zones are shown for all three wells in a northeasterly direction.

- The capture zone widths in the FS Report for wells AT-2 and AT-3 were approximately 320 feet for the 100 gpm flow and 680 feet for the 200 gpm flow. The comparable values for the capture zone widths in the FS Addendum Report are 440 feet and 840 feet respectively. These represent 40 percent and 20 percent increases in capture zone width, respectively.

- In the FS Report, a 180-foot gap existed between capture zones for wells AT-2 and AT-3 for the 100 gpm pumpout. Substantial overlap between capture zones exists between wells AT-3 and AT-5 for both 100 and 200 gpm pumpout rates for the FS Addendum Report system.

If the ground water pumpout alternative is selected, it is recommended that an additional pumping test be performed in the vicinity of wells AT-3 and AT-5. The aquifer material is considered to be significantly different from that of the region surrounding well AT-2, where the previous pumping test had been performed. Therefore, the additional pumping test is recommended for the proper estimation of hydraulic parameters. Six shallow piezometers are also proposed for installation near wells AT-3 and AT-5 in order to monitor the effectiveness of these pumpout systems.

Installation Phasing

Prior to Phase I operations, the following installation activities are proposed:

- Wells AT-1 and AT-2 should be checked for pumpout performance.

- Pumpout wells AT-3, AT-4, and AT-5 should be constructed along with the associated pumps, controls, and piping.

- The water distribution system should be constructed for disposal to the sanitary sewer system.

- Additional monitoring wells should be installed, and the monitoring program should be initiated.

During the first year of the Phase 1 operation, the following activities are proposed:

- Additional investigations in the north shallow soil source area.

- Collection of monitoring and operation data from the pumpout system.

- Pursuance of the NPDES permit.

During the second year of the Phase 1 operation, the following activities are proposed:

- It is assumed that an NPDES permit has been granted.

- It is assumed that pumpout treatment will be to MCL standards.

- Treatability tests for the treatment system should be conducted.

- The distribution system to the storm sewer for pumpout disposal should be constructed.

During the third year of the Phase 1 operation, the following activities are proposed:

- The treatment system should be installed and start-up should be initiated.

- Pumping rates for pumpout wells AT-2, AT-3, and AT-5 should be re-evaluated.

Following the three years of Phase 1 operations, the following activities are proposed for Phase 2 operation:

- Operation of pumpout wells AT-1 and AT-4 should be ceased.
- Long-term pumpout, treatment, and disposal of contaminated ground water to the storm sewer system should be in progress.
- The monitoring program should be in regular operation.

If the NPDES permit application is denied or permit approval is delayed, then Phase 2 operation is likely to consist of continued disposal to the sanitary sewer system without ground water treatment.

Duration of Operation

The duration of operation of this alternative still cannot be reasonably estimated at this time. The duration is based on the number of pore volumes of ground water that need to be flushed through the contaminated saturated soil until a target level of remediation is achieved.

For preparation of the cost estimate, it was assumed that the mass of the volatile organic constituents (VOCs) removed from the ground water decreases five percent per year due to desorption of VOCs from the saturated soil. Sensitivity analyses are presented in Appendix D assuming zero and ten percent decreases in VOCs per year.

Based on the capture zones shown on Figure 4-4, a revised estimate of the duration for pumping one pore volume of ground water at 550 gpm from beneath the site is approximately two years.

As a result of the uncertain duration of the pumpout operation, two alternative durations were evaluated for the cost estimate: 10 years and

30 years. These represent 5 pore volumes and 15 pore volumes, respectively. The 30-year time frame corresponds with the longest time frame recommended by the USEPA (1985a) for purposes of cost estimating.

Operation and Maintenance

Operation and maintenance will be essentially as discussed in the FS Report, with the following changes:

- Sampling for the treatment system will be the same for either Option 1 (air stripping) or Option 2 (GAC).
- The leaching field alternative (Option 2 in the FS Report) is no longer proposed.
- In the cost estimate, operating labor is broken out as a separate line item. It is assumed that one person will be needed on a half-time basis for the duration of the operation.
- Equipment replacement has been identified separately from regular maintenance in the cost estimate.
- Nonhazardous sludge disposal for iron pretreatment is assumed to be necessary, although a significant sludge quantity is not anticipated.

Ground Water Monitoring

The proposed monitoring program for Alternative F, Ground Water Pumpout, Treatment, and Disposal, corresponds with the two proposed phases for this alternative. Quarterly monitoring is proposed for Phase 1, which is estimated to last approximately three years. Semiannual monitoring is proposed for Phase 2. Two durations for Phase 2 operation used for the cost evaluation are 10 years and 30 years. It is proposed that monitoring continue five years after pumpout operations cease.

The sampling programs for the Phase 1 and Phase 2 operations of Alternative F will include the monitoring wells proposed for the No-

Action Alternative of Section 4.3.1. The Phase 1 monitoring program will also include the following additional wells and monitoring points:

- Each of the five ground water pumpout wells.
- The Minneapolis Water Treatment Plant intake.
- The combined pumped ground water at the point of discharge to the sanitary sewer.
- Water levels are also proposed to be measured at each of the pumpout wells and the six piezometers proposed for installation in the vicinity of wells AT-3 and AT-5.

The only modification to the Phase 1 program proposed for the Phase 2 monitoring program is the elimination of monitoring at source control pumpout wells AT-1 and AT-4 and the points of their ground water discharge. Operation of these wells is only proposed for the Phase 1 program.

The monitoring program for Alternative F may be revised based on requirements of either the storm or sanitary sewer discharge permits.

5. EVALUATION OF REMEDIAL ACTION ALTERNATIVES

The remedial action alternatives presented in Section 4 have been re-evaluated based on additional information provided in the RI Addendum Report. The re-evaluation was also made necessary by the proposed modifications to Alternative F. The evaluation criteria are the same as those from the FS Report. These include the following:

- Technical feasibility
- Environmental impacts
- Institutional requirements
- Public health concerns
- Cost comparison

The results of the evaluations for the noncost criteria and the cost analysis are summarized in this section.

5.1 Noncost Criteria Analysis

Revisions to the noncost analyses are based on information provided in Section 2 and Section 4 of this report. Although the RI Addendum Report has contributed substantial additional information regarding the distribution of contaminants in the ground water, aquifer properties, and shallow VOC-contaminated source areas, uncertainty regarding the following items affects the noncost criteria evaluations:

- The complete location and extent of the potential shallow VOC-contaminated source areas that may be contributing significant quantities of VOCs to the ground water.
- The rate of desorption of VOCs from the saturated soil.
- The duration of pumping for Alternative F needed to achieve undetermined target concentrations of contaminants.

- The possible influence of upgradient, off-site contaminant sources.

5.1.1 Technical Feasibility

The summary of the revised evaluation of technical feasibility for each of the remedial action alternatives is presented in Table 5-1. The primary revisions are due to the re-evaluation of the pretreatment system, based on the findings of the bench-scale testing of the RI Addendum Report.

The primary conclusion of the FS Report, that none of the alternatives has any major technical feasibility limitations, has not changed. However, the use of the sanitary sewer for disposal (Option 3) will avoid the potential for mechanical, hydraulic, or contaminant breakthrough failure that exists with the air stripper and liquid-phase GAC options.

5.1.2 Environmental Evaluation

The two potentially adverse impacts that were identified in the FS Report as most important for several of the remedial alternatives are the potential for air quality degradation and continued ground water degradation. For the environmental evaluation, the primary concern for ground water degradation is the potential impact to aquatic life and vegetation in the Mississippi River. Modifications to the potentially adverse environmental impacts resulting from revision of the design of each alternative are discussed below.

TABLE 5-1
SUMMARY OF TECHNICAL FEASIBILITY EVALUATION

Remedial Alternative	PERFORMANCE: Effectiveness	PERFORMANCE: Useful Life	RELIABILITY: Operation and Maintenance Requirements	RELIABILITY: Possible Failure Modes
A. Capping	• Regular inspections	• Repave as needed based on inspections	• Regular semiannual inspections	• Spalling or cracking due to weather or traffic; easily repaired
D. In-Situ Vacuum Extraction	• Periodic soil sampling until completed • Air emissions monitoring • Monitoring of downgradient wells	• Remediation likely to be completed within one year	• Minor maintenance associated with electric motor and blower	• Insufficient flow through soil • Equipment failure
F. Ground Water Pumpout, Treatment, and Disposal		Based on vendor estimates of lifetime:	For entire system Operation:	
F-Pumpout	• Flow metering • Ground water levels and quality monitoring	• Pumps: 10 years • Motors: 10 years • Controls: 5 years	• Monitor flow rates throughout system • Monitor VOC concentrations at treatment inflow, outflow points • Monitor effluent air quality for air stripper and vapor-phase GAC • Monitor pretreatment parameters at inflow and outflow points • Remove sludge from iron pretreatment system settling tank	• Failure to yield adequate ground water flow • Pump, motor failure • Aquifer pumping test for vicinity of AT-3 and AT-5 will minimize possible failure modes
F-Treatment	• Influent and effluent VOC concentration measurements (performance standard) • Influent and effluent pretreatment parameter measurements • Inspections of air stripper or GAC systems and discharge pumps to identify scaling/plugging	• Air Stripper: 20 years • Blower: 20 years • Sand filters: 20 years	Maintenance: • Pumps and wells • Treatment components • Utility lines and remediation structures	• Blockage of air stripper or GAC flow • Insufficiently sized air stripper or GAC • Plugging of sand filter • Pump, motor, or blower failure for air stripper • Contaminant breakthrough for liquid-phase or vapor-phase GAC.
F-Disposal	• Compliance monitoring for appropriate permit	• Storm sewer: indefinite		• Insufficient capacity in discharge lines

TABLE 5-1 (CONT'D)
SUMMARY OF TECHNICAL FEASIBILITY EVALUATION

Remedial Alternative	CONSTRUCTABILITY: Site Conditions	CONSTRUCTABILITY: Conditions External to Site	TIME: To Implement	TIME: To See Desired Results	SAFETY CONSIDERATIONS: Worker Health and Safety	SAFETY CONSIDERATIONS: Neighboring Facilities and Communities
A. Capping	• Other concrete pads and pavement have been successfully constructed on-site • Utilities & obstructions in path of trench excavation	• None foreseen	• Minimal • Storm sewer hook-up permit application time	For Alternatives A and D: • Immediate reduction in leachate generation • Reduction in exposure point contamination, dependent on natural ground water flushing time (order of years), and potential for additional sources of contamination	For Alternatives A, D, and F: • Follow USACE and USEPA guidance documents • Develop and implement health and safety plans	• None foreseen
D. In-Situ Vacuum Extraction	• Apparently sufficient working area • Requires electrical service • Utilities & obstructions in path of electrical conduit trench excavation	• Air emissions requirements may result in additional required treatment	• Mobilization and installation time is on the order of 2 months • Pilot study generally not needed • Air emissions permit application (if necessary) • QA/QC planning document preparation		For Alternatives D and F: • Treatment system emissions monitoring • Boring cuttings disposal	• Air emissions: - short duration (less than one year) - ambient air monitoring - worst-case computer model (run by MPCA) indicates treatment needed
F. Ground Water Pumpout, Treatment, and Disposal	• Explosion-proof pump controls required • Public land easement for wells AT-3 and AT-5 • Space available for treatment equipment pad • Requires electrical service • Obstacles in path of trenches for electrical conduit and water distribution system: existing utilities	• 1 1/2-month current pump delivery time • 3-month air stripper and sand filter delivery time • Possible air stripper air emissions requirements • Discharge permitting requirements • Iron sludge disposal requirements for settling tank (nonhazardous)	• Initial pumping test required (for AT-3, AT-5) • Up-front engineering time approximately 3-6 months • Unknown time required to obtain discharge permit • QA/QC planning document preparation and approval • Project coordination with regulators and USACE • Delivery time for equipment (order of months)	• Immediate reduction in off-site contaminant migration • Long-term reduction in on-site well concentrations depends on soil/ground water equilibrium • Downgradient well contaminant reduction will require natural flushing of existing contamination into river	For Alternative F: • Explosion-proof controls • Sulfuric acid handling for $CaCO_3$ scaling control	• Air emissions: - long duration - ambient air monitoring - worst-case computer model (run by MPCA) indicates air treatment needed

No-Action Alternative

Minor air quality impacts occurred during the excavation of a utility trench at the northern property line of the NIROP in September 1987. It is anticipated that such releases will remain sporadic under the No-Action Alternative.

Alternative A - Capping

No substantive changes to the environmental impacts of the capping alternative are anticipated due to the expanded area proposed for capping.

Alternative D - In-situ Vacuum Extraction

Substantial mitigation of air quality degradation due to the vacuum extraction process is anticipated to result from the incorporation of a vapor-phase granular activated carbon system to treat the contaminated air emissions.

Alternative B1 - Excavation and Off-Site Disposal

No modifications to the potential environmental impacts are anticipated based on the revisions of the FS Addendum Report.

Alternative F - Ground Water Pumping, Treatment, and Disposal

Mitigation of air quality degradation due to air emissions from the air stripping columns proposed for Option 1 is expected to result from the incorporation of a vapor-phase granular activated carbon treatment system for the contaminated air emissions.

Reduced construction disturbance for this alternative will result from the revised and simplified layout of the facilities. The length of on-site utility trench excavation has decreased from over 5,000 feet in the FS Report to under 2,000 feet in the FS Addendum Report.

Discharge to the Mississippi River at either of the proposed storm sewer locations is not expected to have an adverse impact on aquatic life and vegetation because of the treatment to the risk-based standards.

5.1.3 Institutional Requirements

Several revisions to the institutional requirements have occurred since the requirements were evaluated in the FS Report. The following are the most important of these revisions:

- A rule was promulgated in March 1988 called "Nondegradation for All Waters" (MPCA Rules, Chapter 7050.0185). This rule was promulgated based on the promotion of a surface water nondegradation policy by the USEPA. The MPCA is in the process of determining how to implement this rule into its permitting process for storm sewer discharges. It is highly likely that this process will result in a risk-based standard for discharges requiring an NPDES permit. Due to this pending rule implementation process, the technology-based treatment standard that was used in the feasibility study as a basis for developing the air stripping alternative is assumed to be no longer viable.

- Risk-based requirements have superseded mass flow-based requirements for air quality discharge permits, especially for carcinogens such as TCE and PCE. The implementation of this policy is still evolving. The 1 percent threshold limit value guidance that was previously considered in the FS Report is also no longer in effect. Vapor-phase treatment of air emissions for Alternative D, In-situ Vacuum Extraction, and Alternative F, Option 1, air stripping, is believed to be needed based on a preliminary air quality screening for each system conducted by the MPCA. Additional air quality modeling is recommended in order to determine if air treatment is necessary in both cases. According to current MPCA policy, the duration of the operation has no impact on whether air emissions treatment is necessary.

- A service area connection (SAC) fee program is in effect at the Metropolitan Waste Control Commission (MWCC). The SAC fee is assessed for ground water disposal of at least three years duration to develop a reserve capital fund for wastewater treatment plant capacity expansion.

- The written approval of the Board of the MWCC is required for disposal of pumped contaminated ground water into the sanitary sewer system. One condition for approval is that the feasibility of alternative ground water disposal options must be evaluated; in particular, the NPDES storm sewer discharge option. The approval process must be revisited annually. In addition, shut off of the pumpout system would probably be required during rainfall events.

- For Alternative F, Options 1 and 2, an alternative off-site storm sewer disposal hookup may be required in order to discharge the treated ground water downstream of the Minneapolis Water Treatment Plant intake. This decision is made by the MPCA during the NPDES permit application process.

- The use of the RCRA alternate concentration limit as a potential ARAR for ground water clean-up was discussed in Section 2.4.5.

A summary of the institutional requirements discussed above and those presented in the FS Report are presented in Table 5-2.

5.1.4 Public Health Evaluation

The public health evaluation has been revised to incorporate information from the RI Addendum Report.

Evaluation of the No-Action Alternative

The No-Action Alternative was re-evaluated in Section 7 of the RI Addendum Report, to evaluate the threat to public health in the absence of a response action. The public health evaluation was performed for the potential receptor area of the Minneapolis municipal water supply

TABLE 5-2
SUMMARY OF INSTITUTIONAL REQUIREMENTS UNDER CERCLA

Remedial Alternative	Ambient or Chemical-Specific Requirements	Performance, Design, or Action-Specific Requirements
A. Capping	Soil: Non-promulgated Minnesota guidance (unwritten) . Total VOCs less than 1 mg/kg in soil sample from beneath excavation to allow backfilling with clean fill. . May also apply to residual soil concentrations below cap. . Ground water ARARs may apply to leachate extracted from soil sample, or a soil concentration standard may be calculated based on a correlation with an acceptable leachate concentration.	Soil: . RCRA closure design specifications may be relevant and appropriate: - This may result in a substantially modified design and increase in cost. - All or part of RCRA closure requirements may apply. . No percent or numerical cleanup standard is set by the state for contaminated soils. . 5-year review process under SARA and emphasis on permanent remedial measures discourage this alternative.
D. In-Situ Vacuum Extraction	Soil: Same as for Alternative A. Air: No National Ambient Air Quality Standards (NAAQS) are established for constituents of concern.	Soil: Same as for Alternative A, except SARA process favors this alternative. Air: Minnesota air quality discharge permit needed. . Permit requirements are risk-based (no longer mass flow based). . Initial screening model for the NIROP conducted by MPCA indicates air emissions treatment needed for Alt. D and Alt. F (for the air stripper option).
F. Ground Water Pumpout, Treatment, and Disposal	Water: . MCL is the ARAR for TCE at the point-of-use. . RALs are to be considered as ARARs for 1,2-DCE and PCE. . RCRA ACL approach may be considered as an ARAR requiring adoption of standards at the NIROP boundary. Air: Same as for Alternative D, except anticipated duration of Alternative F is long-term.	Water: . Storm sewer discharge will require modification of the current NPDES permit. Permit process is being revised to incorporate recently adapted non-degradation rule for surface water. Risk-based standards are expected. . Sanitary sewer discharge requires negotiated agreement with Metropolitan Waste Control Commission. Pretreatment is only required for TCE and VOCs exceeding 5 mg/l and 15 mg/l respectively. Agreement is revised annually. . Leaching field disposal will require State Disposal System (SDS) permit. Permit is part of compliance with Minnesota non-degradation of ground water policy. Quantitative standards are risk-based. Soil: Same as for Alternative D. Air: Same as for Alternative D.
No-Action Alternative	Water: Must demonstrate compliance with ARARs, proposed ARARs, and/or risk-based advisory levels in range of 10^{-4} - 10^{-7} risk. Soil: Same as for Alternative A.	Soil: RCRA closure requirements may necessitate action on contaminated soil.

intake location, approximately one mile downstream of the NIROP on the Mississippi River. The evaluation incorporated a risk calculation for this potential receptor area. The principal finding of the risk assessment was that the TCE concentration (0.0035 mg/l) calculated at the water supply intake based on the assumption of 10 percent dilution of ground water by the Mississippi River surface water results in a carcinogenic risk level for TCE just above 10^{-6}, the USEPA target risk level for individual carcinogens. This is well within the USEPA allowed risk range of 10^{-4} to 10^{-7}. These values for risk range are defined as a risk in the range of 1-in-10,000 to 1-in-10 million that an adult weighing 154 pounds who drinks 2.1 quarts of water, contaminated with a corresponding range of a cancer-causing constituent, per day for 70 years will develop cancer.

The TCE concentration calculated assuming 10 percent dilution is the most conservative of the four values shown on Figure 7-1 of the RI Addendum Report. The other values shown on Figure 7-1, two average values for measured TCE concentrations at the intake and at the point of use, and the calculated TCE concentration, assuming 100 percent dilution, fall below the 10^{-6} risk level, at approximately the 10^{-7} risk level.

Principal conclusions of the public health evaluation are as follows:

- Downgradient TCE concentrations may continue to increase, due to the high concentrations of TCE in the southeast corner of the NIROP, where neither the source or extent of contamination is adequately defined.

- Reliable estimates of future downgradient TCE concentrations are precluded by uncertainty over the sources of ground water contamination both in the southeast corner of the NIROP and off-site.

- Based on the measurement of decreased concentrations of TCE in treated water from the water treatment plant, during 1987 when the TCE concentration in the ground water was increasing, it is likely that the incremental effect of continued increasing TCE concentrations in the ground water downgradient of the NIROP on untreated water TCE concentrations from the city water treatment plant will be negligible in the near future.

- The 10^{-6} to 10^{-7} risk range for the calculated and measured TCE concentrations at the water treatment plant intake or in the treated water indicates that little or no remediation is necessary based on current risk levels for the Minneapolis Water Supply System.

Evaluation of Alternative F

Based on the revised hydrogeological information in the RI Addendum, the capture zones for wells AT-3 and AT-5 overlap for both the 100 gpm and 200 gpm pumping rates. Consequently, all of the ground water passing underneath the site should be captured at either pumping rate. However, the hydrogeological properties are still not fully defined. Consequently, as a conservative approach, Alternative F has been evaluated at the higher pumping rate.

Summary of Public Health Evaluation for All Alternatives

Table 5-3 summarizes the essential information regarding the public health benefits and costs for each alternative. Alternative B1 was eliminated during the screening process, but is presented here in conformance with the USEPA feasibility study guidance document.

TABLE 5-3
SUMMARY OF PUBLIC HEALTH EVALUATION

Remedial Alternative	TECHNICAL ISSUES: Technologies Used to Minimize Potential Exposures	TECHNICAL ISSUES: Chemical Releases Minimized by Remedial Action	TECHNICAL ISSUES: Chemical Releases Not Minimized by Remedial Action	TECHNICAL ISSUES: Time Until Chemical Concentrations are Reduced at Receptor Locations	EXPOSURE ISSUES: Anticipated Exposure: During Remediation	EXPOSURE ISSUES: Anticipated Exposure: Following Remediation	EXPOSURE ISSUES: ARAR Standards Achieved	EXPOSURE ISSUES: Non-ARAR Standards Achieved/Not Achieved
SOURCE CONTROL:								
A	Cap	Leachate from soil in trench 3	Contaminated ground water	Determined by natural flushing of existing ground water contamination (estimate is within 5 years at downgradient off-site area)	Contaminated ground water and surface water downgradient	None after natural flushing is complete, provided no other sources are on-site	None achieved by remediation, only by natural flushing. Several years will be required to flush residual contamination from saturated soils	Not applicable
D	In-Situ Vacuum Extraction	Same as for Alternative A	Same as for Alternative A	Same as for Alternative A	Contaminated air emissions, ground water and downgradient surface water and contaminated soil during drilling	Same as for Alternative A	Same as for Alternative A	Worst-case air quality modeling indicates vapor phase treatment is needed to achieve air quality ARAR
B1	Excavate and Off-Site Disposal	Same as for Alternative A	Same as for Alternative A	Same as for Alternative A	Contaminated soil, ground water, and downgradient surface water and contaminated soil during drilling	Same as for Alternative A	Same as for Alternative A	Soil with VOC concentration greater than 1 mg/kg would be removed
MIGRATION MANAGEMENT:								
F	Pumpout and either air strip or use GAC Option 3 - Disposal to sanitary sewer Possible storm sewer disposal downstream of intake	Contaminated ground water	Leachate from soil in area north of the plant	Less than 1 year; downgradient plume must be flushed to river first	Contaminated air emissions, (in absence of vapor phase GAC), ground water, and downgradient surface water	Contaminated plume is expected to continue unless contamination source is remediated	All ARAR standards are anticipated to be met if all contamination sources are remediated	It is anticipated that each appropriate standard would be met
No Action	None	None	All	Several years based on natural aquifer flushing and flushing of contamination sources by recharge	All current exposures	All current exposures	None except after natural flushing	Not applicable

5.2 Cost Analysis

A revised cost analysis has been prepared for Alternatives A, D, and F. The analysis consists of an estimation of costs for each alternative and an evaluation of present worth. A sensitivity analysis for the interest rate included the use of 7 percent and 10 percent interest rates. Additional sensitivity analyses were performed for Alternative F. Alternative operation durations of 10 years and 30 years were evaluated. The cost estimates are intended to have an accuracy of -30 percent to +50 percent, as recommended by the USEPA (USEPA, 1985a).

The results of the analyses for both the source control and management of migration alternatives are presented in Table 5-4. For source control alternatives, the increase in costs for both the capping and vacuum extraction alternatives is predominantly due to the larger area of identified shallow soil contamination. The increase in capital cost from that presented in the FS Report is 40 percent for the capping alternative and 50 percent for the vacuum extraction alternative, indicating a comparable scale of costs. The increase in the operation and maintenance costs for the capping alternative is primarily due to the incorporation of a cap replacement cost over the 30-year period of evaluation. The increased cost for the vacuum extraction system is due to the addition of a vapor-phase granular activated carbon (GAC) system for air emissions and the incorporation of a pilot study into the start-up. The cost for this alternative would be revised downward on the

TABLE 5-4

PRESENT WORTH COST SUMMARY OF
DETAILED ALTERNATIVES

Alternative	Costs ($1,000s)				
	Capital	O & M		Total(3)	
		10 years	30 years	10 years	30 years
Interest Rate = 7 percent					
A: Capping	210	N/A	140	N/A	340
D: Vacuum Extraction	1,000	N/A	N/A	N/A	1,000
F: Pump, Treat, and Dispose of Ground Water					
Option 1: Air Stripper	1,100	2,100	3,200	3,200	4,300
Option 2: GAC	800	2,700	4,200	3,500	5,000
Option 3: Sanitary Sewer	200	3,900	5,900	4,100	6,100
Interest Rate = 10 percent					
A: Capping	210	N/A	100	N/A	310
D: Vacuum Extraction	1,000	N/A	N/A	N/A	1,000
F: Pump, Treat, and Dispose of Ground Water					
Option 1: Air Stripper	1,100	1,800	2,500	3,000	3,700
Option 2: GAC	800	2,400	3,400	3,200	4,100
Option 3: Sanitary Sewer	200	3,500	4,700	3,700	4,900

NOTES:
1. Costs exclude ground water monitoring.
2. N/A = Not applicable for this alternative.
3. Because of rounding, all total costs do not equal capital costs plus O&M costs.

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order of $100,000 in the absence of vapor-phase GAC treatment. The increased monthly cost of extraction operation was off-set by the shorter estimated duration.

Alternative F represents an expansion and a modification of the Alternative F presented in the feasibility study. Therefore, it is difficult to make a point-by-point comparison of cost. Although the two air stripping alternatives presented in the FS Report and FS Addendum Report are different in that the latter system involves a two-stage air stripper along with vapor-phase carbon adsorption, the present worth costs presented for the air stripping alternative in the case of a 10 percent interest rate and a 30-year operation are comparable to the costs presented in the feasibility study for this alternative. However, the capital cost for the FS Addendum system is nearly 50 percent lower than the system in the FS Report. The primary reasons for this are as follows:

- The system has been streamlined (tanks, pumps, pipes).
- Percent costs for design and installation were scaled down based on additional information from vendors.
- The maintenance cost was scaled down based on additional communication with vendors.

The total costs presented in Table 5-4 are effectively comparable to each other, for both the 10-year and 30-year durations and for the 7 and 10 percent interest rates. The total costs are within -30 percent to +42 percent of each other. Thus, no ground water pumpout alternative may be screened out or preferred based on total cost alone.

Each of the three options presented contains a different composition of costs, however. For Option 1, with air stripping and vapor-phase carbon treatment, most of the cost is evenly divided among sanitary sewer disposal costs for the first three years, the long-term operation and maintenance cost, and the capital cost. For this system, the cost of the granular activated carbon is on the order of 10 to 15 percent, mainly due to the higher carbon efficiency for vapor-phase treatment. For Option 2, with liquid-phase GAC treatment, approximately 30 to 35 percent of the cost is for carbon replacement. The remaining costs are divided between capital cost and the sanitary sewer disposal cost with a smaller cost for operation and maintenance.

For Option 3, with disposal to the sanitary sewer, over half of the cost is for sewer discharge fees. These costs are determined by the City of Fridley. Therefore, the ultimate cost of this alternative could vary substantially from the projections presented in Appendix D. Another large portion (20 percent to 25 percent) of the cost is for a one-time SAC fee, which, for this cost estimate, is assumed to be at the end of the third year of operation. The capital cost for Option 3 is less than 10 percent of the total cost for both the 10-year and 30-year operationg durations.

The cost estimates for the monitoring program have been separated from the cost estimates for the remedial action alternatives. The cost estimates for the monitoring program are presented in Table 5-5. The monitoring programs for the FS Addendum Report include a capital cost

TABLE 5-5

PRESENT WORTH COST SUMMARY OF
GROUND WATER MONITORING FOR
DETAILED ALTERNATIVES

Alternative	Costs ($1,000s)				
	Capital	Annual		Total	
		10 years	30 years	10 years	30 years
	Interest Rate = 7 percent				
No Action & Source Control	40	N/A	590	N/A	630
Alternative F	70	450	570	510	630
	Interest Rate = 10 percent				
No Action & Source Conrol	40	N/A	450	N/A	490
Alternative F	70	420	450	480	520

NOTE: N/A = Not applicable for this alternative.

component which incorporates estimated costs for the installation of additional monitoring wells for the No-Action and Source Control Alternatives and monitoring wells and piezometers for Alternative F.

The present worth cost of the annual monitoring program for each of the alternatives is from 5 to 40 percent lower than the present worth cost estimate for the monitoring program in the FS Report. This is due to the reduced number of samples proposed for chemical analysis and the revised estimate of the unit cost for chemical analysis. The present worth of the Alternative F annual monitoring costs is approximately the same as the present worth cost for either the No-Action or Source Control Alternative. The Phase 2 monitoring program for Alternative F is semiannual as compared with the quarterly monitoring program over the 30-year lifetime for the No-Action Alternative. There is a 10 to 25 percent difference between the monitoring cost estimated for the annual monitoring for the 15-year monitoring program and the 30-year monitoring program for Alternative F.

Sensitivity Analysis

Sensitivity analyses were performed over the assumed operational duration of Alternative F and at two interest rates. The increase in cost due to increasing the system operation from 10 to 30 years is on the order of 20 to 50 percent, with the largest cost increase being for Option 3, with sanitary sewer disposal. The effect of increasing the interest rate from 7 to 10 percent is a decrease in total cost on the order of 10 to 30 percent with no apparent incremental cost difference between alternatives.

For Option 2, with liquid-phase carbon treatment, and for Option 1, with vapor-phase carbon treatment, the amount of carbon used is based on two factors: the quantity of VOCs extracted from the ground water, and the carbon usage rate for a given quantity of VOCs. The carbon usage rate and the unit price of carbon assumed for both the vapor-phase and liquid-phase carbon treatments are based on vendor experience. Bench-scale testing is recommended for more accurate estimates of the carbon usage rate for the NIROP.

A sensitivity analysis, presented in Appendix D, was performed for the total carbon usage cost. Carbon usage was estimated based on 0, 5 and 10 percent annual decreases in the quantity of VOCs extracted from the ground water. Total carbon cost decreases on the order of 40 to 80 percent with each 5 percent decrease in the quantity of VOCs extracted annually. For this cost estimate, a 5 percent annual decrease in extracted VOCs was used. This scenario assumes that 57 tons (approximately 9,400 gallons) of TCE would be removed over a 30-year operating lifetime of the system. With no annual decrease in the quantity of extracted VOCs, the quantity of TCE would double. At a 10 percent annual decrease in extracted VOCs, the quantity of TCE removed over 30 years would be approximately 35 tons (approximately 5,700 gallons). The assumption that an annual decrease in TCE quantity pumped from the aquifer will occur is justified because the quantity of TCE stored in the aquifer is expected to decrease as contaminated ground water is pumped from the aquifer and TCE is desorbed from the saturated soil. This assumes that a continuing off-site or shallow soil source is not contributing additional TCE to the aquifer beneath the NIROP.

No sensitivity analysis was performed to support the following assumptions and estimates:

- Different levels of pretreatment are assumed to be needed for the GAC treatment system and the air stripping treatment system, as noted in Section 4.

- If the alternative downstream storm sewer system is needed for Options 1 or 2, the additional installation cost would be approximately $200,000, where $50,000 would be for piping and $150,000 for pipe jacking, permitting, and ancillary activities.

- For the sanitary sewer disposal option, the one-time SAC fee is assumed to be assessed at the end of the third year of operation. The cost, provided by the MWCC, is $2/gpd of ground water discharged to the sanitary sewer.

- The sewer usage fee of $1.10 per 1,000 gallons is based on current City of Fridley prices.

6. SUMMARY OF ALTERNATIVES

Only the management of migration alternative is proposed for the initial implementation of the remedial action. Additional investigations to better characterize the source area are recommended for the shallow soils before the final selection of a source control alternative is made. An interim period of approximately three years is assumed for the evaluations in the Feasibility Study Addendum Report.

Three options are presented for Alternative F, where Option 3, sanitary sewer disposal, is effectively Alternative E of the FS Report. The options are not substantially differentiated by cost, considering the level of accuracy of the estimates. However, the sanitary sewer present worth estimate is approximately $1,200,000 more than that for air stripping for the 30-year operation (at 10 percent interest).

While each option for Alternative F uses standard technologies, installation for Option 3, sanitary sewer disposal, involves the least site disturbance of the three, and the fewest mechanical components. The relatively low capital cost of Option 3 compared with Options 1 and 2 reflects this. The operation and maintenance for Option 3 will also be simpler and less costly than that for the options involving ground water treatment. However, the unit cost for the sanitary sewer disposal fee may increase substantially in the future.

Institutional factors will probably affect the selection of the disposal option under Alternative F. The storm sewer disposal options will be affected by the NPDES permit conditions. The periodic permit

TABLE 6-1
SUMMARY OF DETAILED EVALUATION OF ALTERNATIVES

Remedial Alterantive	Cost ($1,000s) Capital	Present Worth[1] 10 years	Present Worth[1] 30 years	Public Health Concerns	Environmental Concerns	Technical Concerns	Other Factors
No Action	NA	NA	NA	• Release of contaminants to ground water and Mississppi River down-gradient of NIROP	• Continued migration of contaminated ground water	• Only monitoring is involved	• No-action is viewed as a baseline case, not as a viable alternative
Source Control							
A - Capping of Contaminated Area	210	NA	310	• Public health threat due to existing ground water will not be addressed • Continued aquifer contamination will be minimized	• Existing ground water contamination from the source would continue for several years	• Technology and maintenance are standard	• RCRA-type requirements would substantially alter the cost and design of this alternative
D - In-Situ Vacuum Extraction	1,000	NA	1,000	• Same as Alt. A. Air quality degradation is not anticipated if vapor-phase GAC treatment of air emissions is used	• Same as Alt. A. Potential odor problems are not anticipated if vapor-phase GAC treatment of air emissions is used	• Innovative technology • Likely to work well with NIROP site conditions	• Source contamination would be minimized within one year
Management of Migration							
F - Pumpout, Treatment, and Disposal				• Containment and removal of contaminant plume in ground water • Potential continued contamination from shallow soil sources	• More site disturbance than for other alternatives • Minimizes downgradient degradation rapidly	• Component technologies are well-proven	• Disposal to off-site storm sewer increases capital cost, but eliminates disposal upstream of water supply intake • The choice of treatment and disposal options will be affected by institutional issues (proposed MPCA rules)
Option 1: Air Stripper	1,100	3,000	3,700				
Option 2: GAC	800	3,200	4,100				
Option 3: Sanitary Sewer	200	3,700	4,900				

NOTES: 1. Present worth cost is with 10 percent interest and excludes monitoring program.
2. NA = Not Applicable

review condition for both the storm and sanitary sewer options leaves open the possibility of the loss of the permit or changes to permit conditions at some time during remediation.

Regarding the source control alternatives, capping remains the more cost-effective alternative, while vacuum extraction coupled with vapor-phase GAC treatment would remove and potentially destroy contaminants from the site. The GAC treatment of the air emissions (if necessary) provides an opportunity for the destruction of the contaminants as the GAC is being regenerated. Capping would lose its cost advantage if RCRA closure requirements were applied.

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APPENDIX A

EVALUATION OF RESIDUAL CONTAMINATION IN SHALLOW SOILS

COMPUTATION SHEET

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SHEET 1 OF 5

PROJECT / PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT/PROPOSAL NO.
USACE-NIROP / FS ADDENDUM	SAM	8/9/88	MAW	8-22-88	1473.10

ANALYSIS OF RESIDUAL SOIL CONTAMINATION (REVISED FROM FS REPORT, APP. A)

OBJECTIVE. To estimate the mass and concentration of TCE and other VOCs in contamination source area (shallow, VOC-contam. soils).

REFERENCES. 1) FS Report (July 1988), Appendix A
2) RI Addendum Report, Section 4.1.4, Soil Pore Gas Survey

ASSUMPTIONS.

1) See "CONTAM. SOURCE AREA EST." calcs. dated 8/9/88.

2) Findings are for use in cost estimate for Alt. D, Vacuum Extraction, to estimate poss. treatment duration based on extraction rate and mass of contam. in soil. The contam. mass is estimated here.

3) Estimate is based on the source area shown on Sheet 2, of "Contam. Source Area Est.", dated 8/9/88.

4) Sheet 8 of 11 in App A of FS report showed a semi-log relationship between TCE and PCE concentrations and depth of contamination, at two soil borings from 6-1985 (borings P3-6, P3-7). Concentrations at a 5-ft depth were extrapolated from soil samples at 10, 15 and 20 foot depths. Ratios of est. conc. @ 5' depth to measured conc. @ 10' depth were as follows:

BORING	RATIO	est. conc. @ 5' depth
P3-6	1.8	3.70
P3-7	46	64.00

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SHEET 2 OF 5

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USACE-NIROP / FS ADDENDUM	SAM	8/9/88	[illegible]	8-22-88	1473.10

ASSUMPTIONS (cont'd).

4) (cont'd).

Incorporating data from Jan. 1984, where TCE conc. < 100 mg/kg at depth of 1' below excavation bottom for trench 3, the ratio of 1.8 will be used to re-evaluate the TCE mass in the source area used in the FS Report. This is still an assumption, requiring a re-evaluation with more current borings.

See sheet 3 for the revised estimate of TCE mass.

5) Modify estimated mass of PCE to maintain ratio of PCE to TCE from FS report: 95# PCE / 1300# TCE = 7% PCE

6) Assume total quantity of other VOCs is equal to 5% of TCE.

7) To re-evaluate mass of TCE and VOCs assume the following:

- Average conc. of TCE outside area eval. for FS:

$$C_{TCE,OUT} = \left(\frac{\text{SOIL GAS CONC. OUTSIDE}}{\text{SOIL GAS CONC. INSIDE}}\right) C_{TCE,IN}$$

where SOIL GAS CONC. INSIDE = 270 ppm

SOIL GAS CONC. OUTSIDE = Average of hatched area.

= ~~111~~ 120 ppm in vicinity of trench 3

= ~~206~~ 210 ppm in decon. pad area.

(assume > 300 ppm = 330 ppm

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USACE - NIROP	SAM	11-15-87	FMS	1-11-88	1332.10

TCE MASS APPROXIMATION
RESIDUAL SOIL
TRENCH 3
SOIL DENSITY = 45 KG / CF

BORING	MEAN SAMPLE DEPTH (FT)	THICKNESS (FT)	REPRESENTATIVE SURFACE AREA (FT²)	VOLUME (FT³)	SOIL MASS (KG)	REPRESENT. CONC. (mg/KG)	MASS TCE (lb)	
P3-6	5.75	3.25	65.0	211.0	9500.0	370	77	
	10.75	4.75	65.0	309.0	139000	207	63	
	15.25	4.25	65.0	276.0	124000	127	35	
	19.25	2.75	65.0	179.0	81000	79	14	
	TOTAL	15.00		975.0			189	189
P3-7	5.75	3.25	47.5	154.0	69000	~~6400~~ 250	~~913~~	38
	10.75	4.75	47.5	226.0	102000	139	31	
	15.25	4.25	47.5	202.0	91000	7	1	
	19.25	2.75	47.5	131.0	59000	0.5	0	
	TOTAL	15.00		713.0			~~1005~~	70
P3-11	5.75	3.25	17.5	57.0	26000	~~1800~~ 72	103	4
	10.75	4.75	17.5	83.0	37000	40	3	
	15.25	4.25	17.5	74.0	33000	2	0	
	19.25	2.75	17.5	48.0	22000	0.2	0	
	TOTAL	15.00		262.0			~~106~~	7
	TOTAL		1300	1950.0	0.88 MKG		~~1300~~ lb TCE	270

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SHEET 4 OF 5

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USACE - NIROP/FS ADDEND.	SAM	8/9/88	MAW	8-22-88	1473.10

ASSUMPTIONS (cont'd)

B) DIMENSIONS:

	SOURCE AREA	THICKNESS (FT)	SURFACE AREA (FT²)	SOIL VOLUME (CF)	SOIL MASS MKG
1.	trench 3	15	630	9450	0.43
2	adjacent to trench 3	10	2870	28700	1.29
3.	adj. to decon. pad	5	1900	9500	0.43
					2.15

a) Surface area estimates are from sheet 2 of "contam. source area est." calcs., dated 8/9/88.

b) Thickness. (1) – from FS. (2) est w/o boring data. (3) assume a shallow spill.

c) Soil mass for FS Addend = 2.15/0.88 = 2.4 x FS soil mass in trench 3.

ANALYSIS

1) Conc. of TCE in trench 3 (revised):

Conc. TCE = (mass TCE)/(soil mass)

mass TCE = 270 lb. (see sheet 3)

soil mass = 0.88 million kg (MKG) for area where above TCE mass calc.

Conc. TCE = 270#/0.88 MKG
= (3.1 x 10⁻⁴ #/KG)(0.454 x 10⁶ mg/#)
SAM 140 mg/kg
= ~~141~~ mg/kg SAM 140 mg/kg

Conc. VOCs = (1.12)(Conc. TCE)
= ~~157~~ mg/kg SAM 160 mg/kg

2) Compute mass and average TCE and total VOC conc. at three source areas listed in assumption B, where

mass TCE = (conc. TCE)(mass, soil)/(454000 mg/lb)

and soil mass is calculated in assumption B and conc. TCE + VOC is calculated from assump. 5, 6, and 7.

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SHEET 5 OF 5

PROJECT / PROPOSAL NAME	PREPARED By	Date	CHECKED By	Date	PROJECT/PROPOSAL NO.
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ANALYSIS (cont'd)

2) COMPUTATION OF MASS FOR FS ADDENDUM EST. OF SOIL TREATMENT DURATION

SOURCE AREA	CONCENTRATION (mg/kg) TCE	CONCENTRATION (mg/kg) Total VOC	MASS (LB) TCE	MASS (LB) Total VOC
trench 3	140	160	130	150
adj to trench 3	60	70	170	200
adj. to decon pad	110	120	100	110
TOTAL			400	460
FS TOTAL @ trench 3:			1300	1600
(FS Addend./FS) Percent Ratio:			31	29

CONCLUSIONS 1) Re-evaluation results in a substantially smaller est. of mass of VOCs, although both area and volume of contam. soil estimates are substantially higher.

2) Concentration estimates are more in line with results of 1984, 1985 soil samples, than those of the FS.

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SHEET 1 OF 2

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CONTAM. SOURCE AREA EST. (Shallow, VOC-contam. soils)

1. Source area is based on soil gas findings from RI Addendum.

2. Actual extent of source area is uncertain, as large areas of northern NIROP site are untested.

3. Extent of impact of source areas on ground water contam. is uncertain.

4. To estimate the area, the following assumptions were made:

   - Area where soil gas conc. of TCE+DCE = 270 ppm is approx. area evaluated for source control remed. for FS.

     ∴ Assume 270 ppm in soil gas corresponds with TCE mass est. from 1994/1995 borings.

   - To be conservative, assuming 270 ppm corresp. w/ borings P3-6, P3-7, P3-11, use 50 ppm in soil gas as trigger level for remediation.

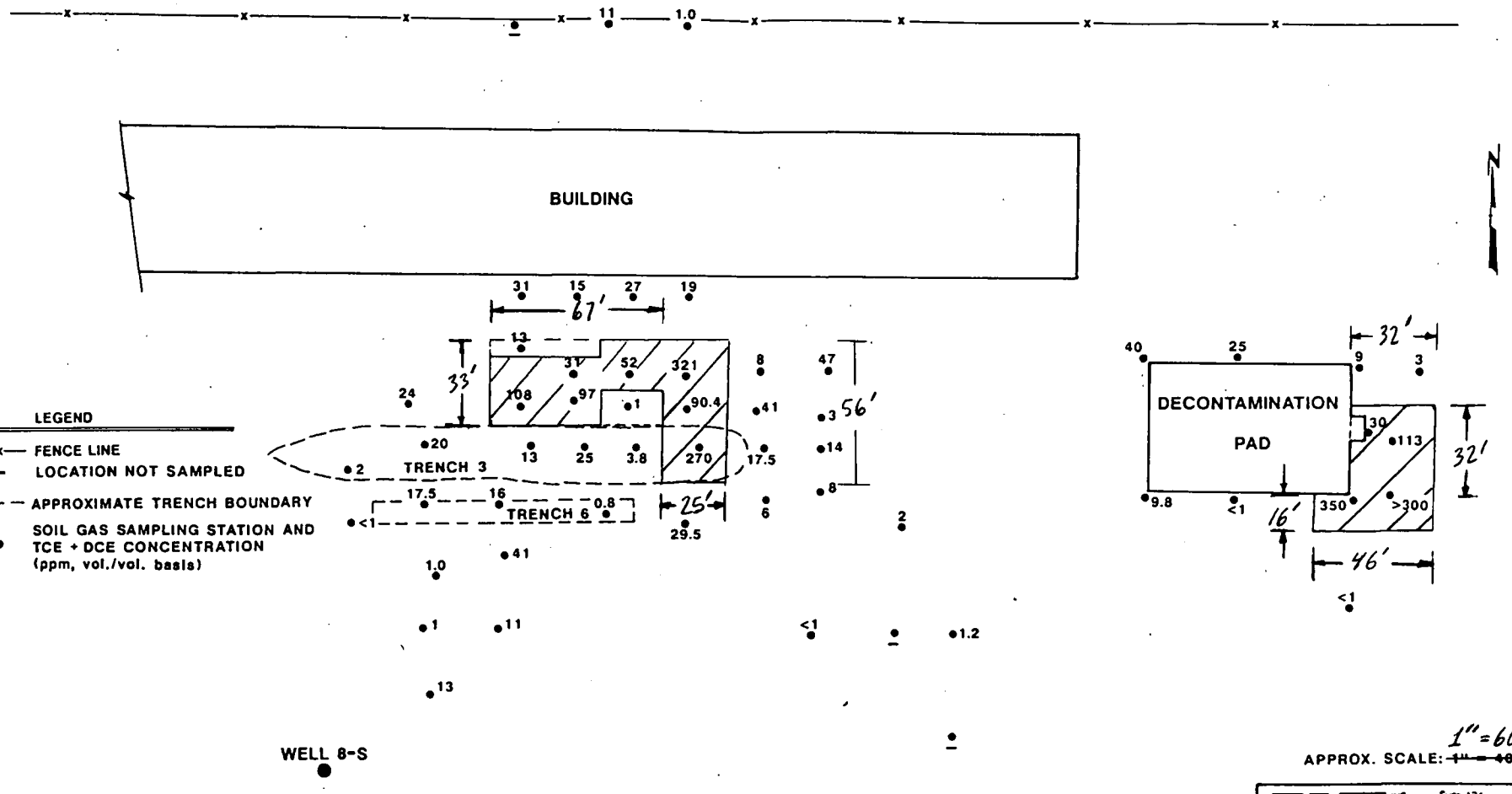
   - Other areas within Trench 3 show TCE+DCE soil gas concentrations to 25 ppm. Soil boring samples in these areas had total VOC levels < 1 mg/kg.

   - It is reasonable to assume that some contam. mass has been reduced by natural volatilization and biodegradation.

5. The area evaluated for source control remediation is shown on Sheet 2 as the hatched area.

   This area is several times larger than the area estimated for the FS. However, the estimated area may again be revised based on additional investigations with soil borings and on the determination of a trigger level for remediation.

6. For purposes of cost estimating, the area evaluated for source control alternatives is bounded by the dashed lines, where needed to complete a rectangular area.



TRENCH LOCATIONS APPROXIMATED, BASED ON FIGURE 2-2 OF JUNE 1987 RI REPORT.

AREA II
(SEE FIGURE 4-3A)

APPROX. SCALE: ~~1" = 40'~~ 1" = 60'

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Dwn.by: DM | Date: 7/6/88 | Proj.#:1332.53

TCE + DCE CONCENTRATION IN SOIL GAS SAMPLES (PPM)

JUL 7 1988

FIGURE 4-3B

SHEET 2 OF 2

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EVALUATE VACUUM EXTRACTION DURATION

1. From FS Report, file notes.

Max. (saturation) extraction conc. of TCE (empirical, from KRS)

$C_{M,TCE} = (500\ ppm)(131\ g/mole)/(24.5 \times 1000) = 2.7\ mg\ TCE/liter$ air

2. Vacuum Extraction System Air Flow.

$Q_{AIR} = (100\ scfm/well)(24\ extraction\ wells)(3.78\ l/gal)(7.48\ gal/ft^3)$

$= 68{,}000\ l/min.$

3. TCE Mass Flow in Air Emissions.

$M_{TCE} = (2.7\ mg/l)(68000\ l/min)(1440\ min/day)/(454000\ mg/lb)$

$= 580\ lb/day$

VOC Mass Flow. Assume total VOC = (1.12) × (TCE)

Based on 7% PCE + 5% other VOC in soil ("Analysis of Resd. Soil Contam.", 9-9-88 calcs.)

$M_{VOC} = (1.12)(M_{TCE}) = (1.12)(580) = 670\ lb/day$ 650 #/d

4. VOC & TCE Mass in shallow soil. See "Analysis of Resd. Soil Contam.", 9-9-88 calcs.

$M_{TCE} = 400\ lb.$ in soil

$M_{VOC} = 460\ lb$ in soil.

5. DURATION

1. M_{SOIL}/M_{AIR} for VOC = (460 lb)/(670 lb/day) = 0.7-day. 650 #/d

if TCE conc. in extraction remains at maximum.

2. Prob C_{AIR} & C_{SOIL} will decrease together (eq. exponentially)

3. Vendor est. TerraVac phone memo to RMT, dated 12-2-87 and letter dated 11-16-87.

- C_{VOC} in soil decreases @ rate of approx. 1 order-of-magnitude per month
- For soil cleanup to 1 ppm headspace, w/ FS assumptions
  - duration is approx. 6-8 mos.

COMPUTATION SHEET

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SHEET 2 OF 2

PROJECT / PROPOSAL NAME	PREPARED By	Date	CHECKED By	Date	PROJECT/PROPOSAL NO.
USACE-NIROP / FS ADDENDUM	SAM	8/16/88	MAW	8.22.88	1473.10

5. DURATION (cont'd)

3. Vendor est. (cont'd)

- FS Addendum system has est. VOC conc. in soil @ 70-160 mg/kg compared w/ 830 mg/kg in FS Report (10-20% of FS conc.) (60-140 mg/kg TCE)
  A faster cleanup would be expected w/ lower initial conc.

- With cleanup to 3 orders-of-magnitude over 3 mos., soil
  $C_{VOC} \sim 0.07-0.16$ mg/kg @ end of 3 mos.
  $C_{TCE} \sim 0.06-0.14$ mg/kg " "

- Using soil/water partition of "Source Control Strategy" calcs., dated 7-31-88:
  For TCE: $C_{WATER} = C_{SOIL} / (0.01 \times 26.9)$

  $C_W = 3.7\, C_{SOIL}$ $C_W \sim$ mg/l, $C_S \sim$ mg/kg

- The partition-based leachate conc. for TCE should be in range of 0.22-0.52 mg/l, on average, based on 1% organic content in soil.

- The conc. in ground water @ property line should be substantially less due to mixing, dilution and dispersion in ground water and readsorption w sat. soils.

- A 6-mos. duration provides for substantial additional conc. decrease and incorporates uncertainties of the process and parameters. It also provides time to check progress of system over several mos. and permits time to coord. w/ MPCA re. closure.

∴ EST. 6 MO. DURATION.

APPENDIX B

INITIAL SCREENING OF

REMEDIAL ACTION ALTERNATIVES

(No changes to the July 1988 FS Report.)

APPENDIX C

GROUND WATER PUMPING DESIGN CALCULATIONS

COMPUTATION SHEET

RMT INC.

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SHEET 1 OF 13

PROJECT / PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT/PROPOSAL NO.
USACE - NIROP / FS ADDENDUM	SKM	7/22/88		8/2/88	1473.10

Ground Water Pumping Calculations

1. PUMPING WELL LOCATIONS.

a. The locations for wells AT-3 and AT-5 proposed in the FS Report appear to be reasonable.

- They are about 500' apart.
- AT-3 is within the highest TCE contour for the shallow aquifer, and AT-5 is within this contour for the deep aquifer.
- Both AT-3 and AT-5 are within the area of the missing till layer of Fig. 5-4B of the RI Addendum.

b. The Locations of AT-1 and AT-2 were finalized for the pump tests. They are close to the locations proposed in the FS.

c. The location of AT-4 need not be fixed at present based on the ground water flow direction variability in the North 40 and the uncertainty over the area with the highest source concentration.

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SHEET 2 OF 13

PROJECT / PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT/PROPOSAL NO.
USACE-NIROP / FS ADDENDUM	SAM	7/27/88	S	8/2/88	1473.10

2. Pumping Well Depths.

a. AT-3, AT-5. Screening these wells over the full aquifer thickness is supported by the following data.

1. Monitoring wells 18-S and 8-D have had TCE concentrations ranging between 1.5 and 12.7 mg/l over 3 sample rounds between April, 1986 and January, 1988 (1 year, 9 mos), with the highest concentrations in the latest round.
2. TCE concentrations in Jan '88 samples from wells 18-S, 4-I and 8-D spanning the full aquifer thickness range between 0.1 and 12.7 mg/l.
3. The area where wells AT-3 and AT-5 are located is interpreted to be homogeneous sand, with an absent till layer.
4. Related to items 1 & 2, Figs. 5-8 through 5-10 of the RI Addendum Report, Extent of TCE Contamination...", indicate that wells AT-3 and AT-5 would be in or adjacent to the most highly contaminated downgradient TCE contours over the shallow, intermediate and deep aquifer.

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2. b. AT-1, AT-2. These wells, as installed, appear to be adequate for remediation purposes.

1. Both wells are screened within and above till layers.
2. TCE was not detected in monitoring wells beneath the till layers.
3. The highest local levels of TCE were detected at AT-1 (11.3 mg/l) and AT-2 (0.6 mg/l), indicating their capacity to remove TCE contaminated groundwater.

c. AT-4. The appropriate depth for AT-4 is not clear.

1. TCE was detected at concentrations ranging from 0.33 mg/l (12-D) to 6.8 mg/l (8-S), with 2.7 mg/l at 3-I.
2. The TCE concentration decreases with depth.
3. The well is located in the area of the missing till layer.
4. The well is a source control well.

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SHEET 4 OF 13

PROJECT / PROPOSAL NAME	PREPARED By	Date	CHECKED By	Date	PROJECT/PROPOSAL NO.
USACE - NIROP / FS ADDENDUM	SAM	9/22/88		8/21/90	1473.10

3 PUMPING RATES

A. Overview.

1. Proposed downgradient pumping wells AT-2, AT-3 and AT-5 are re-evaluated for use as management of contaminant migration wells and contaminant removal wells, based on the new data and interpretations of the RI Addendum Report.
2. Capture zones and radii of influence (area of influence) are calculated for a range of pumping rates to determine the level of pumping needed to prevent or minimize off-site contaminant migration and to determine how long it would take to pump one volume of aquifer water from the capture zone or area of influence beneath the site (pore volume).
3. The area of influence calculations are performed with a sensitivity analysis for key parameters, using maximum, minimum and geometric mean values. The mean values are graphically presented for selected pumping rates in Figure 4-4.
4. The assumptions are the same as those used in the FS Report, except for the choice of parameter values.

COMPUTATION SHEET

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SHEET 5 OF 13

PROJECT / PROPOSAL NAME	PREPARED By	Date	CHECKED By	Date	PROJECT/PROPOSAL NO.
USACE - NIROP / FS ADDENDUM	SAM	7/12/88		8/2/88	1473.10

3. PUMPING RATES (cont'd)

BRI Addendum Notes (1332.53)

1. Avg Linear velocity (from KEB calcs. dated 6-2-88 & 6-4-88): AT-3, AT-5

a. Hydraulic conductivity (geom. mean), K: In-situ permeability

Nests
10-D, 15-S
13-D, 25-S

1. Shallow. (15-S, 22-S, 23-S, 24-S, 25-S), K_M = > 94 ft/d.
   (22-S, 23-S, 24-S, 25-S: w/o AT-3, AT-5; 24-S: near AT-2)
2. Deep. (10-D, 13-D), K_M = 5 ft/d
3. Shallow well depths 35-43 ft
4. Deep well depths 102-104 ft
5. Interim well depths (1-I, 4-I) 77-78 ft
   (1-I: w/15-S, 10-D; 4-I: near AT-3, AT-5; K_M = 7 ft/d.; K > 43 ft/d.)

b. Horiz. Gradients, J_H

1. Shallow.

a. Gradients A & C represent gradient along flow path in vicinity of AT-3 & AT-5.

J_A 0.0078
J_C 0.0017

b. Gradients B & D represent J along path in vicinity of AT-2.

J_B 0.067
J_D 0.00010

c. Gradients A, B represent both the capture zone (CZ) near the pumping wells. The CZ will widen as gradient flattens.

2. Deep.

a. Gradients B & C represent conditions around AT-3 & AT-5.

J ≃ 0.004

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SHEET 6 OF 13

PROJECT / PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT/PROPOSAL NO.
USACE – FS ADDENDUM	SAM	7/22/88		9/2/89	1473.10

1.c. Linear (seepage) velocity, $V = KJ_H/n = Ki/n$

1. Based on single well response tests & gradients from Jan. '88 interpreted ground water contours.

2. AT-3, AT-5. Assume $n = 0.3$

a. K. Shallow ("7" = greater than)

23-S	>540 ft/d	← max.
22-S	> 79 ft/d	
Mean	> 94 ft/d	

Intermed.

4-I	> 43 ft/d	← max.
Mean	7 ft/d	

Deep

13-D (max.)	28 ft/d	← max.
Mean	5 ft/d	

Range 1 – >540 ft/d.

Depth-averaged geom. mean: of means 15 ft/d
of max. >87 ft/d
of mins.

Representative values (Depth-averaged) for AT-3, AT-5

Max. ≈ 23-S	> ~~540~~ ft/d	SAY	600
Mean ≈ Mean Max.*	> ~~87~~ ft/d	SAY	100
Min ≈ Mean mean	~~15~~ ft/d	SAY	10

* Also depth-averaged mean along AT-3, AT-5 flow line.

b. J.

Max. ≈	J_A	= 0.0078	SAY	0.008
Mean ≈	J_{DEEP}	= 0.004		
Min ≈	J_C	= 0.0017	SAY	0.002

c. Linear velocity. (Depth-averaged) – for AT-3, AT-5

	K (ft/d)	J (ft/ft)	n (assumed)	V (ft/yr)	
Max.	600	0.008	0.3	~~5,840~~	SAY 6000
Mean	100	0.004	0.3	~~490~~	SAY 500
Min	10	0.002	0.3	20	
Geom. Mean (of Max., Mean, Min)				~~390~~	SAY 400

Feet/yr

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PROJECT / PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT/PROPOSAL NO.
USACE – FS ADDENDUM				3/22/3	1473.10

2. Pumping well AT-2.

a. Well is screened above and into fill layer. Neglect intermediate and deep results.

b. KEB calcs. dated 6-2 & 6-4-88

1. Hydr. cond. Use well 24-S response test, K_{NEAR} 16 ft/d say 20
15-S " " , $K_{U/G}$ = ~~78~~ ft/d say 100

2. Gradient. Near well ≈ align. B J_B = 0.067 ft/ft
U/G ≈ align. D J_D = 0.00010 ft/ft

3. Velocity, V = kJ/n Near well V = ~~1,630~~ ft/yr say 1600
, n = 0.3 (assume) U/G V = ~~12~~ ft/yr say 10
Geom. mean V = ~~126~~ ft/yr say 130

c. Pump Test QCSR. AT-2 Q_p ≈ 150 gpm ; 3-days

1. Shallow aquifer, B ≈ 28 ft
Clay confining layer in vicinity of AT-2.

2. RESULTS. K = T/B

Location		Transmissivity (ft^2/d)	Hydr. Cond. ft/d	Storativity	Radius (ft) of Influence (3-days)
Well	24-S	8,300	300	0.13	
Range	AT-2, 5-S, 6-S	5,500 -	200 - 420		
	10-S, 17-S	11,800			
Alignment	NW (5-S, 6-S)	5,500 -	200 - 220	0.04 - 0.06	1,400
		6,100			
	NE (10-S)	8,000	290		
	SW (17-S)	11,800	420	0.21 - 0.35	

Barriers: 1. Direction of Miss. R.
2. NE of well 24-S – approx. 75 ft (poss. gravelly sand pinch out into silty sand).
3. AT-2 after 700-min. pumping

3. CONCLUSIONS. a. K_{AT-2} (200-420 ft/d) > K_{NEAR}-$K_{U/G}$ (16-100 ft/d) → use higher velocity est.

b. No pump test results are available for soil in area of AT-3, AT-5. (homog. sand).

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PROJECT / PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT/PROPOSAL NO.
USACE - FS ADDENDUM	SAM	7/22/88		8/2/89	1473.10

3. PUMPING RATES (cont'd)

c. Pumping Wells Areas of Influence

Objectives:

Calculate capture zones and radii of influence of downgradient pumping wells AT-2, AT-3 & AT-5.

Method:

1. Use capture zone method of Bear, 1979
2. Use Jacob (1950) equation for radius of influence equation (Bear, 1979).
3. Follow procedures and use assumptions of Feasibility Study Report (RMT, 1988).
4. Use updated parameter values, geologic interpretations and ground water contours from RI Addendum report (RMT, 1988)
5. Evaluate the capture zones and radii of influence for a mean, maximum and minimum set of ground water velocities and hydraulic conductivities as determined in sheets 6 through 7 and summarized in sheet 9

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PROJECT / PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT/PROPOSAL NO.
USACE-NIROP/FS ADDENDUM	SAM	7/22/89	SZ	8/2/89	1473.10

Downgradient Well
Pumping Rate Parameters

Well No.	Value Type	Hydraulic Conductivity (ft/day)	Natural Velocity (ft/yr)	Aquifer Thickness (ft)	Effective Porosity (-)	Pumping Rate (gpm)
AT-2	Maximum	100	1600	NA	NA	200
	Mean	45	130	30	0.2	100
	Minimum	20	10	NA	NA	50
	Pump Test	300	NA	30	0.13	150
AT-3 and AT-5	Maximum	600	6000	NA	NA	200
	Mean	100	500	100	0.3	100
	Minimum	10	20	NA	NA	50
Feasibility Study		1250	730	100	0.3	50 to 200

Notes:

1. Effective porosity for AT-2 is average of pump test value and typical value of 0.3.
2. Mean values are calculated using geometric mean.
3. For radius of influence values, the time to equilibrium is assumed to be 5-days, and the radius is assumed to be reached for drawdown, s = 0.1 foot.

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PROJECT / PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT/PROPOSAL NO.
USACE - NIROP / FS ADDENDUM	SAM	9/12/88		9/12/88	1473.10

CAPTURE ZONE CALCULATION (Bear, 1979)

1. Stagnation Point, $r_s = Q_p / 2\pi B n V_n$; Q_p (FT³/D), V_n (FT/D)

For AT-2: $r_s = Q_p / (2\pi)(30)(0.2) V_n = 0.027 (Q_p / V_n)$

For AT-3, AT-5: $r_s = Q_p / (2\pi)(100)(0.3) V_n = 0.0053 (Q_p / V_n)$

STAGNATION POINT (FT)
NATURAL VELOCITY, FT/YR (FT/DAY)

PUMPING RATE FT³/D (GPM)	WELL AT-2 10 (0.027)	130 (0.36)	1600 (4.4)	WELLS AT-3, AT-5 20 (0.055)	500 (1.4)	6000 (16)
9600 (50)	9600 > R_o	720 > R_o	59 < R_o	930 > R_o	36 < R_o	3.2 < R_o
19300 (100)	19300 > R_o	1400 > R_o	120 < R_o	1900 > R_o	73 < R_o	6.4 < R_o
28900 (150)	28900 > R_o	2200 > R_o	180 = R_o	2800 > R_o	110 < R_o	9.6 < R_o
38500 (200)	38500 > R_o	2900 > R_o	240 > R_o	3700 > R_o	150 < R_o	13 < R_o

PUMPING RATE	MAXIMUM CAPTURE ZONE WIDTH, $E = 2\pi r_s$ (FT)					
9600 (50)	60000	4500	370	5800	220	20
19300 (100)	120000	8800	750	12000	460	40
28900 (150)	180000	14000	1100	18000	690	60
38500 (200)	240000	18000	1500	23000	940	82

Note: R_o is defined on sheet 11.

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PROJECT / PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT/PROPOSAL NO.
USACE-NIROP / FS ADDENDUM	SAM	7/22/88		8/2/88	1473.10

Radius of Influence, $R_o = \exp\left\{\left[\ln\left(\frac{2.25Bt}{S}\right) + \ln K - \left[\frac{(4\pi)(s)(B)}{Q_p}\right]K\right]/2\right\}$

For AT-2: $R_o = \exp\{[7.4 + \ln K - 38K/Q_p]/2\}$

where $B = 30$ ft, $t = 5$-d, $S = 0.2$, $s = 0.1$ ft

For AT-3, AT-5: $R_o = \exp\{[8.2 + \ln K - 130K/Q_p]/2\}$

where $B = 100$ ft, $t = 5$-d, $S = 0.3$, $s = 0.1$ ft

RADIUS OF INFLUENCE (FT), R_o
HYDRAULIC CONDUCTIVITY (FT/DAY)

PUMPING RATE FT³/D (GPM)	WELL AT-2 20	50	100	300 **	WELLS AT-3, AT-5 10	100	600
9600 (50)	170	260	330	390	100	310	25
19300 (100)	180	270	370	520	180	430	200
28900 (150)	180	280	380	580	190	480	380
38500 (200)	180	280	390	600	190	510	540
28900 (150)	NA	NA	NA	1100 *	NA	NA	NA

* Extrapolated from 3-day pump test from distance-drawdown data at wells 5-S, 6-S, 24-S, for s = 0.1 ft.

** Value for hydraulic conductivity estimated from pump test data. See sheet ___ for graphical extrapolation, from pump test analysis.

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PROJECT / PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT/PROPOSAL NO.
USACE-NIROP/FS ADDENDUM	SAM	7/22/88	S	8/2/88	1473.10

Assume that where $r_s > R_o$, the natural ground water gradient may be neglected, and the area of influence of the pumping well is defined by the radius of influence.

For AT-2, use radius of influence to indicate area of influence, for $Q_p = 150$ gpm, and $K = 50, 300$ ft/d, along with R_o estimated from pump test.

For AT-3, AT-5, calculate u/G distance where capture zone width $\simeq E$. This distance is calculated from capture zone (CZ) equation, where $y/r_s = 3$ radians

Capture zone equation: $y/x = \pm \tan(y/r_s)$

For $y/r_s = 3$, $y/x = -0.14$, $E = 2\, y_{max}$.

Pumping Rate (ft^3/d)	Natural Velocity (ft/d)	Stagnation Point, r_s (ft)	Maximum CZ Width (ft)	Approx. u/G Dist. ($-x$, ft)	Pumping Rate (gpm)
9600	1.4	36	220	1500	50
19300	1.4	73	460	3200	100
28900	1.4	110	690	4800	150
38500	1.4	150	940	6600	200
9600	16	3.2	20	140	50
19300	16	6.4	40	280	100
28900	16	9.6	60	420	150
38500	16	13	82	580	200

COMPUTATION SHEET

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SHEET 13 OF 13

PROJECT / PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT/PROPOSAL NO.
USACE-NIROP / FS ADDENDUM	SAM	4/22/88	[illegible]	8/2/88	1473.10

CAPTURE ZONE CALCULATION

Pumping Rate (gpm)	Natural Velocity (ft/d)		CAPTURE ZONE COORDINATES y/r_s (radians) 1	π/2	2	2.5	3
50	1.4	y	36	57	72	90	108
		x/y	0.64	NA	-0.46	-1.34	-7.02
		x	23	0	-33	-120	-760
100	1.4	y	73	110	150	180	220
		x/y	0.64	NA	-0.46	-1.34	-7.02
		x	47	0	-69	-240	-1500
150	1.4	y	110	170	220	280	330
		x/y	0.64	NA	-0.46	-1.34	-7.02
		x	70	0	-100	-370	-2300
200	1.4	y	150	240	300	380	450
		x/y	0.64	NA	-0.46	-1.34	-7.02
		x	100	0	-140	-500	-3200
50	16	y	3.2	5.0	6.4	8.0	10
		x/y	0.64	NA	-0.46	-1.34	-7.02
		x	2.1	0	-2.9	-11	-70
100	16	y	6.4	10	13	16	19
		x/y	0.64	NA	-0.46	-1.34	-7.02
		x	4.1	0	-5.9	-21	-130
150	16	y	9.6	15	19	24	29
		x/y	0.64	NA	-0.46	-1.34	-7.02
		x	6.1	0	-8.8	-32	-200
200	16	y	13	20	26	33	39
		x/y	0.64	NA	-0.46	-1.34	-7.02
		x	8.3	0	-12	-44	-270

APPENDIX D

COST ESTIMATES

RMT, Inc.
OPINION OF PROBABLE COST
(COSTEST1)

PROJECT NAME: FRIDLEY
PROJECT #: 1473.10
WORK CODE(S):

TEMPLATE: CAPPING
BY: SAM 8/12/88
DATE: 11-Aug-88
REVISIONS:

ITEM NUMBER	ITEM DESCRIPTION	UNITS	UNIT COST($)	QUANTITY	TOTAL($)
	ALTERNATIVE A CAPPING CONTAMINATED PORTION OF SITE				
1.0000	EXCAVATE/STOCKPILE CLEAN OVERBURDEN	CY	$3.00	300	$900
2.0000	CONSTRUCT CONCRETE CAP				
2.1000	GRADE	SY	$2.00	1350	$2,700
2.2000	CONCRETE CURB	LF	$8.00	630	$5,040
2.3000	GRAVEL FILL (6-IN; BORROW)	CY	$20.00	150	$3,000
2.4000	CEMENT CONCRETE (6-IN; IN PLACE)	SY	$30.00	850	$25,500
3.0000	INSTALL STORM SEWER EXTENSION				
3.1000	GRAVITY PIPE	LF	$16.00	1100	$17,600
3.2000	MANHOLES	EA	$2,000.00	6	$12,000
4.0000	INSTALLED COST SUBTOTAL (ITEMS 1-3)				$66,740
5.0000	HEALTH AND SAFETY (LEVEL D)	LS	$25,000	1	$25,000
6.0000	PIPING	LS	$10,000	1	$10,000
7.0000	ENGINEERING AND DESIGN	LS	$60,000	1	$60,000
8.0000	CONTINGENCIES (30%)	LS	$66,740	30.00%	$20,022
9.0000	CAPITAL COST SUBTOTAL (ITEMS 4-8)				$181,762
10.0000	MOBILIZATION/DEMOBILIZATION	LS	$5,000	1	$5,000
11.0000	SITE PREPARATION/RESTORATION	LS	$10,000	1	$10,000
12.0000	NPDES PERMIT MODIFICATION (STORM)	LS	$10,000	1	$10,000
13.0000	TOTAL CAPITAL COST (ITEMS 9-12)				$206,762

RMT, Inc.
OPINION OF PROBABLE COST
(COSTEST1)

PROJECT NAME: FRIDLEY
PROJECT #: 1473.10
WORK CODE(S):

TEMPLATE: CAPPING
BY: SAM 8/12/88
DATE: 11-Aug-88
REVISIONS:

ITEM NUMBER	ITEM DESCRIPTION	UNITS	UNIT COST($)	QUANTITY	TOTAL($)
	OPERATIONS AND MAINTENANCE (ANNUAL COST)				
14.0000	MAINTENANCE	LS	$4,000	1	$4,000
15.0000	REPLACEMENTS	LS	$7,000	1	$7,000
16.0000	TOTAL ANNUAL O&M (ITEMS 14-15)				$11,000
	PRESENT WORTH ANALYSIS (30 YEARS)				
17.0000	OPERATION AND MAINTENANCE				
17.1000	INTEREST = 10%		9.43	$11,000	$103,696
17.2000	INTEREST = 7%		12.41	$11,000	$136,499
18.0000	TOTAL PRESENT WORTH				
18.1000	INTEREST = 10%				$310,458
18.2000	INTEREST = 7%				$343,261

RMT, Inc.
OPINION OF PROBABLE COST
(COSTEST1)

PROJECT NAME: FRIDLEY
PROJECT #: 1473.10
WORK CODE(S):

TEMPLATE: VACUUM
BY: SAM 8/12/88
DATE: 11-Aug-88
REVISIONS:

ITEM NUMBER	ITEM DESCRIPTION	UNITS	UNIT COST($)	QUANTITY	TOTAL($)
	ALTERNATIVE D IN SITU VACUUM EXTRACTION TREATMENT OF SOILS				
1.0000	INSTALL VACUUM EXTRACTION SYSTEM	LS	$225,000	1	$225,000
2.0000	GAC VAPOR TREATMENT SYSTEM	LS	$40,000	1	$40,000
3.0000	BUILDING	LS	$5,000	1	$5,000
4.0000	INSTALLED COST SUBTOTAL (ITEMS 1-3)				$270,000
5.0000	HEALTH AND SAFETY (25%)		25.00%	$270,000.00	$67,500
6.0000	CIVIL/STRUCTURAL (15%)		15.00%	$270,000.00	$40,500
7.0000	ELECTRICAL/INSTRUMENTATION (25%)		25.00%	$270,000.00	$67,500
8.0000	PIPING (10%)		10.00%	$270,000.00	$27,000
9.0000	ENGINEERING AND DESIGN (30%)		30.00%	$270,000.00	$81,000
10.0000	CONTINGENCIES (15%)		15.00%	$270,000.00	$40,500
11.0000	CAPITAL COST SUBTOTAL (ITEMS 4-10)				$594,000
12.0000	EQUIPMENT MOBILIZATION	LS	$15,000	1	$15,000
13.0000	STARTUP/SHAKEDOWN	LS	$120,000	1	$120,000
14.0000	WELL CUTTINGS HANDLING/DISPOSAL	EA	$100	24	$2,400
15.0000	AIR EMISSIONS PERMITTING	LS	$10,000	1	$10,000
16.0000	TOTAL CAPITAL COST (ITEMS 11-15)				$741,400

RMT, Inc.
OPINION OF PROBABLE COST
(COSTEST1)

PROJECT NAME: FRIDLEY
PROJECT #: 1473.10
WORK CODE(S):

TEMPLATE: VACUUM
BY: SAM 8/12/88
DATE: 11-Aug-88
REVISIONS:

ITEM NUMBER	ITEM DESCRIPTION	UNITS	UNIT COST($)	QUANTITY	TOTAL($)
	OPERATION AND MAINTENANCE (6 MONTHS)				
17.0000	EXTRACTION OPERATION (LABOR & EQUIPMENT)	MO	$19,000	6	$114,000
18.0000	SITE VISITS	LS	$27,000	1	$27,000
19.0000	CARBON REPLACEMENT	LS	$6,000	1	$6,000
20.0000	ELECTRICITY	LS	$10,000	1	$10,000
21.0000	SOIL SAMPLING/ANALYSIS	QUARTER	$35,000	3	$105,000
22.0000	TOTAL ANNUAL O&M (ITEMS 17-21)				$262,000
23.0000	TOTAL PRESENT WORTH (ITEMS 16&22)				$1,003,400

RMT, Inc.
OPINION OF PROBABLE COST
(COSTEST1)

PROJECT NAME: FRIDLEY
PROJECT #: 1473.10
WORK CODE(S):

TEMPLATE: FRIDAIR
BY: SAM BEP 8/12/88
DATE: 11-Aug-88
REVISIONS:

ITEM NUMBER	ITEM DESCRIPTION	UNITS	UNIT COST($)	QUANTITY	TOTAL($)
	ALT. F - PUMP, TREAT, AND DISPOSE OF GROUND WATER				
	OPTION 1 - AIR STRIPPING				
1.0000	INSTALL DEEP WELL EXTRACTION SYSTEM				
1.1000	EXTRACTION WELL @ 120 FT	EA	$20,000.00	2	$40,000
1.2000	EXTRACTION WELL @ 60 FT	EA	$10,000.00	1	$10,000
1.3000	PUMP (Q=200 GPM, 5 HP)	EA	$5,000.00	2	$10,000
1.4000	PUMP (Q=150 GPM, 5 HP)	EA	$5,000.00	1	$5,000
1.5000	PUMP (Q=50 GPM, 2 HP)	EA	$2,500.00	2	$5,000
2.0000	INSTALL TREATMENT SYSTEM				
2.1000	COLLECTION TANK	EA	$15,000.00	2	$30,000
2.2000	PUMP	EA	$18,000.00	1	$18,000
2.3000	PRETREATMENT SYSTEM (Fe + Ca)	LS	$160,000.00	1	$160,000
2.4000	AIR STRIPPING SYSTEM (Q=650 GPM)	LS	$120,000.00	1	$120,000
2.5000	BUILDING, SUMP AND PUMP	LS	$60,000.00	1	$60,000
2.6000	GAC VAPOR TREATMENT	LS	$50,000.00	1	$50,000
3.0000	INSTALL WATER DISTRIBUTION SYSTEM				
3.1000	PRESSURE PIPE, INSTALLED	LF	$14.00	1800	$25,200
4.0000	INSTALLED COST SUBTOTAL (ITEMS 1-3)				$533,200
5.0000	HEALTH AND SAFETY (15%)		15.00%	$533,200.00	$79,980
6.0000	CIVIL/STRUCTURAL (15%)		15.00%	$533,200.00	$79,980
7.0000	ELECTRICAL/INSTRUMENTATION (25%)		25.00%	$533,200.00	$133,300
8.0000	PIPING (10%)		10.00%	$533,200.00	$53,320
9.0000	ENGINEERING AND DESIGN (15%)		15.00%	$533,200.00	$79,980
10.0000	CONTINGENCIES (15%)		15.00%	$533,200.00	$79,980

RMT, Inc.
OPINION OF PROBABLE COST
(COSTEST1)

PROJECT NAME: FRIDLEY
PROJECT #: 1473.10
WORK CODE(S):

TEMPLATE: FRIDAIR
BY: SAM 8/12/88
DATE: 11-Aug-88
REVISIONS:

ITEM NUMBER	ITEM DESCRIPTION	UNITS	UNIT COST($)	QUANTITY	TOTAL($)
11.0000	CAPITAL COST SUBTOTAL (ITEMS 4-10)				$1,039,740
12.0000	DRILLING AND TREATMENT MOBILIZATION	LS	$40,000.00	1	$40,000
13.0000	STARTUP OF TREATMENT SYSTEMS	LS	$20,000.00	1	$20,000
14.0000	WELL CUTTINGS HANDLING/DISPOSAL	LS	$500.00	3	$1,500
15.0000	PERMITTING				
15.1000	MWCC (SANITARY)	LS	$5,000.00	1	$5,000
15.2000	NPDES MODIFICATION (STORM)	LS	$25,000.00	1	$25,000
15.3000	AIR EMISSIONS	LS	$10,000.00	1	$10,000
16.0000	TOTAL CAPITAL COST (ITEMS 11-15)				$1,141,240
	OPERATION AND MAINTENANCE (ANNUAL COST)				
17.0000	SANITARY SEWER DISPOSAL (650 GPM)	1000 GALS	$1.10	342,000	$376,200
18.0000	OPERATING LABOR				
18.1000	EXTRACTION	LS	$12,000.00	1	$12,000
18.2000	TREATMENT	LS	$12,000.00	1	$12,000
18.3000	SITE VISITS (MONTHLY)	MO	$1,000.00	12	$12,000
19.0000	ELECTRICITY ($0.08/KWH)	HP	$530.00	53	$28,090
20.0000	O&M SUBTOTAL (ITEMS 18-19)				$64,090
21.0000	MAINTENANCE (5% OF ITEM 4)		5.00%	$533,200	$26,660
22.0000	EQUIP. REPLACEMENT (10% OF ITEM 4)		10.00%	$533,200	$53,320
23.0000	PRETREATMENT SLUDGE DISPOSAL	LS	$500.00	1	$500

RMT, Inc.
OPINION OF PROBABLE COST
(COSTEST1)

PROJECT NAME: FRIDLEY
PROJECT #: 1473.10
WORK CODE(S):

TEMPLATE: FRIDAIR
BY: SAM BSA 8/12/88
DATE: 11-Aug-88
REVISIONS:

ITEM NUMBER	ITEM DESCRIPTION	UNITS	UNIT COST($)	QUANTITY	TOTAL($)
24.0000	TREATMENT ANALYSIS (INC. PRETRTMNT)	EA	$1,000.00	24	$24,000
25.0000	TOTAL ANNUAL O&M (ITEMS 20-24)				$168,570
	PRESENT WORTH ANALYSIS (i=10%)				
26.0000	SANITARY SEWER DISPOSAL (3 YEARS)		2.49	$376,200	$935,554
	30 YEARS:				
27.0000	CARBON REPLACEMENT (-5% PER YR.)	LS	$440,000	1	$440,000
28.0000	O&M (27 YEARS AFTER YEAR 3)		6.94	$168,570	$1,169,886
	10 YEARS:				
29.0000	CARBON REPLACEMENT (-5% PER YR.)	LS	$290,000	1	$290,000
30.0000	O&M (7 YEARS AFTER YEAR 3)		3.66	$168,570	$616,581
	PRESENT WORTH ANALYSIS (i=7%)				
31.0000	SANITARY SEWER DISPOSAL (3 YEARS)		2.62	$376,200.00	$987,268
	30 YEARS:				
32.0000	CARBON REPLACEMENT (-5% PER YR.)	LS	$570,000	1	$570,000
33.0000	O&M (27 YEARS AFTER YEAR 3)		9.78	$168,570	$1,649,411
	10 YEARS:				
34.0000	CARBON REPLACEMENT (-5% PER YR.)	LS	$340,000	1	$340,000
35.0000	O&M (7 YEARS AFTER YEAR 3)		4.40	$168,570	$741,584
	TOTAL O&M PRESENT WORTH				
36.0000	30 YEARS, i=10%				$2,545,440
37.0000	30 YEARS, i=7%				$3,206,679
38.0000	10 YEARS, i=10%				$1,842,135
39.0000	10 YEARS, i=7%				$2,068,852

RMT, Inc.
OPINION OF PROBABLE COST
(COSTEST1)

PROJECT NAME: FRIDLEY
PROJECT #: 1473.10
WORK CODE(S):

TEMPLATE: FRIDAIR
BY: SAM 8/12/88
DATE: 11-Aug-88
REVISIONS:

ITEM NUMBER	ITEM DESCRIPTION	UNITS	UNIT COST($)	QUANTITY	TOTAL($)
	TOTAL PRESENT WORTH				
40.0000	30 YEARS, i=10%				$3,686,680
41.0000	30 YEARS, i=7%				$4,347,919
42.0000	10 YEARS, i=10%				$2,983,375
43.0000	10 YEARS, i=7%				$3,210,092

RMT, Inc.
OPINION OF PROBABLE COST
(COSTEST1)

PROJECT NAME: FRIDLEY
PROJECT #: 1473.10
WORK CODE(S):

TEMPLate: FRIGAC
BY: SAM 8/12/88
DATE: 11-Aug-88
REVISIONS:

ITEM NUMBER	ITEM DESCRIPTION	UNITS	UNIT COST($)	QUANTITY	TOTAL($)
	ALT. F - PUMP, TREAT, AND DISPOSE OF GROUND WATER				
	OPTION 2 - ACTIVATED CARBON				
1.0000	INSTALL DEEP WELL EXTRACTION SYSTEM				
1.1000	EXTRACTION WELL @ 120 FT	EA	$20,000.00	2	$40,000
1.2000	EXTRACTION WELL @ 60 FT	EA	$10,000.00	1	$10,000
1.3000	PUMP (Q=200 GPM, 5 HP)	EA	$5,000.00	2	$10,000
1.4000	PUMP (Q=150 GPM, 5 HP)	EA	$5,000.00	1	$5,000
1.5000	PUMP (Q=50 GPM, 2 HP)	EA	$2,500.00	2	$5,000
2.0000	INSTALL TREATMENT SYSTEM				
2.1000	COLLECTION TANK	EA	$15,000.00	2	$30,000
2.2000	PUMP	EA	$18,000.00	1	$18,000
2.3000	PRETREATMENT SYSTEM (Ca)	LS	$70,000.00	1	$70,000
2.4000	GAC SYSTEM (Q=650 GPM)	LS	$90,000.00	1	$90,000
2.5000	BUILDING, SUMP AND PUMP	LS	$60,000.00	1	$60,000
3.0000	INSTALL WATER DISTRIBUTION SYSTEM				
3.1000	PRESSURE PIPE, INSTALLED	LF	$14.00	1800	$25,200
4.0000	INSTALLED SUBTOTAL (ITEMS 1-3)				$363,200
5.0000	HEALTH AND SAFETY (15%)		15.00%	$363,200.00	$54,480
6.0000	CIVIL/STRUCTURAL (15%)		15.00%	$363,200.00	$54,480
7.0000	ELECTRICAL/INSTRUMENTATION (25%)		25.00%	$363,200.00	$90,800
8.0000	PIPING (10%)		10.00%	$363,200.00	$36,320
9.0000	ENGINEERING AND DESIGN (15%)		15.00%	$363,200.00	$54,480
10.0000	CONTINGENCIES (15%)		15.00%	$363,200.00	$54,480

RMT, Inc.
OPINION OF PROBABLE COST
(COSTEST1)

PROJECT NAME: FRIDLEY
PROJECT #: 1473.10
WORK CODE(S):

TEMPLATE: FRIGAC
BY: SAM SAD 8/12/88
DATE: 11-Aug-88
REVISIONS:

ITEM NUMBER	ITEM DESCRIPTION	UNITS	UNIT COST($)	QUANTITY	TOTAL($)
11.0000	CAPITAL COST SUBTOTAL (ITEMS 4-10)				$708,240
12.0000	DRILLING AND TREATMENT MOBILIZATION	LS	$35,000.00	1	$35,000
13.0000	STARTUP OF TREATMENT SYSTEMS	LS	$10,000.00	1	$10,000
14.0000	WELL CUTTINGS HANDLING/DISPOSAL	LS	$500.00	1	$500
15.0000	PERMITTING				
15.1000	MWCC (SANITARY)	LS	$5,000.00	1	$5,000
15.2000	NPDES MODIFICATION (STORM)	LS	$25,000.00	1	$25,000
15.3000	AIR EMISSIONS	LS	$10,000.00	1	$10,000
16.0000	TOTAL CAPITAL COST (ITEMS 11-15)				$793,740
	OPERATION AND MAINTENANCE (ANNUAL COST)				
17.0000	SANITARY SEWER DISPOSAL (650 GPM)	1000 GALS	$1.10	342,000	$376,200
18.0000	OPERATING LABOR				
18.1000	EXTRACTION	LS	$12,000.00	1	$12,000
18.2000	TREATMENT	LS	$12,000.00	1	$12,000
18.3000	SITE VISITS (MONTHLY)	MO	$1,000.00	12	$12,000
19.0000	ELECTRICITY ($0.08/KWH)	HP	$530.00	34	$18,020
20.0000	O&M SUBTOTAL (ITEMS 18-19)				$54,020
21.0000	MAINTENANCE (5% OF ITEM 4)		$363,200.00	5.00%	$18,160
22.0000	EQUIP. REPLACEMENT (10% OF ITEM 4)		$363,200.00	10.00%	$36,320
23.0000	TREATMENT ANALYSIS (INC. PRETRTMNT)	EA	$1,000.00	24	$24,000

RMT, Inc.
OPINION OF PROBABLE COST
(COSTEST1)

PROJECT NAME: FRIDLEY
PROJECT #: 1473.10
WORK CODE(S):

TEMPLATE: FRIGAC
BY: SAM 8/12/88
DATE: 11-Aug-88
REVISIONS:

ITEM NUMBER	ITEM DESCRIPTION	UNITS	UNIT COST($)	QUANTITY	TOTAL($)
24.0000	TOTAL ANNUAL O&M (ITEMS 20-23)				$132,500
	PRESENT WORTH ANALYSIS (i=10%)				
25.0000	SANITARY SEWER DISPOSAL (3 YEARS)		2.49	$376,200.00	$935,554
	30 YEARS:				
26.0000	CARBON REPLACEMENT (-5% PER YR.)	LS	$1,500,000	1	$1,500,000
27.0000	O&M (27 YEARS AFTER YEAR 3)		6.94	$132,500.00	$919,558
	10 YEARS:				
28.0000	CARBON REPLACEMENT (-5% PER YR.)	LS	$1,000,000	1	$1,000,000
29.0000	O&M (7 YEARS AFTER YEAR 3)		3.66	$132,500.00	$484,647
	PRESENT WORTH ANALYSIS (i=7%)				
30.0000	SANITARY SEWER DISPOSAL (3 YEARS)		2.62	$376,200.00	$987,268
	30 YEARS:				
31.0000	CARBON REPLACEMENT (-5% PER YR.)	LS	$1,900,000	1	$1,900,000
32.0000	O&M (27 YEARS AFTER YEAR 3)		9.78	$132,500.00	$1,296,476
	10 YEARS:				
33.0000	CARBON REPLACEMENT (-5% PER YR.)	LS	$1,100,000	1	$1,100,000
34.0000	O&M (7 YEARS AFTER YEAR 3)		4.40	$132,500.00	$582,903
	TOTAL O&M PRESENT WORTH				
35.0000	30 YEARS, i=10%				$3,355,112
36.0000	30 YEARS, i=7%				$4,183,744
37.0000	10 YEARS, i=10%				$2,420,201
38.0000	10 YEARS, i=7%				$2,670,170

RMT, Inc.
OPINION OF PROBABLE COST
(COSTEST1)

PROJECT NAME: FRIDLEY
PROJECT #: 1473.10
WORK CODE(S):

TEMPLate: FRIGAC
BY: SAM 8/12/88
DATE: 11-Aug-88
REVISIONS:

ITEM NUMBER	ITEM DESCRIPTION	UNITS	UNIT COST($)	QUANTITY	TOTAL($)
	TOTAL PRESENT WORTH				
39.0000	30 YEARS, i=10%				$4,148,852
40.0000	30 YEARS, i=7%				$4,977,484
41.0000	10 YEARS, i=10%				$3,213,941
42.0000	10 YEARS, i=7%				$3,463,910

RMT, Inc.
OPINION OF PROBABLE COST
(COSTEST1)

PROJECT NAME: FRIDLEY
PROJECT #: 1473.10
WORK CODE(S):

TEMPLate: FRINONE
BY: SAM BA 8/12/88
DATE: 11-Aug-88
REVISIONS:

ITEM NUMBER	ITEM DESCRIPTION	UNITS	UNIT COST($)	QUANTITY	TOTAL($)
	ALT. F - PUMP, TREAT, AND DISPOSE OF GROUND WATER OPTION 3 - NO TREATMENT				
1.0000	INSTALL DEEP WELL EXTRACTION SYSTEM				
1.1000	EXTRACTION WELL @ 120 FT	EA	$20,000.00	2	$40,000
1.2000	EXTRACTION WELL @ 60 FT	EA	$10,000.00	1	$10,000
1.3000	PUMP (Q=200 GPM, 5 HP)	EA	$5,000.00	2	$10,000
1.4000	PUMP (Q=150 GPM, 5 HP)	EA	$5,000.00	1	$5,000
1.5000	PUMP (Q=50 GPM, 2 HP)	EA	$2,500.00	2	$5,000
2.0000	INSTALL WATER DISTRIBUTION SYSTEM				
2.1000	PRESSURE PIPE, INSTALLED	LF	$14.00	1400	$19,600
3.0000	INSTALLED COST SUBTOTAL (ITEMS 1-3)				$89,600
4.0000	HEALTH AND SAFETY (15%)		15.00%	$89,600.00	$13,440
5.0000	CIVIL/STRUCTURAL (15%)		15.00%	$89,600.00	$13,440
6.0000	ELECTRICAL/INSTRUMENTATION (25%)		25.00%	$89,600.00	$22,400
7.0000	PIPING (10%)		10.00%	$89,600.00	$8,960
8.0000	ENGINEERING AND DESIGN (15%)		15.00%	$89,600.00	$13,440
9.0000	CONTINGENCIES (15%)		15.00%	$89,600.00	$13,440
10.0000	CAPITAL COST SUBTOTAL (ITEMS 3-9)				$174,720
11.0000	DRILLING MOBILIZATION	LS	$20,000.00	1	$20,000
12.0000	WELL CUTTINGS HANDLING/DISPOSAL	LS	$500.00	3	$1,500
13.0000	PERMITTING				
13.2000	MWCC (SANITARY)	LS	$5,000.00	1	$5,000

RMT, Inc.
OPINION OF PROBABLE COST
(COSTEST1)

PROJECT NAME: FRIDLEY
PROJECT #: 1473.10
WORK CODE(S):

TEMPLate: FRINONE
BY: SAM BA 8/12/88
DATE: 11-Aug-88
REVISIONS:

ITEM NUMBER	ITEM DESCRIPTION	UNITS	UNIT COST($)	QUANTITY	TOTAL($)
14.0000	TOTAL CAPITAL COST (ITEMS 10-13)				$201,220
	OPERATION AND MAINTENANCE (ANNUAL COST)				
15.0000	SANITARY SEWER DISPOSAL (650 GPM)	1000 GALS	$1.10	342,000	$376,200
16.0000	SANITARY SEWER DISPOSAL (550 GPM)	1000 GALS	$1.10	289,100	$318,010
17.0000	OPERATING LABOR				
17.1000	EXTRACTION	LS	$12,000.00	1	$12,000
17.2000	SITE VISITS (MONTHLY)	MO	$1,000.00	12	$12,000
18.0000	ELECTRICITY ($0.08/KWH)	HP	$530.00	19	$10,070
19.0000	O&M SUBTOTAL (ITEMS 17-18)				$34,070
20.0000	MAINTENANCE (5% OF ITEM 3)		5.00%	$89,600	$4,480
21.0000	EQUIP. REPLACEMENT (10% OF ITEM 3)		10.00%	$89,600	$8,960
22.0000	TOTAL ANNUAL O&M (ITEMS 19-21)				$47,510
	PRESENT WORTH ANALYSIS (i=10%)				
23.0000	SANITARY DISPOSAL (3 YRS @ 650 GPM)		2.49	$376,200	$935,554
24.0000	SAC FEE (AT END OF YEAR 3)		0.75	$1,600,000	$1,202,104
	30 YEARS (27 YEARS AFTER YEAR 3):				
25.0000	SANITARY DISPOSAL (550 GPM)		6.94	$318,010	$2,207,009
26.0000	O&M		6.94	$47,510	$329,722
	10 YEARS (7 YEARS AFTER YEAR 3):				
27.0000	SANITARY DISPOSAL (550 GPM)		3.66	$318,010	$1,163,190
28.0000	O&M		3.66	$47,510	$173,778

RMT, Inc.
OPINION OF PROBABLE COST
(COSTEST1)

PROJECT NAME: FRIDLEY
PROJECT #: 1473.10
WORK CODE(S):

TEMPLate: FRINONE
BY: SAM BA 8/12/88
DATE: 11-Aug-88
REVISIONS:

ITEM NUMBER	ITEM DESCRIPTION	UNITS	UNIT COST($)	QUANTITY	TOTAL($)
	PRESENT WORTH ANALYSIS (i=7%)				
29.0000	SANITARY DISPOSAL (3 YRS @ 650 GPM)		2.62	$376,200.00	$987,268
30.0000	SAC FEE (AT END OF YEAR 3)		0.82	$1,600,000	$1,306,077
	30 YEARS (27 YEARS AFTER YEAR 3):				
31.0000	SANITARY DISPOSAL (550 GPM)		9.78	$318,010	$3,111,640
32.0000	O&M		9.78	$47,510	$464,872
	10 YEARS (7 YEARS AFTER YEAR 3):				
33.0000	SANITARY DISPOSAL (550 GPM)		4.40	$318,010	$1,399,010
34.0000	O&M		4.40	$47,510	$209,009
	TOTAL O&M PRESENT WORTH				
35.0000	30 YEARS, i=10%				$4,674,389
36.0000	30 YEARS, i=7%				$5,869,857
37.0000	10 YEARS, i=10%				$3,474,625
38.0000	10 YEARS, i=7%				$3,901,364
	TOTAL PRESENT WORTH				
39.0000	30 YEARS, i=10%				$4,875,609
40.0000	30 YEARS, i=7%				$6,071,077
41.0000	10 YEARS, i=10%				$3,675,845
42.0000	10 YEARS, i=7%				$4,102,584

RMT, Inc.
OPINION OF PROBABLE COST
(COSTEST1)

PROJECT NAME: FRIDLEY
PROJECT #: 1473.10
WORK CODE(S):

TEMPLate: MONITOR
BY: SAM / BWR 12 AUG 88
DATE: 11-Aug-88
REVISIONS:

ITEM NUMBER	ITEM DESCRIPTION	UNITS	UNIT COST($)	QUANTITY	TOTAL($)
	GROUND WATER MONITORING				
	NO ACTION and SOURCE CONTROL ALTERNATIVES				
1.0000	INSTALL ADDITIONAL MONITORING WELLS				
1.1000	MONITORING WELL @ 45-FT EACH	EA	$2,500	1	$2,500
1.2000	MONITORING WELL @ 75-FT EACH	EA	$3,750	2	$7,500
2.0000	INSTALLED COST SUBTOTAL (ITEM 1)				$10,000
3.0000	HEALTH AND SAFETY	LS	$5,000	1	$5,000
4.0000	ENGINEERING AND DESIGN	LS	$10,000	1	$10,000
5.0000	CONTINGENCIES	LS	$5,000	1	$5,000
6.0000	CAPITAL COST SUBTOTAL (ITEMS 2-5)				$30,000
7.0000	DRILLING MOBILIZATION	LS	$2,000	1	$2,000
8.0000	WELL DEVELOPMENT	EA	$500	3	$1,500
9.0000	WELL CUTTINGS HANDLING/DISPOSAL	EA	$250	3	$750
10.0000	BNRR PERMITTING	LS	$3,000	1	$3,000
11.0000	TOTAL CAPITAL COST (ITEMS 6-10))				$37,250
	ANNUAL MONITORING COSTS				
12.0000	SAMPLING	ROUND	$3,000	4	$12,000

RMT, Inc.
OPINION OF PROBABLE COST
(COSTEST1)

PROJECT NAME: FRIDLEY
PROJECT #: 1473.10
WORK CODE(S):

TEMPLATE: MONITOR
BY: SAM / BWR 12AUG88
DATE: 11-Aug-88
REVISIONS:

ITEM NUMBER	ITEM DESCRIPTION	UNITS	UNIT COST($)	QUANTITY	TOTAL($)
13.0000	ANALYSIS	EA	$400	64	$25,600
14.0000	REPORTING	EA	$10,000	1	$10,000
15.0000	TOTAL ANNUAL MONITRNG (ITEMS 12-14)				$47,600
	PRESENT WORTH ANALYSIS				
16.0000	ANNUAL MONITORING (30 YEARS)				
16.1000	INTEREST = 10%		9.43	$47,600	$448,721
16.2000	INTEREST = 7%		12.41	$47,600	$590,670
17.0000	TOTAL MONITORING PRESENT WORTH				
17.1000	INTEREST = 10%				$485,971
17.2000	INTEREST = 7%				$627,920

RMT, Inc.
OPINION OF PROBABLE COST
(COSTEST1)

PROJECT NAME: FRIDLEY
PROJECT #: 1473.10
WORK CODE(S):

TEMPLate: MONITOR
BY: SAM / BWR 12 AUG 88
DATE: 11-Aug-88
REVISIONS:

ITEM NUMBER	ITEM DESCRIPTION	UNITS	UNIT COST($)	QUANTITY	TOTAL($)
	GROUND WATER MONITORING				
	ALTERNATIVE F				
	PUMP, TREAT, AND DISPOSE OF GROUND WATER				
1.0000	INSTALL ADDITIONAL PIEZOMETERS				
1.1000	PIEZOMETER @ 50-FT EACH	EA	$2,500	6	$15,000
2.0000	INSTALL ADDITIONAL MONITORING WELLS				
2.1000	MONITORING WELL @ 45-FT EACH	EA	$2,500	1	$2,500
2.2000	MONITORING WELL @ 75-FT EACH	EA	$3,750	2	$7,500
3.0000	INSTALLED COST SUBTOTAL (ITEMS 1-2)				$25,000
4.0000	HEALTH AND SAFETY	LS	$7,500	1	$7,500
5.0000	ENGINEERING AND DESIGN	LS	$15,000	1	$15,000
6.0000	CONTINGENCIES	LS	$7,500	1	$7,500
7.0000	CAPITAL COST SUBTOTAL (ITEMS 3-6)				$55,000
8.0000	DRILLING MOBILIZATION	LS	$5,000	1	$5,000
9.0000	WELL DEVELOPMENT	LS	$500	9	$4,500
10.0000	WELL CUTTINGS HANDLING/DISPOSAL	EA	$250	9	$2,250
11.0000	BNRR PERMITTING	LS	$3,000	1	$3,000
12.0000	TOTAL CAPITAL COST (ITEMS 7-11)				$69,750

RMT, Inc.
OPINION OF PROBABLE COST
(COSTEST1)

PROJECT NAME: FRIDLEY
PROJECT #: 1473.10
WORK CODE(S):

TEMPLate: MONITOR
BY: SAM / BWR 12 AUG 88
DATE: 11-Aug-88
REVISIONS:

ITEM NUMBER	ITEM DESCRIPTION	UNITS	UNIT COST($)	QUANTITY	TOTAL($)
	ANNUAL MONITORING COSTS				
13.0000	PHASE 1				
13.1000	SAMPLING	ROUND	$4,000	4	$16,000
13.2000	ANALYSIS	EA	$400	124	$49,600
13.3000	REPORTING	EA	$15,000	1	$15,000
14.0000	PHASE 1 MONITORING ANNUAL COST				$80,600
15.0000	PHASE 2				
15.1000	SAMPLING	ROUND	$3,500	2	$7,000
15.2000	ANALYSIS	EA	$400	48	$19,200
15.3000	REPORTING	EA	$10,000	1	$10,000
16.0000	PHASE 2 MONITORING ANNUAL COST				$36,200
	PRESENT WORTH ANALYSIS				
17.0000	INTEREST = 10%				
17.1000	PHASE 1 MONITORING (3 YEARS)		2.49	$80,600	$200,440
17.2000	PHASE 2 MONITORING (27 YEARS)		6.94	$36,200	$251,230
17.3000	PHASE 2 MONITORING (12 YEARS)		5.97	$36,200	$216,022
18.0000	INTEREST = 7%				
18.1000	PHASE 1 MONITORING (3 YEARS)		2.62	$80,600	$211,520
18.2000	PHASE 2 MONITORING (27 YEARS)		9.78	$36,200	$354,207
18.3000	PHASE 2 MONITORING (12 YEARS)		6.48	$36,200	$234,706
	ANNUAL MONITORING PRESENT WORTH				
19.0000	30 YEARS, i = 10%				$451,671
20.0000	30 YEARS, i = 7%				$565,727
21.0000	15 YEARS, i = 10%				$416,462
22.0000	15 YEARS, i = 7%				$446,226

RMT, Inc.
OPINION OF PROBABLE COST
(COSTEST1)

PROJECT NAME: FRIDLEY
PROJECT #: 1473.10
WORK CODE(S):

TEMPLATE: MONITOR
BY: SAM / BWR 12 AUG 88
DATE: 11-Aug-88
REVISIONS:

ITEM NUMBER	ITEM DESCRIPTION	UNITS	UNIT COST($)	QUANTITY	TOTAL($)
	TOTAL MONITORING PRESENT WORTH				
23.0000	30 YEARS, i = 10%				$521,421
24.0000	30 YEARS, i = 7%				$635,477
25.0000	15 YEARS, i = 10%				$486,212
26.0000	15 YEARS, i = 7%				$515,976

PRESENT WORTH ANALYSIS OF CARBON USAGE COSTS
GAC TREATMENT FOR ALT. F, OPTION 2
(No Annual Decrease in Extracted VOCs)

-YEAR-	EXTRACTED ---TCE--- Mass (1,000s lbs)	----CARBON USAGE---- Mass (1,000s lbs)	Cost ($1000s)	----PRESENT WORTH ($1000s)---- Interest Rate 3%	7%	10%
1	7.2	160	208	208	208	208
2	7.2	160	208	202	194	189
3	7.2	160	208	196	182	172
4	7.2	160	208	190	170	156
5	7.2	160	208	185	159	142
6	7.2	160	208	179	148	129
7	7.2	160	208	174	139	117
8	7.2	160	208	169	130	107
9	7.2	160	208	164	121	97
10	7.2	160	208	159	113	88
11	7.2	160	208	155	106	80
12	7.2	160	208	150	99	73
13	7.2	160	208	146	92	66
14	7.2	160	208	142	86	60
15	7.2	160	208	138	81	55
16	7.2	160	208	134	75	50
17	7.2	160	208	130	70	45
18	7.2	160	208	126	66	41
19	7.2	160	208	122	62	37
20	7.2	160	208	119	58	34
21	7.2	160	208	115	54	31
22	7.2	160	208	112	50	28
23	7.2	160	208	109	47	26
24	7.2	160	208	105	44	23
25	7.2	160	208	102	41	21
26	7.2	160	208	99	38	19
27	7.2	160	208	96	36	17
28	7.2	160	208	94	33	16
29	7.2	160	208	91	31	14
30	7.2	160	208	88	29	13
TOTAL	216.0	4,800	$6,240	$4,199	$2,762	$2,157

Phase 1:
No Carbon Usage
(Years 1 to 3)

ASSUMPTIONS:

(1) - Carbon usage is based on 20 lb. carbon per lb. total VOCs extracted (Calgon, 1988), where TCE is 90% of total VOCs.
(2) - Initial extracted TCE mass is based on concentration of 3 mg/l TCE pumped at 550 gpm.
(3) - Carbon cost of $1.30 per lb. includes $1.00 per lb. for regeneration (Calgon, 1988) and $0.30 per lb. for hauling.

PRESENT WORTH ANALYSIS OF CARBON USAGE COSTS
GAC TREATMENT FOR ALT. F, OPTION 2
(5 Percent Annual Decrease in Extracted VOCs)

-YEAR-	EXTRACTED ---TCE--- Mass (1,000s lbs)	----CARBON USAGE---- Mass (1,000s lbs)	Cost ($1000s)	----PRESENT WORTH ($1000s)---- Interest Rate 3%	7%	10%	
1	7.2	160	208	208	208	208	Phase 1:
2	6.8	152	198	192	185	180	No Carbon Usage
3	6.5	144	188	177	164	155	(Years 1 to 3)
4	6.2	137	178	163	146	134	
5	5.9	130	169	151	129	116	Phase 2
6	5.6	124	161	139	115	100	Carbon Usage
7	5.3	118	153	128	102	86	for 10-Year
8	5.0	112	145	118	90	75	Duration
9	4.8	106	138	109	80	64	(Years 4 to 10)
10	4.5	101	131	100	71	56	
11	4.3	96	125	93	63	48	
12	4.1	91	118	85	56	41	
13	3.9	86	112	79	50	36	Phase 2
14	3.7	82	107	73	44	31	Carbon Usage
15	3.5	78	101	67	39	27	for 30-Year
16	3.3	74	96	62	35	23	Duration
17	3.2	70	92	57	31	20	(Years 4 to 30)
18	3.0	67	87	53	28	17	
19	2.9	64	83	49	24	15	
20	2.7	60	78	45	22	13	
21	2.6	57	75	41	19	11	
22	2.5	54	71	38	17	10	
23	2.3	52	67	35	15	8	
24	2.2	49	64	32	13	7	
25	2.1	47	61	30	12	6	
26	2.0	44	58	28	11	5	
27	1.9	42	55	25	9	5	
28	1.8	40	52	23	8	4	
29	1.7	38	49	22	7	3	
30	1.6	36	47	20	7	3	Phase 2
TOTAL	113.1	2,513	$3,267	$2,441	$1,802	$1,507	Operation Duration (years)
		2,057	2,673	2,868*	1,915*	1,483*	27
				1,397*	1,128*	971*	7

ASSUMPTIONS:

(1) - Carbon usage is based on 20 lb. carbon per lb. total VOCs extracted (Calgon, 1988), where TCE is 90% of total VOCs.

(2) - Initial extracted TCE mass is based on concentration of 3 mg/l TCE pumped at 550 gpm.

(3) - Carbon cost of $1.30 per lb. includes $1.00 per lb. for regeneration (Calgon, 1988) and $0.30 per lb. for hauling.

* Revised unit cost of liquid phase carbon is $2 / lb.
Multiply cost by 0.3 to find present worth of vapor phase carbon, assuming $3 / lb. unit cost and a usage rate of 4 lb. carbon per lb. total VOCs.

PRESENT WORTH ANALYSIS OF CARBON USAGE COSTS
GAC TREATMENT FOR ALT. F, OPTION 2
(10 Percent Annual Decrease in Extracted VOCs)

-YEAR-	EXTRACTED ---TCE--- Mass (1,000s lbs)	----CARBON USAGE---- Mass (1,000s lbs)	Cost ($1000s)	----PRESENT WORTH ($1000s)---- Interest Rate 3%	7%	10%
1	7.2	160	208	208	208	208
2	6.5	144	187	182	175	170
3	5.8	130	168	159	147	139
4	5.2	117	152	139	124	114
5	4.7	105	136	121	104	93
6	4.3	94	123	106	88	76
7	3.8	85	111	93	74	62
8	3.4	77	99	81	62	51
9	3.1	69	90	71	52	42
10	2.8	62	81	62	44	34
11	2.5	56	73	54	37	28
12	2.3	50	65	47	31	23
13	2.0	45	59	41	26	19
14	1.8	41	53	36	22	15
15	1.6	37	48	31	18	13
16	1.5	33	43	27	16	10
17	1.3	30	39	24	13	8
18	1.2	27	35	21	11	7
19	1.1	24	31	18	9	6
20	1.0	22	28	16	8	5
21	0.9	19	25	14	7	4
22	0.8	18	23	12	5	3
23	0.7	16	20	11	5	3
24	0.6	14	18	9	4	2
25	0.6	13	17	8	3	2
26	0.5	11	15	7	3	1
27	0.5	10	13	6	2	1
28	0.4	9	12	5	2	1
29	0.4	8	11	5	2	1
30	0.3	8	10	4	1	1
TOTAL	68.9	1,532	$1,992	$1,619	$1,302	$1,141

Phase 1: No Carbon Usage (Years 1 to 3)

ASSUMPTIONS:

(1) - Carbon usage is based on 20 lb. carbon per lb. total VOCs extracted (Calgon, 1988), where TCE is 90% of total VOCs.
(2) - Initial extracted TCE mass is based on concentration of 3 mg/l TCE pumped at 550 gpm.
(3) - Carbon cost of $1.30 per lb. includes $1.00 per lb. for regeneration (Calgon, 1988) and $0.30 per lb. for hauling.