REMEDIATION SYSTEM EVALUATION

SOUTH TACOMA CHANNEL/WELL 12A
SUPERFUND SITE
TACOMA, WASHINGTON

Report of the Remediation System Evaluation,
Site Visit Conducted at the
Commencement Bay/South Tacoma Channel Well 12A Superfund Site
August 21-22, 2001

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

NOTICE

Work described herein was performed by GeoTrans, Inc. (GeoTrans) and the United States Army Corps of Engineers (USACE) for the U.S. Environmental Protection Agency (U.S. EPA). Work conducted by GeoTrans, including preparation of this report, was performed under Dynamac Contract No. 68-C-99-256, Subcontract No. 91517. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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EXECUTIVE SUMMARY

The first operable unit (OU1) of the Commencement Bay/South Tacoma Channel Superfund Site addresses soil and groundwater contamination associated with the Time Oil property that was first discovered in public supply Well 12A in 1981. Site contamination primarily consists of chlorinated solvents such as 1,1,2,2, tetrachloroethane (PCA), tetrachloroethylene, and trichloroethylene as well as waste oils and lead. A number of removal actions have been conducted at the site including excavation of contaminated filter cake, operation of a vapor extraction system (VES), and operation of a groundwater extraction and treatment system (GETS). After approximately three years of operation, the VES was shut down in 1997 after removing over 50,000 pounds of contaminants. The GETS has operated since 1988. Contaminated filter cake as well as light and dense non-aqueous phase liquids (LNAPL and DNAPL) remain in the subsurface as continuing sources of dissolved phase groundwater contamination.

Based on review of the site documents and a site tour, the RSE team suggests the following recommendations to improve system effectiveness:

- Site managers could use assistance in analyzing capture offered by the GETS and determining the optimal remedial strategy for the site. A reliable groundwater flow model, and potentially a contaminant transport model, should be developed and used for simulations to provide this assistance.

- To date, capture zone analyses have been unreliable and adequate capture may not be provided by the current GETS. Aquifer monitoring data and water level measurements should be used to construct plume maps showing target capture zones and potentiometric surface maps showing actual capture zones. The two maps should then be compared as a preliminary analysis of capture. Augmentation of this analysis should be accomplished by analyzing water quality data from sentinel monitoring wells and comparing measured water level data with groundwater flow model predictions.

- The current monitoring program involves irregularly spaced sampling events in which different monitoring wells are sampled. As a result, consistent trends in plume area and migration cannot be easily gleaned from monitoring data. A selected group of monitoring well should be sampled on a regular basis so that trends, especially in plume migration, can be determined.

- Well 9, like Well 12A, is a public supply well that operates during periods of high water demand. Given the history of contamination at Well 12A and the proximity of Well 9 to Well 12A, the influent to Well 9 should be sampled and analyzed for volatile organic compounds.

These recommendations might require approximately $75,000 in capital costs and might increase annual costs by approximately $16,000 per year, but could be as high as $125,000 in capital costs and $28,000 in annual costs if development and use of a contaminant transport model is included.

Recommendations to reduce life-cycle costs include the following:

- If it is determined through a capture zone analysis that pumping rates do not need to increase by more than a factor of five, then the pumps in three of the extraction wells should be replaced with smaller models to reduce the use of electricity. While pump replacement may cost up to $14,000, approximately $8,500 per year could be saved in electricity costs.

- The costs associated with discharging the treated water to the stormwater sewer amount to $60,000. Typically, the RSE team has only seen "hook-up" costs associated with discharges to the stormwater sewer and not annual costs. The site managers should examine the city polices on stormwater discharge and investigate alternative locations for discharging the treated water.

- If the current carbon treatment system reaches its operating lifetime and requires replacement or if pumping rates increases substantially, the current treatment system should be replaced by an air stripper. The capital costs could require as much as $350,000, and annual operation and maintenance costs would be approximately $40,000 to $50,000 less than the annual costs associated with the current system.

Implementing the recommendations to reduce costs would require initial investments, but savings from operations and maintenance could offset these initial investments as well as the costs associated with recommendations for enhanced system effectiveness and technical improvement.

The RSE team agrees with the site managers that the remaining filter cake should be excavated as it is currently providing a continuing source of groundwater contamination. In addition, the RSE team supports the site managers' efforts to identify and screen alternative remedial technologies and strategies. Three strategies are discussed in this report, and the RSE team suggests that pump and treat continue (for plume containment) until an appropriate technology is selected and implemented for source removal.

Finally, an approach to implementing the recommendations is provided in Section 6.6, and a summary of recommendations, including estimated costs and/or savings associated with those recommendations, is presented in Section 7.0 of the report.

PREFACE

This report was prepared as part of a project conducted by the United States Environmental Protection Agency (USEPA) Technology Innovation Office (TIO) and Office of Emergency and Remedial Response (OERR). The objective of this project is to conduct Remediation System Evaluations (RSEs) of pump-and-treat systems at Superfund sites that are "Fund-lead" (i.e., financed by USEPA). RSEs are to be conducted for up to two systems in each EPA Region with the exception of Regions 4 and 5, which already had similar evaluations in a pilot project.

The following organizations are implementing this project.

Organization	Key Contact	Contact Information
USEPA Technology Innovation Office (USEPA TIO)	Kathy Yager	11 Technology Drive (ECA/OEME) North Chelmsford, MA 01863 phone: 617-918-8362 fax: 617-918-8417 yager.kathleen@epa.gov
USEPA Office of Emergency and Remedial Response (OERR)	Paul Nadeau	1200 Pennsylvania Avenue, NW Washington, DC 20460 Mail Code 5201G phone: 703-603-8794 fax: 703-603-9112 nadeau.paul@epa.gov
GeoTrans, Inc. (Contractor to USEPA TIO)	Rob Greenwald	GeoTrans, Inc. 2 Paragon Way Freehold, NJ 07728 (732) 409-0344 Fax: (732) 409-3020 rgreenwald@geotransinc.com
Army Corp of Engineers: Hazardous, Toxic, and Radioactive Waste Center of Expertise (USACE HTRW CX)	Dave Becker	12565 W. Center Road Omaha, NE 68144-3869 (402) 697-2655 Fax: (402) 691-2673 dave.j.becker@nwd02.usace.army.mil

The project team is grateful for the help provided by the following EPA Project Liaisons.

Region1	Darryl Luce and Larry Brill	**Region 6**	Vincent Malott
Region 2	Diana Cutt	**Region 7**	Mary Peterson
Region 3	Kathy Davies	**Region 8**	Armando Saenz and Richard Muza
Region 4	Kay Wischkaemper	**Region 9**	Herb Levine
Region 5	Dion Novak	**Region 10**	Bernie Zavala

They were vital in selecting the Fund-lead P&T systems to be evaluated and facilitating communication between the project team and the Remedial Project Managers (RPM's).

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1.0 INTRODUCTION

1.1 PURPOSE

In the *OSWER Directive No. 9200.0-33, Transmittal of Final FY00 - FY01 Superfund Reforms Strategy, dated July 7,2000*, the Office of Solid Waste and Emergency Response outlined a commitment to optimize Fund-lead pump-and-treat systems. To fulfill this commitment, the US Environmental Protection Agency (USEPA) Technology Innovation Office (TIO) and Office of Emergency and Remedial Response (OERR), through a nationwide project, is assisting the ten EPA Regions in evaluating their Fund-lead operating pump-and-treat systems. This nationwide project is a continuation of a demonstration project in which the Fund-lead pump-and-treat systems in Regions 4 and 5 were screened and two sites from each of the two Regions were evaluated. It is also part of a larger effort by TIO to provide USEPA Regions with various means for optimization, including screening tools for identifying sites likely to benefit from optimization and computer modeling optimization tools for pump and treat systems.

This nationwide project identifies all Fund-lead pump-and-treat systems in EPA Regions 1 through 3 and 6 through 10, collects and reports baseline cost and performance data, and evaluates up to two sites per Region. The site evaluations are conducted by EPA-TIO contractors, GeoTrans, Inc. and the United States Army Corps of Engineers (USACE), using a process called a Remediation System Evaluation (RSE), which was developed by USACE. The RSE process is meant to evaluate performance and effectiveness (as required under the NCP, i.e., and “five-year" review), identify cost savings through changes in operation and technology, assure clear and realistic remediation goals and an exit strategy, and verify adequate maintenance of Government owned equipment.

The South Tacoma Channel/ Well 12A Superfund Site was chosen to receive an RSE based on an initial screening of the pump-and-treat systems managed by USEPA Region 10 as well as discussions with the Superfund Reform Initiative Project Liaison for that Region. This site has high operation costs relative to the cost of an RSE and a long projected operating life. This report provides a brief background on the site and current operations, a summary of the observations made during a site visit, and recommendations for changes and additional studies. The cost impacts of the recommendations are also discussed.

A report on the overall results from the RSEs conducted for this system and other Fund-lead P&T systems throughout the nation will also be prepared and will identify lessons learned and typical costs savings.

1.2 TEAM COMPOSITION

The team conducting the RSE consisted of the following individuals:

Frank Bales, Chemical Engineer, USACE, Kansas City District
Rob Greenwald, Hydrogeologist, GeoTrans, Inc.
Peter Rich, Civil and Environmental Engineer, GeoTrans, Inc.
Doug Sutton, Water Resources Engineer, GeoTrans, Inc.

1.3 DOCUMENTS REVIEWED

Author	Date	Title
US EPA	3/18/1983	Record of Decision for an Initial Remedial Measure, Commencement Bay/South Tacoma Channel Well 12A, Groundwater
US EPA	5/3/1985	Record of Decision, Commencement Bay/South Tacoma Channel Well 12A, Groundwater and Soil
ICF Technology, Inc.	5/1990	Final Work Plan: Operation and Maintenance of Groundwater Extraction and Carbon Adsorption Treatment System (Revision 0)
ICF Technology, Inc.	1/1991	Final Work Plan for Time Oil Investigation
ICF Technology, Inc.	11/1991	Evaluation of GET Effectiveness, Commencement Bay-South Tacoma Channel (Well 12-A) Site
EPA	7/1998	Five Year Review
ICF Kaiser/ URS Greiner	9/1999	LNAPL and Soil Investigation Report Revision 1
EPA	9/1999	Explanation of Significant Differences (ESD) Soil and Groundwater 1994 ROD
URS Greiner	10/1999	Preliminary Remedial Process Option Screening and Data Gaps Memorandum, Commencement Bay, South Tacoma Channel/Well 12A Superfund Site, Tacoma, Washington
URS Greiner	12/1999	Groundwater Summary Report
URS Greiner	9/2000	Quarterly Status Report

1.4 PERSONS CONTACTED

The following individuals were present for the site visit:

Kevin Rochlin, RPM, USEPA Region 10
Bernard Zavala, Hydrologist, USEPA Region 10
Neil Thompson, RPM, USEPA Region 10

1.5 SITE LOCATION, HISTORY, AND CHARACTERISTICS

1.5.1 LOCATION AND HISTORY

The Commencement Bay, South Tacoma Channel Superfund Site located in Tacoma, Washington consists of three geographically isolated operable units (OUs): the City of Tacoma Well 12A (OU1), the Tacoma

Landfill (OU2), and the South Tacoma Field (OU3). The remedies at the individual OUs are not expected to affect the remedies at the other OUs. This report documents the findings and recommendations associated with a Remediation System Evaluation (RSE) conducted at OU1 (Well 12A) and therefore does not address the remedies at OU2 or OU3.

OU1 encompasses City of Tacoma Production Well 12A, located on Pine Street between 38th Avenue and South Tacoma Way, and the primary source of contamination for the OU, which is the property of the former Time Oil Company located at 3811 South Tacoma Way, 0.5 miles to the northeast of Well 12A. The area near the Time Oil property is industrial and commercial, and the area near Well 12A is residential and commercial. A map of the area is included in Figure 1-1. Commencement Bay is located approximately 6 miles directly to the north or 3 miles to the northeast. Interstate 5 is adjacent to the operable unit to the east.

Various removal and remedial actions have been conducted at the site:

- In 1983 an initial remedial measure involved installing and operating air stripping towers on Well 12A. That well and the stripping towers continue to operate for public water supply during periods of peak demand.

- A groundwater extraction and treatment system (GETS) was constructed and began operation in 1988 and continues to operate. According to the 5-year review, as of March 31, 1998 more than 13,364 pounds of volatile organic compounds had been removed from groundwater.

- A vapor extraction system (VES) was constructed on and adjacent to the Time Oil property between September 1992 and August 1993, and 5,000 cubic yards of contaminated filter cake were concurrently excavated during construction. Operation of the VES began in 1994 and ended in February 1997 resulting in the removal of 53,545 pounds of hydrocarbons and chlorinated solvents.

1.5.2 POTENTIAL SOURCES

Chlorinated organic solvents were first discovered in Well 12A in 1981 leading to listing of the site on the National Priority List (NPL) on September 8, 1983. A 1982 Remedial Investigation identified the Time Oil property, located approximately 0.5 miles to the northeast of the well, as the primary source of contamination.

The Time Oil property had historically been used for various practices including oil recycling as well as paint and lacquer manufacturing. Oil recycling and solvent processing began as early as 1927 and continued to 1991 with occasional interruptions due to changes in ownership and a large fire in 1976. The Time Oil Company vacated the premises in 1991, and the space has since been used as a warehouse for heating, ventilation, and air conditioning equipment.

In addition to a number of possible leaks and spills over the years, some of the filter cake generated during oil recycling was used as fill material in 1982 for constructing the Burlington North Railroad spur to the north of the Time Oil Property. Subsequent investigations have identified this filter cake as a primary source of dissolved phase contamination of 1,1,2,2 tetrachloroethane (PCA), tetrachloroethylene (PCE), and other organic solvents discovered in Well 12A.

Despite previous efforts of source removal, a number of sources of dissolved phase contamination still remain on or near the Time Oil property. Both light and dense non-aqueous phase liquids (LNAPL and DNAPL) have been identified beneath the property and an additional area of filter cake has been identified to the east of the Time Oil building. Figure 1-2 outlines approximate known or suspected locations of the filter cake, LNAPL, and DNAPL. The LNAPL exists primarily within a smear zone near the water table where it coats soil particles and partially fills voids in the soil. The presence of DNAPL is evidenced by high soil concentrations of chlorinated solvents (in excess of 29,500,000 ug/kg of combined PCA and PCE, as stated in Table 3-1 of the 1999 Groundwater Summary Report) at depths exceeding the historical low groundwater level of 40 feet below ground surface.

1.5.3 HYDROGEOLOGIC SETTING

The site is located in the Puget Lowland, which is underlain by thick accumulations of unconsolidated to semi-consolidated late Tertiary to Holocene age deposits. These sediments partly fill the Puget Trough, a large north-south structural basin. Within the immediate area comprising Well 12A and the Time Oil building, the following geologic depositional sequence exists from the surface downward: Holocene alluvium, Pleistocene till of the Vashon glaciation, Pleistocene pro-glacial and recessional outwash deposits of the Vashon glaciation, Pleistocene Pre-Vashon unconsolidated deposits, and older semi-consolidated sediments. The principal aquifers of interest reside in the Vashon and Pre-Vashon glacial deposits which are primarily sand and gravel and extend 200 to 300 feet below ground surface.

The surface topography ranges between approximately 245 to 325 feet above National Geodetic Veritcal Datum (NGVD) from the South Tacoma Channel northeast of the Time Oil property to the southwest uplands. The Time Oil property is approximately 255 feet above NGVD, and the water table at that location is 30 to 35 feet below ground surface. The high porosity and high permeability deposits of the aquifer often form discontinuous lenses with occasional deposits of silts and clays. As a result, the quantity of water available at different locations varies greatly.

According to the December 1999 Groundwater Summary Report, groundwater beneath the site primarily flows through a 50-foot thick sand and gravel layer that extends from the water table at 225 feet above NGVD to 175 feet NGVD. Reportedly, in the area of the Time Oil property and beneath this layer there is a fine-grained till aquitard with an approximate thickness of 40 feet, but this aquitard does not appear to exist near Well 12A. In fact, Well 12A is screened between 155 and 180 feet above NGVD and had a sustained pumping rate during the period of high demand in 1998 of approximately 670 gpm.

The regional groundwater flow is from west to east with a relatively flat gradient of 0.0006 feet/foot. Previous calculations of groundwater velocity indicated flow to the northeast at 120 feet per year between Well 12A and the Time Oil property and 690 feet per year to the northeast of the Time Oil Property. The operation of Well 12A, however, depresses the potentiometric surface and reverses the normal groundwater direction up to and including the Time Oil building and surrounding properties. Operation of the well only occurs around August of each year during the periods of high demand for water.

1.5.4 DESCRIPTION OF GROUND WATER PLUME

Chlorinated solvents including PCA and PCE were originally discovered in Well 12A suggesting migration of the contaminants nearly 2,000 feet to the southwest of the Time Oil property. Aquifer monitoring from 1993 confirms this southwesterly extent of contamination with concentrations of PCA as high as 100 ug/L (CBW-9) over 500 feet to the southwest of Well 12A. Sampling records in the 1999 Groundwater Summary Report indicate that no samples have been collected in monitoring wells in the vicinity of Well

12A since 1993. The City of Tacoma has sampled Well 12A for volatile organic compounds, however, and, according to Figure 5-1 in the 1999 Groundwater Summary Report, has found a decreasing trend from approximately 550 ppb in May 1988 to less than 10 ppb in October 1997.

The 1998 aquifer monitoring event indicates trichloroethylene (TCE) contamination in monitoring wells 500 to 1000 feet downgradient (to the northeast) of the Time Oil property (5.2 ppb in CH2M-4 and 20.3 ppb in CH2M-3); however, the other site-related contaminants including PCA, PCE, and DCE were undetectable in these wells during that monitoring event.

Concentrations in the immediate vicinity of the Time Oil property in 1998 were as high as 17,100 ug/L PCA and 3,400 ug/L TCE. Thus, while concentrations near Well 12A have decreased significantly since discovery in 1982 and concentrations to the northeast of the Time Oil property remain relatively low or even undetectable, the concentrations in the source area remain high enough to suggest that LNAPL, DNAPL, and remaining filter cake are likely providing a continuing source of contamination.
Figure 1-2 highlights wells sampled during the 1993 and 1998 aquifer monitoring events that had contaminant concentrations exceeding the maximum contaminant levels (MCLs).

2.0 SYSTEM DESCRIPTION

2.1 SYSTEM OVERVIEW

The groundwater extraction and treatment system (GETS) was installed and began operation in 1988. The system, which uses granular activated carbon (GAC) to remove the contaminants from the extracted groundwater, has a design capacity of 500 gpm but operates at approximately 50 gpm due to unexpectedly low yielding extraction wells.

2.2 EXTRACTION SYSTEM

The extraction system originally consisted of a single extraction well (EW-1) designed to extract water at 500 gpm. While a maximum sustained pumping rate of approximately 300 gpm was achieved in this well during 1988, the maximum sustained pumping rate decreased to approximately 150 gpm by November 1988. By January 1991 the pumping rate had decreased to below 100 gpm, and it continued to decrease to approximately 50 gpm in 1999. Evidence of iron fouling was found in the treatment system and wells; however, despite treatment in 1996 with hydroacetic acid, redevelopment, and downhole camera work that confirmed the well screen was free from fouling, the well continues to operate at approximately 50 gpm.

To augment EW-1, four additional extraction wells were installed in 1995. While the design yield of each of these wells is 50 gpm, each well is only capable of operating at approximately 10 gpm. In June 2000 the extraction system (excluding EW-5, which was not operational due to thermal overloading) collectively pumped approximately 74 gpm.

The locations of all extraction wells are indicated on Figure 1-2.

2.3 TREATMENT SYSTEM

The treatment system is located outside on a concrete pad surrounded by a chain-link fence. The system consists of two bag filters arranged in parallel that precede two 20,000-pound GAC units arranged in series. Effluent from the second carbon unit is discharged to the Thea Foss Waterway via storm drains. During carbon replacement, extracted water is stored in a 7,050-gallon effluent tank that is filtered to capture GAC fines after carbon replacement.

2.4 MONITORING SYSTEM

Approximately 8 aquifer monitoring events have occurred at the site since operation of the GETS began in 1988. Samples have been collected from over 60 sampling locations, but a maximum of 20 wells has been sampled during any one event. Approximately 30 active monitoring wells in addition to the 5 extraction wells remain. Although samples have been analyzed for semi-volatile organic compounds and pesticides, samples are generally analyzed only for VOCs and total petroleum hydrocarbons (TPH).

Process monitoring includes sampling from three locations in the treatment plant on a monthly basis. The samples are collected from the influent, intermediate, and effluent water and are analyzed for VOCs. Intermediate samples represent process water after passing through the first carbon vessel but before passing through the second vessel.

3.0 SYSTEM OBJECTIVES, PERFORMANCE AND CLOSURE CRITERIA

3.1 CURRENT SYSTEM OBJECTIVES AND CLOSURE CRITERIA

The GETS is operating based on the 1985 ROD. This ROD does not establish cleanup goals for soils or groundwater; rather, it proposes to establish cleanup goals at some later date. These goals have not been established for the site. The default limits are the MCLs:

Contaminant	Concentration (ug/l)
tetrachloroethylene (PCE)	5
trichloroethylene (TCE)	5
trans 1,2 dichloroethylene (trans 1,2 DCE)	100
cis 1,2 dichloroethylene (trans 1,2 DCE)	70
vinyl chloride	2

An MCL has not been set for 1,1,2,2 tetrachlorethane (PCA). The Washington Sate Model Toxics Control Act specifies 0.219 ug/L; however, this concentration limit does not apply as a cleanup level for the site.

3.2 TREATMENT PLANT OPERATION GOALS

The GETS effluent is discharged via storm sewer to the Thea Foss Waterway. The discharge requirements differ in the 5-year review (based on surface water discharge to the Thea Foss Waterway) and the April-June 2000 Quarterly Status Report (based on 1988 water quality criteria for organisms). The limits as stated in both documents are provided in the following table.

Contaminant	Concentration (ug/l)	
	5-year review	Quarterly report
1,1,2,2 PCA	6.48	10.7*
PCE	4.15	10.7*
trans 1,2 DCE	32,800	1.85
TCE	55.6	80.7
vinyl chloride	2.92	100
pH	6-9	6-9

* Effluent discharge for for PCA and PCE combined is 10.7 ug/L.

3.3 ACTION LEVELS

The action levels for the removal of the air stripping towers for wellhead treatment at Well 12A have not been established, nor have the action levels for soils and groundwater been established. The influent VOC concentrations to Well 12A have remained significantly below the design criteria for the air stripper. The decision to discontinue the vapor extraction system at the source area was made based on a substantial decrease in the amount of contamination recovered and by the correspondingly reduced concentrations in extracted vapor concentrations. It was not based on predetermined levels.

4.0 FINDINGS AND OBSERVATIONS FROM THE RSE SITE VISIT

4.1 FINDINGS

The RSE team found a maintained and functional facility. The GETS is now 13 years old and is reaching the end of its designed life. The observations and recommendations given below are not intended to imply a deficiency in the work of the designers, operators or site managers but are offered as constructive suggestions in the best interest of the EPA and the public. These recommendations have the benefit of several years of operating data unavailable to designers or site managers.

Acknowledgment of LNAPL and DNAPL as continuing sources of dissolved phase contamination has caused site managers to reconsider the approach to addressing contamination associated with the Well 12A operable unit. Recent efforts have focused on screening remedial options and identifying data gaps necessary for evaluating these options. A Preliminary Remedial Process Options Screening and Data Gaps Memorandum dated October 1999 identifies a number of remedial options and suggests the compilation of a remedy evaluation and optimization (REO) report to further evaluate these options. In addition, this memorandum identifies data gaps such as the extent of DNAPL. The Groundwater Summary Report dated December 1999 also provides a site conceptual model, outlines data deficiencies, and discusses various remedial options.

4.2 SUBSURFACE PERFORMANCE AND RESPONSE

With respect to groundwater extraction, the GETS has underperformed the design criteria for the extraction rate by half an order of magnitude (i.e., a factor of 5), possibly resulting in lower than expected contaminant recovery and capture.

4.2.1 WATER LEVELS

Although water levels have historically been measured in monitoring wells within the operable unit, the 1999 Groundwater Summary Report suggests that water levels measured prior to October 1999 may have been biased due to improperly surveyed wells. Thus, water level measurements made on October 21, 1999 and October 27, 1999 (after the wells were re-surveyed) may provide the most reliable information pertaining to water levels. However, the potentiometric surface maps that have been generated from the October 1999 measurements contain questionable interpretations. For both October 1999 data sets, water level contours are found intersecting each other, suggesting that at a given point and time the water table is at two elevations. In addition, it appears that these potentiometric surfaces incorporate water levels measured in the extraction wells during pumping, thereby biasing the drawdown in favor of contaminant capture.

4.2.2 CAPTURE ZONES

The GETS was originally designed to pump 500 gpm and to prevent contaminant migration toward Well 12A. However, the system operates at less than 100 gpm and in the absence of pumping from Well 12A (which does not pump a majority of the time), contamination is more likely to migrate to the northeast, which is away from Well 12A and toward Commencement Bay. With this discrepancy between the original design parameters and the current operating conditions, it is possible the system is not adequately capturing targeted contamination.

While a capture zone analysis was attempted in the 1999 Groundwater Summary Report, it is based on potentiometric surfaces that are unreliable due to intersecting water level contours and the incorporation of water levels measured from extraction wells.

4.2.3 CONTAMINANT LEVELS

Contaminant levels in source area wells have fluctuated, but EW-1, EW-2, and EW-3 show significant decreases in VOC concentrations since 1995. EW-4 and EW-5, however, have not shown such decreases. In spite of the progress made in EW-1, EW-2, and EW-3, however, concentrations are still well above cleanup levels and the presence of LNAPL and DNAPL provides continuing sources of contamination.

As for the extended portions of the plume, data have not been consistently collected in monitoring wells near Well 12A. Yearly samples from Well 12A taken and analyzed by the City of Tacoma indicate that VOC concentrations in the public well have declined. Despite this sampling effort it is difficult to determine progress made in reducing plume extent to the southwest (toward Well 12A). Wells over 100 feet to the east and northeast of the Time Oil property that were sampled in April 1998 have undetectable concentrations of VOCs with the exception of TCE, which was detected at concentrations above MCLs at locations over 1,000 feet to the east and northeast of the property. The greatest extent of PCA, TCE, DCE, and PCE contamination, as determined by the same sampling event, is to the south and southeast of the Time Oil property.

4.3 COMPONENT PERFORMANCE

The system was operational approximately 90% of the time in 2000 and was operational 95% of the time in November 2001.

4.3.1 EXTRACTION WELLS AND PUMPS

All five extraction wells have failed to meet design criteria since installation. EW-1 was designed to extract 500 gpm but extracted a maximum of 300 gpm and now only extracts 50 gpm. EW-2 through EW-5 were designed to each extract 50 gpm, but collectively, they extract less than 50 gpm. Iron fouling is suspected as the primary reason for the consistent decrease in performance of EW-1; however, previous rehabilitation attempts of that well have not increased performance. The reduced capacity of EW-2 through EW-5 compared to EW-1 is likely due to the smaller well diameters and because they reach less permeable glacial till at shallower depths. Thus, EW-1 may screen a larger interval of sand and gravel and is also deeper allowing for more drawdown within the well before the pump is shut off by level controls.

4.3.2 BAG FILTERS

Two bag filters are arranged in parallel to filter the influent to the treatment system and reduce fouling of the carbon units due to suspended solids.

4.3.3 GAC Units

Two GAC units are arranged in series and each contain 20,000 pounds of GAC. Pressure gauges are present before and after each vessel to indicate the pressure drop across each vessel and the potential need for replacement. Between November 1991 and December 1998 ten replacements of the lead vessel occurred, with an average of 293 days between each one. As few as 181 days and as many as 710 days have passed between a carbon replacement. Based on carbon usage statistics provided in the 1999 Groundwater Summary Report, on average 640 pounds of contaminants are removed with 20,000 pounds of GAC suggesting a ratio of approximately 30 pounds of carbon to one pound of contaminants.

In 2000 and the first half of 2001 replacement of carbon occurred approximately every four months. At an influent concentration of approximately 1 mg/L and a total extraction rate of 75 gpm, chemical loading is approximately 0.9 pounds per day of VOCs, which translates to approximately 185 pounds of carbon to 1 pound of contaminant.

$$\frac{20{,}000 \text{ lbs of carbon}}{4 \text{ months}} \times \frac{\text{month}}{30 \text{ days}} \times \frac{\text{day}}{0.9 \text{ lbs of contam.}} = \frac{185 \text{ lbs of carbon}}{1 \text{ lb of contam.}}$$

Thus, the recent use of carbon per pound of contaminant is higher than has previously been achieved.

4.3.4 Controls

The system has an autodialer and emergency stop switches for plant safety.

4.4 Components or Processes that Account for Majority of Monthly Costs

The following monthly costs were approximated by the RSE team based on information provided by the RPM.

labor: plant operation (3 man days per month)	$2,500
labor: project management	$2,500
labor: sampling events	$2,500
GAC (replacement and disposal)	$5,000
Stormwater discharge	$5,000
Electricity	$1,200
	$18,700 per month

This monthly cost of $18,700 translates to an approximate annual cost of $225,000 per year.

4.4.1 Utilities

Natural gas is not used at the site, but electric motors with a combined rating of over 35 horsepower are used to power the 5 extraction well pumps. The costs for discharge to the storm sewer were obtained from the site manager and suggest an average monthly cost of approximately $5,000.

4.4.2 Non-utility Consumables and Disposal Costs

Carbon replacement costs required approximately $1.50 per pound and equaled approximately $60,000 in 2000.

4.4.3 Labor

Approximately three man days per month are used to operate and maintain the system. This includes any oversight for carbon replacement, cleaning the paddle wheels on flow sensors, inspecting the pump and looking for leaks, and general cleanup.

4.4.4 Chemical Analysis

Costs for chemical analysis are not billed to the site as chemical analysis is accomplished in the EPA Regional laboratory through the Contract Laboratory Program (CLP).

4.5 Recurring Problems or Issues

The most significant problem affecting the site is the reduced yield from all of the extraction wells.

4.6 Regulatory Compliance

The plant regularly meets all discharge requirements.

4.7 Treatment Process Excursions and Upsets, Accidental Contaminant/Reagent Releases

In one documented instance, the flow meter for an extraction well ruptured allowing extracted water to fill the extraction well vault and discharge onto the street and into the storm sewer.

4.8 Safety Record

The GETS has an excellent safety record with no documented injuries.

5.0 EFFECTIVENESS OF THE SYSTEM TO PROTECT HUMAN HEALTH AND THE ENVIRONMENT

5.1 GROUND WATER

Well 12A and the rest of the public wells in that well field, including Well 9 (located 1,000 feet to the west of Well 12A), represent the most significant known receptors of groundwater contamination. However, Well 12A is protected by an air stripping system that has regularly met its design criteria and influent concentrations to Well 12A are consistently far below the designed influent concentration. Thus, water provided by Well 12A is not threatened by VOC contamination from the Time Oil property. It is believed that Well 12A captures contaminants that are pulled to the southwest of the Time Oil property and therefore provides protection to the other public wells when they operate. Institutional controls prohibit extraction and use of water that exceeds the 10^{-6} hazard level.

5.2 SURFACE WATER

Commencement Bay is the closest surface water body to the site. It is located approximately 3 miles downgradient of the site. The April 1998 aquifer sampling event suggests that site related contamination has not extended more than 1,000 feet from the Time Oil property. Given the relatively flat hydraulic gradients and previous estimates of groundwater velocity to the northeast of the source provided in the 1999 Groundwater Summary Report, the travel time for contamination to reach the bay (approximately 3 miles away) in the absence of adequate capture may be approximately 20 years. With adequate capture, surface water is not and will not be impacted by site-related contamination.

5.3 AIR

Asphalt and concrete around the site limit passage of any vapor contamination from the subsurface to the ambient air. Air from the stripping towers on Well 12A is not treated with vapor phase carbon and is discharged to the atmosphere. However, at influent concentrations less than 100 ug/L and a pumping rate of 670 gpm (which was sustained during the high-demand period for water in 1998) the discharge to air is less than 1 pound per day during periods of operation.

5.4 SOILS

Contaminated soils including the filter cake remaining to the east of the Time Oil building are covered with asphalt or concrete and therefore do not represent exposure pathways to the public.

5.5 WETLANDS AND SEDIMENTS

Wetlands and sediments are not impacted by site-related contamination.

6.0 RECOMMENDATIONS

6.1 RECOMMENDED STUDIES TO ENSURE EFFECTIVENESS

6.1.1 OBTAIN ACCURATE AND RELIABLE WATER LEVEL MEASUREMENTS AND DEVELOP ASSOCIATED POTENTIOMETRIC SURFACE MAPS

The 1999 Groundwater Summary Report states, "The capture zone analysis, completed in October 1999, consisted of a survey of wells (northings, eastings, and elevations) because existing survey information was questionable and some wells had no survey data." This statement puts into question all water level measurements made prior to October 1999. The RSE team recommends that the site managers review the site survey information, including the 1999 surveying data, and use previous depth-to-water measurements to "correct" historical water level measurements at the site. Accurate water level measurements at different points in the Site's history are important for calibration of the recommended groundwater flow model as well as providing insight into capture provided by the GETS during different pumping and hydrologic conditions.

Site records indicate the following survey events at the site:

- In 1989 Woodward and Clyde Consultants surveyed a number of wells labeled WCC.
- In 1989 HCE, Inc. resurveyed all existing wells near the Time Oil property.
- In 1995 White Shield, Inc. surveyed mostly extraction wells and some monitoring wells.
- In 1999 White Shield, Inc. resurveyed the monitoring wells.

Once accurate and reliable water level measurements have been obtained, potentiometic surface maps should be generated. Development of these maps should not include the water levels from operating extraction wells because water levels from these operating wells may be substantially lower than in the surrounding aquifer. Use of water levels from extraction wells could therefore potentially bias the potentiometric surface maps in favor of capture.

Assuming reliable and complete survey information is available, approximately $5,000 may be required to convert the historical depth-to-water measurements to water level measurements and to develop the associated potentiometric surfaces.

6.1.2 DEVELOP GROUNDWATER FLOW MODEL OF THE WELL 12A OPERABLE UNIT

A reliable groundwater flow model of the Well 12A operable unit would provide two significant benefits to site management:

- It would allow a more accurate analysis of the capture zone of the current GETS and optimization of well locations and pumping rates for a modified GETS.

- It would provide site managers with a tool to better evaluate remedial process options and choose among passive, moderate, and aggressive remedial strategies.

The history of groundwater extraction in the Well 12A operable unit provides an abundance of hydraulic data to develop a well-calibrated model. The complexity of the site and the associated model would likely require a moderate to high level of expertise with groundwater modeling.

The model should be developed with a sufficiently large three-dimensional domain to adequately address future site management decisions. Such a domain would include Well 12A, Well 9, and possibly other supply wells in the southwest portion of the operable unit and possibly Commencement Bay to the north and northeast. In the vertical extent, the model should include the conductive aquifer and aquitard beneath the Time Oil property but should also extend to a depth beyond the bottom of Well 12A.

Once the domain and proper boundary conditions are established, the model should be calibrated using the abundance of pumping and water level data. The calibrated model should be able to reproduce with reasonable accuracy the measured water levels resulting from three pumping scenarios: 1) Well 12A pumping with the GETS shutdown, 2) both Well 12A and the GETS pumping, and 3) the GETS pumping with Well 12A shutdown. Such a model will require specifying heterogeneity of aquifer recharge and hydraulic conductivity (i.e., those parameters varying with location) and therefore must be numerical rather than analytical.

Once these steps have been achieved, the model can be used for capture zone analysis and as a tool in the decision-making process. A contaminant transport model (that uses either particle tracking or finite-difference approximations) may also help in the decision-making process as it would help estimate time frames for contaminant transport and degradation as well as the potential benefit of aggressive source removal. Such a transport model would incorporate both advection and dispersion and would require contaminant sources to be specified, including the remaining filter cake as well as LNAPL and DNAPL. A well-delineated contaminant plume would be required for calibration, and estimated parameters for contaminant sorption and degradation would also have to be specified. In the opinion of the RSE team, incorporation of multiphase transport into the transport model would not be cost or time effective. Development and initialization of the groundwater flow model, however, may require additional field efforts to characterize the extent of the DNAPL.

A well-calibrated groundwater flow model (as briefly described in this report) could be developed by modeling experts for approximately $50,000. An accompanying transport model, if constructed, would cost another $50,000. In addition, between $12,000 and $24,000 per year would be required for updating the model calibrations based on new data. The RSE team would defer development of the proposed transport model until the groundwater flow model is developed, calibrated, and proven reliable as a site management tool.

By comparison, modeling efforts proposed by the current contractors for "reverse modeling" (memorandum dated August 13, 2001) to estimate distances of contaminants from various receptors would require significantly less effort than the modeling efforts recommended in this RSE report and could not be used in analyzing the capture zone. Two potential shortcomings of the proposed reverse modeling effort should be noted.

- First, the reverse modeling effort will utilize a quasi three-dimensional analytical model. While relatively easy to implement, such models are incapable of incorporating heterogeneity in recharge and hydraulic conductivity and therefore could not be adequately calibrated using site pumping and water level data. Without adequate calibration, the model cannot reliably represent the subsurface conditions around Well 12A and beneath the Time Oil property.

- Second, the list of principal assumptions in the "reverse modeling" memorandum will assume groundwater flow in the direction of Well 12A and no pumping from the GETS. However, previous hydrogeologic data suggest, in the absence of pumping from the GETS, that groundwater near the source flows away from Well 12A and groundwater flow directions vary depending on the extent of pumping from Well 12A.

In the opinion of the RSE team, the above shortcomings of the proposed reverse modeling effort could render the results unreliable and therefore adversely impact site management decisions.

6.1.3 ANALYZE CAPTURE ZONE OF EXTRACTION WELLS

To date, capture zone analyses at the Well 12A operable unit have included questionable interpretations (intersecting groundwater contours on the interpreted potentiometric surfaces and the use of water level data from operating extraction wells). These previous capture zone analyses also do not include a clear presentation of the capture zone superimposed on the extent of the contaminant plume targeted for capture. Thus, analysis of the capture zone for the site should be revisited and updated regularly given newly obtained data.

Due to the complexity of subsurface environments, adequate capture is difficult to determine with any one process; rather, converging lines of evidence are often needed to demonstrate capture.

<u>Preliminary analysis using measured water levels:</u>
For this preliminary analysis, the first step is to accurately delineate the contaminant plume through aquifer monitoring events and construct a plume map. Once this map is complete, the target capture zone should be determined based on the remedial objectives. This target zone may encompass the entire plume, or it may only encompass the source areas and/or highly contaminated areas of the plume.

The second step is to develop a reliable potentiometric surface map using water level data collected from piezometers and monitoring wells. This map should not include water levels taken from operating extraction wells because the reduced water levels in these wells inaccurately represent the water levels in the surrounding aquifer thereby biasing the analysis in favor of capture. Arrows indicating groundwater flow directions and the associated capture zone should be provided on this map. It should be noted that capture is indicated by groundwater flow directions toward the extraction wells and not simply by evidence of drawdown.

The third step is to overlay the plume map (including the target capture zone) with the potentiometric surface map including the interpreted capture zone. If the actual capture zone encompasses the target capture zone, then this preliminary analysis suggests capture.

It should be noted that while this approach provides the best preliminary analysis for capture, an insufficient number of monitoring wells and piezometers may be available for clearly resolving the potentiometric surface in heterogeneous formations.

<u>Secondary analysis using sentinel monitoring wells:</u>
Monitoring wells downgradient of the contaminant plume can be regularly sampled and analyzed for the contaminants of concern. If the concentrations in these monitoring wells remain undetectable then this adds evidence supporting capture at least between the source and the monitored well. However, because groundwater flow and contaminant transport is relatively slow, a long period of time, perhaps years, may be

required before sentinel monitoring wells would show a potential increase in concentration. Thus, the use of sentinel monitoring wells may require years of sampling and analysis to confirm capture.

Similarly wells within the extended portions of a plume can be monitored to determine if contaminant concentrations are decreasing, remaining the same, or increasing. If concentrations are decreasing this may (but does not necessarily) suggest capture of the source or upgradient portions of the plume. If concentrations remain the same or increase, however, capture is not adequate. Once again, a substantial amount of time, perhaps years, may be required before a definitive conclusion about capture can be drawn from concentration trends in such wells.

Secondary analysis using gradient pairs or triplets:
The hydraulic gradient indicating the direction of groundwater flow can be measured by placing two or three piezometers in a cluster and measuring water levels from each of the piezometers. By comparing the measured water levels in each of the piezometers, the groundwater flow direction can be determined in the proximity of the cluster. A flow direction in the vicinity of a cluster directed toward an extraction well provides additional evidence for capture, at least at the location of the cluster.

It should be noted that this approach only indicates flow directions in specific areas where clusters are located, and placing a sufficient number of clusters to adequately evaluate capture can be costly.

Secondary analysis using a groundwater flow model:
By constructing a well-calibrated groundwater flow model, site managers can compare measured water levels with modeled water levels. If the two sets compare and the model indicates capture, then actual capture in the aquifer is likely occurring. This often provides the most thorough analysis of capture as the model has the capability of incorporating site-specific recharge, hydraulic conductivity zones, and pumping configurations. In instances where a three-dimensional model is available, this approach also allows for evaluation of capture in both the vertical and horizontal directions, an evaluation that is extremely difficult with the aforementioned preliminary and secondary analyses. The complexity of the model would depend on the complexity of the site. In the case of the Well 12A operable unit the complexity of the subsurface and the various pumping configurations that occur (including Well 12A and the other supply wells), a numerical model with at least moderate complexity is recommended.

The RSE team recommends that converging lines of evidence be drawn from a number of these types of analyses. A preliminary analysis should be accomplished with plume maps and potentiometric surfaces, and the results from this preliminary analysis should be augmented with those from monitoring already installed sentinel wells and groundwater flow modeling. This comprehensive approach should be conducted on a regular basis, perhaps semi-annually or annually. The preliminary analysis will likely require approximately $15,000 upfront to collect and organize previously obtained data and to develop appropriate CADD drawings for the site. Compilation of previous plume and potentiometric surface maps and comparison of the associated target and measured capture zones would likely cost an additional $5,000. Regular analysis incorporating new data on a annual or semi-annual basis would likely cost an additional $4,000 per year. Augmenting this analysis by viewing trends in monitoring wells should result in a negligible cost increase, and augmenting it with modeling simulations as described in Section 6.1.1 are included in the $12,000 to $24,000 estimate provided in that section.

6.1.4 MAKE AQUIFER MONITORING PROGRAM CONSISTENT

The aquifer monitoring program has not resulted in regularly scheduled monitoring events since 1993. Between 1989 and 1993 one event was conducted per year. Two events were conducted in 1995 and one in

1998. In addition, each monitoring event involves sampling different wells, making it difficult to analyze remediation progress or to validate plume capture. For example, monitoring in 1993 involved sampling of wells to the southwest of the Time Oil property near Well 12A; however monitoring in 1998 did not involve sampling of these wells. Thus, it is difficult to evaluate the progress toward remediation in that portion of the aquifer.

Up to 20 monitoring wells (the same number sampled in 1998) should be sampled on a semi annual basis with the purpose of delineating the plume. The results will be helpful in constructing plume maps for capture zone analyses and for initializing a transport model if one is developed. If plume containment is chosen as the final remedy for the site, the sampling of wells in the source area will not be as significant as sampling near the border of the target capture zone and the extended plume. Thus, in the case of a containment strategy, only a few of the selected 20 monitoring wells should be located in the extraction area. In addition, sampling the concentrations from the individual extraction wells could be eliminated, especially given that the treatment plant influent is sampled monthly.

Sampling up to 20 wells twice per year would cost approximately $30,000 for labor such that no increase in costs is expected. As analytical costs are not billed to the site, they are not included in the cost estimates. However, as a note, approximately 25 samples (including field and trip blanks) would need analysis for VOCs per event, at a cost of approximately $125 per sample (approximately $6,500 per year).

6.1.5 ENSURE ANNUAL SAMPLING AND ANALYSIS OF VOCS IN WATER FROM WELL 9

Water from Well 12A is sampled and analyzed annually for VOCs, and these samples have indicated a reduction in VOC contamination in the influent to that well. It is unclear if the other supply wells in the same well field, including Well 9, are sampled for VOCs. Given that Well 9 is the closest supply well to Well 12A, it would be prudent to sample and analyze for VOCs the influent to it. If contamination is present beyond suitable risks, consideration should be given to treating the extracted water from the well or shutting down the well.

6.2 RECOMMENDED CHANGES TO REDUCE COSTS

6.2.1 REPLACE EXTRACTION WELL PUMPS

The pumps in EW-2, EW-3, and EW-4 are oversized for the yields of these wells. EW-2 and EW-4 have 7.5 horsepower pumps and EW-3 has a 10 horsepower pump. These pumps each push approximately 10 gpm of water against approximately 115 feet of head— 35 feet from the water table to the ground surface, approximately 20 feet to the top of the GETS, and across 60 feet of pressure drop (over 25 psi) through the GETS. Movement of water with a pump efficiency of 50% would require approximately 0.6 horsepower. Using a 1.5 horsepower pump would easily accommodate this current load and could provide additional flow if necessary. Thus, converting from the current pumps to 1.5 horsepower pumps as currently used in EW-5 would save over 20 horsepower. Assuming approximately $0.05 per kilowatt hour, a savings of approximately $700 would be realized each month (approximately $8,500 per year). Installing the three new pumps would likely cost approximately $14,000. Thus, if the current GETS is selected as the final remedy or as an interim remedy for three or more years, it would be cost-effective to replace the pumps as suggested.

6.2.2 EXAMINE CITY OF TACOMA POLICIES ON STORMWATER DISCHARGE AND/OR CONSIDER ALTERNATIVE DISCHARGE LOCATIONS

The costs associated with discharging plant effluent to the stormwater system are the highest seen by the RSE team during a nationwide evaluation of pump and treat systems. Although the RSE team has found equivalent costs for discharging to a sanitary sewer, in the course of evaluating 17 Fund-lead P&T systems and other professional experience, the RSE team has only found costs associated with "hook up" to a stormwater system and not a continuing cost for discharge. The site managers should examine the policies of the City of Tacoma related to stormwater discharge and investigate alternative discharge locations. In this rare case, it may actually be cost effective to discharge to a sanitary sewer instead. Also, through negotiations, it may be possible to reduce the costs of stormwater discharge by further reducing effluent concentrations. If this is the case, it may be cost effective to enhance the GETS.

The discharge policies should also be evaluated to estimate costs if increased pumping is required for improved capture or more aggressive source removal through pumping. The RSE team is unable to quantify costs associated with EPA personnel examining the City of Tacoma policies or negotiating with the City. If a contractor is hired for this purpose, one could estimate approximately $4,000 (16 hours for examining the policies and 24 hours for possible negotiations with a billing rate of $100 per hour). Costs of alternate discharge locations or improvements to the GETS should be weighed against the potential savings in eliminating or reducing the current discharge costs of $60,000 per year.

6.2.3 CONSIDER REPLACING GAC TREATMENT WITH AIR STRIPPING

Depending on the future of the remedy, consideration should be given to replacing the current GAC treatment system with an air stripping system. Plant maintenance for an air stripper would be similar to the current maintenance associated with the carbon system. While a cost increase of $13,000 per year would result from operation of an air stripper with a 15 horsepower blower, the estimated cost of $63,000 per year for carbon replacement could be eliminated. Thus, a net potential savings of $50,000 per year could result. At current flow rates and influent concentrations chemical loading from the air stripper to the atmosphere would be less than 1 pound per day (similar to the loading from operation of Well 12A). However, if pumping rates were to increase due to the need for increased capture, that chemical loading could increase if influent concentrations remain the same. If vapor phase carbon is required to polish the air stripper offgas, additional costs would be approximately $10,000 per year (replacement of 3,000 pounds of carbon once per year at approximately $3 per pound). In this case, approximate savings of $40,000 per year would result.

The decision to implement this change should be weighed against the capital costs for scoping the work, contracting, design, implementation, and maintenance associated with operation start up. The expected costs for design and construction of an air stripping system with a design flow rate of 500 gpm with offgas treatment would likely cost $350,000 if it is installed in the current location of the GETS. Such a change would not likely be cost effective unless the current GETS required replacement or pumping rates and chemical loading increase by a factor of two or more resulting in a substantial increase in carbon replacement costs.

It should be noted that an air stripping system could also be installed in the VES building and plumbed into the already installed vapor phase carbon units with the capability of onsite steam regeneration. Installing such a system would likely cost approximately $500,000 and would require an additional $60,000 per year to operate due to the steam regeneration system. Thus, installation of such a system should only be considered if chemical loading rates are expected to reach 5 to 10 pounds per day for a number of years.

6.3 MODIFICATIONS INTENDED FOR TECHNICAL IMPROVEMENT

The RSE team did not note any recommendations for technical improvement beyond those cited as recommendations to improve effectiveness, reduce costs, or gain site close-out. In the opinion of the RSE team, the issue of underproducing extraction wells remains the most consistent problem meriting technical improvement at the site. As addressing this issue depends on the remedial options considered by the site managers, this topic of improving groundwater extraction is discussed in Section 6.4.2.2

6.4 MODIFICATIONS INTENDED TO GAIN SITE CLOSE-OUT

6.4.1 EXCAVATE REMAINING FILTER CAKE

Despite removal filter cake on the Time Oil and Burlington North Railroad properties, approximately 300 to 500 cubic yards of filter cake still remains on the east side of the Time Oil building. This filter cake provides a continuing source for the contaminants of concern, and the RSE team agrees with the site managers that it should be excavated. Estimates from the site managers indicate that excavation and disposal of the filter cake will cost approximately $500,000.

6.4.2 EVALUATE REMEDIAL PROCESS OPTIONS BASED ON ANALYSIS OF GROUNDWATER MODELING

As mentioned in Section 6.1.1, the RSE team recommends a groundwater flow model, and potentially a contaminant transport model, to evaluate both capture of the contaminant plume and to assist in deciding on future remedial approaches. The RSE team notes three categories of approaches to future remedial strategy ranging from passive to aggressive depending on future monitoring and modeling results.

6.4.2.1 PASSIVE APPROACH: SWITCH TO MONITORED NATURAL ATTENUATION

This passive approach becomes valid if further monitoring and modeling efforts suggest that site-related contamination will not adversely impact any receptors. Transport modeling, for example, would have to demonstrate that although a continuing source remains, migration of contaminants is sufficiently slow to allow natural degradation of the contamination before it reaches any receptors.

Such modeling efforts would require a well-calibrated transport model and reliable evidence regarding in situ degradation of site-related contaminants. The 1999 Groundwater Summary Report suggests that elevated chloride concentrations indicate the possibility for degradation of chlorinated solvents. Also, hydrocarbons from waste oil exist in the subsurface and provide nutrients for reductive dechlorination through cometabolism in anaerobic conditions. Additional data should be collected on parameters that affect the potential for reductive dechlorination, including but not limited to oxidation-reduction potential (ORP), dissolved oxygen, iron, nitrate, and sulfate. However, it should be noted that reductive dechlorination may successfully transform PCE to TCE, TCE to DCE, and DCE to vinyl chloride as well as transform PCA to trichloroethane or other daughter products. These daughter products are as significant or possibly more significant hazards for human and environmental health and more effectively degraded in aerobic conditions. Thus, complete degradation of chlorinated aliphatic compounds such as PCE and TCE to harmless constituents would ideally involve anaerobic conditions to transform these compounds to vinyl chloride and aerobic conditions to transform vinyl chloride to harmless end products.

With two contrasting environments required for full degradation of contamination, the potential of a successful remedy with natural attenuation is unlikely unless aquifer conditions are artificially adjusted through nutrient and/or oxygen addition.

6.4.2.2 MODERATE APPROACH: CONTINUE PUMP AND TREAT AS A CONTAINMENT REMEDY

Given the presence of LNAPL and DNAPL as continuing sources of dissolved phase contamination, pump and treat likely will not succeed as a restoration remedy. Pump and treat, however, can potentially succeed as a containment remedy. The current GETS or modifications to the current GETS may provide adequate containment of site-related contaminants. A capture zone analysis conducted as specified in Recommendation 6.1.2 will indicate if the GETS provides adequate capture. If it does, then the current system can be used as a containment remedy until new approaches are developed to address the source areas.

If adequate capture is not provided by the current GETS, then increased pumping and new extraction wells may be required. The groundwater flow model, especially in conjunction with optimization packages such as MODMAN, could be used to determine the optimal locations and pumping rates for new wells.

If new wells are installed, steps should be taken during design and installation to ensure the maximum amount of flow is available. EW-1 was originally capable of extracting 300 gpm compared to the approximate extraction rates of 10 gpm for each of the other extraction wells. Thus, the design features responsible for the relatively high initial yield of EW-1 should be emulated. These features include 1) using a large diameter casing and 2) drilling the well deeper to allow for more drawdown within the well before the pump is shut off by level controls.

To avoid reductions in flow over time as were apparent with EW-1, a well maintenance program should be initiated to prevent new wells from fouling. In the case of EW-1, iron fouling likely decreased the yield of the well. The flow rate continued to decrease from installation in 1988 to the present, but the only documented well rehabilitation effort occurred in 1996, eight years after fouling became evident. Regular monitoring of the specific capacity of the wells and a yearly well-maintenance program would warn of significant fouling and address the problem before irreversible reductions in the well yields occurred. More information about well maintenance can be found in USACE Engineering Pamphlet EP 1110-1-27 at **http://www.usace.army.mil/inet/usace-docs**.

6.4.2.3 AGGRESSIVE APPROACH: SOURCE REDUCTION OR REMOVAL

A number of proven and experimental technologies exist that can aid in reducing subsurface sources of contamination. These technologies include but are not limited to excavation, in situ heating, air sparging, and injection of chemicals for in situ oxidation or enhancement of biodegradation. Despite the abilities of these technologies to remove mass, each of these technologies have limitations that should be considered.

One limitation common to each of these technologies (with the exception of extensive excavation) is that inevitably some LNAPL or DNAPL will remain in pore spaces providing continuous sources of contamination and possibly making it impracticable to return groundwater to its “beneficial use”. However, aggressive source removal may sufficiently reduce the extent of the source such that monitored natural attenuation is subsequent a viable option.

Another limitation is the potential for short or long term impact of above-ground business operations. Excavation would result in a long term impact and destruction of some local buildings. The other technologies would likely result in relatively short term impacts but also possible destruction of local buildings. Many of these technologies generate heat and vapor that could impact business activity at the surface. Heating the subsurface facilitates contaminant recovery by mobilizing or vaporing the contaminants, and in situ chemical oxidation destroys contaminants producing heat and vapors as a byproduct. If restarted, the VES could serve to help control and extract vapors generated from such technologies.

Simulations with a groundwater flow and contaminant transport model could assist site managers in determining the amount of source reduction necessary to proceed with monitored natural attenuation. The RSE team recommends that site managers compile a brief description of the site and to distribute this to vendors of various technologies to determine if site conditions merit bench and/or pilot testing of the vendors' respective technologies. Developing and distributing the site description should require approximately $5,000. Vendors typically provide an initial assessment of the applicability of their technology free of charge.

6.5 UNUSED EQUIPMENT

The VES system, which includes an onsite carbon regeneration system and phase separator, has not operated since February 1997. Elements of this system, if not used in conjunction with aggressive source removal technologies, may be useful at other EPA sites. USACE has a program designed to help the transfer of unused government equipment from Fund-lead sites to other Fund-lead sites where the equipment can be used. The contact for this program is

Lindsey K. Lien, PE
U.S. Army Corps of Engineers
12565 West Center Road
Omaha, NE 68144-3869
(402) 697-2580
Lindsey.K.Lien@nwd02.usace.army.mil

6.6 SUGGESTED APPROACH TO IMPLEMENTATION OF RECOMMENDATIONS

As evidenced by site documents such as the Preliminary Remedial Process Options Screening and Data Gaps Memorandum dated October 1999, the site managers for the Well 12A operable unit are considering alternate remedial strategies for the site because site data indicate the current GETS likely will not restore the aquifer to its "beneficial use". The RSE team applauds this proactive site management and encourages further consideration of remedial options.

The RSE team recommends continuing to screen alternative remedial technologies and strategies, but suggests that the current GETS or a modified version continue operation to provide capture of the contamination until an alternate strategy is selected and implemented. As the current GETS may not offer sufficient capture, the RSE team recommends immediate implementation of the recommendations in Section 6.1. A thorough analysis of the capture zones (6.1.2) will likely require the recommended groundwater flow model (6.1.1) and changes in the monitoring program (6.1.3). A preliminary capture zone analysis as suggested in 6.1.2, however, can and should be conducted based on existing water level and water quality data. In addition to assisting in the capture zone analysis, the recommended model can also be used for evaluating and planning the site remedial strategy.

In terms of cost reduction, the RSE team suggests immediate examination of the City of Tacoma discharge policies and consideration of alternate discharge locations (6.2.2). A cost savings of up to $60,000 per year could result if discharge fees can be eliminated. Such costs savings may even be more significant if the extraction rate of the GETS is increased. Replacement of the extraction well pumps (6.2.1) should wait until the preliminary capture zone analysis is completed. If this preliminary analysis suggests that adequate capture would require pumping on the order of 300 to 500 gpm or larger, new extraction wells with a larger capacity may be required and the current pumps could be used. Otherwise, the current pumps should be replaced as soon as possible with smaller models. Replacement of the GETS with an air stripper (6.2.3) should only be considered if additional pumping for capture would more than double the chemical loading rates to the GAC units or if the GETS requires replacement due to substantial maintenance.

For recommendations regarding site closeout, removal of the filter cake (6.4.1) can be conducted immediately while evaluation of the remedial strategies should be largely based on rigorous modeling and data analysis. The RSE team advises that pump and treat continue as an interim remedy to provide capture of the contamination until a source removal process can be identified that will remove the LNAPL and DNAPL or sufficiently reduce their extent such that monitored natural attenuation is viable based on modeling efforts and risk assessments.

7.0 SUMMARY

The observations and recommendations given below are not intended to imply a deficiency in the work of either the designers or operators, but are offered as constructive suggestions in the best interest of the EPA and the public. These recommendations obviously have the benefit of the operational data unavailable to the original designers.

The RSE process is designed to help site operators and managers improve effectiveness, reduce operation costs, improve technical operation, and gain site closeout. Recommendations to improve effectiveness include generating a groundwater flow model (and potentially a contaminant transport model) to assist in evaluating capture and screening remedial technologies, conducting a thorough capture zone analysis, improving the current monitoring program, and sampling influent to a local supply well for VOCs. Recommendations to reduce costs include examining the discharge policies of the City of Tacoma and investigating alternative discharge locations, replacing extraction well pumps with smaller models, and possibly replacing the carbon treatment system with an air stripper. Recommendations regarding site closeout include excavating the remaining filter cake that provides a continuing source of contamination and proceeding with screening of remedial strategies based on data analysis and modeling efforts. For this report, independent recommendations for technical improvement were not made; rather, they were included in the other recommendation categories.

Table 7-1 summarizes the costs and cost savings associated with each recommendation. Both capital and annual costs are presented. Also presented is the expected change in life-cycle costs over a 30-year period for each recommendation both with discounting (i.e., net present value) and without it.

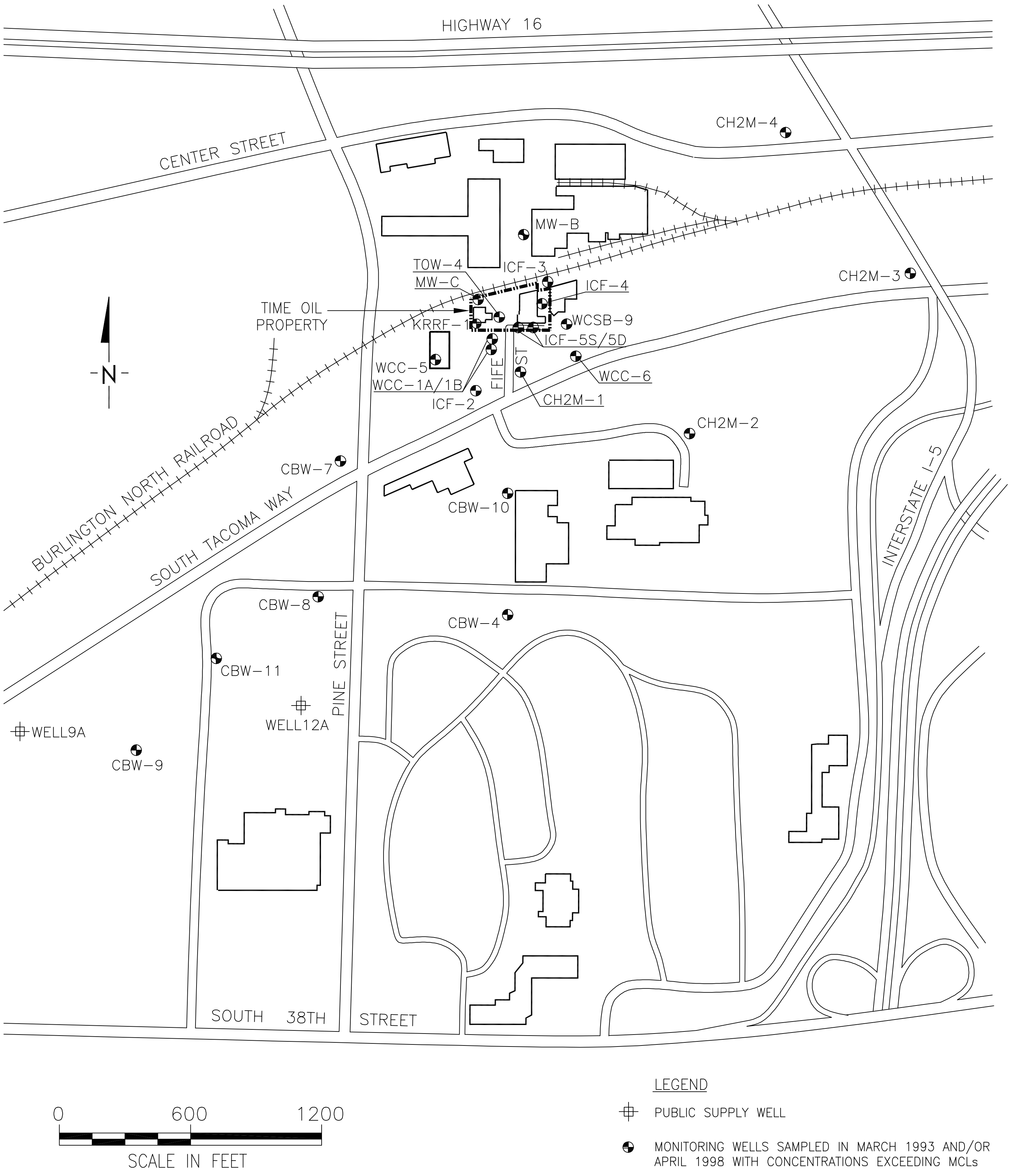
Table 7-1. Cost Summary Table

Recommendation	Reason	Estimated Change in			
		Capital Costs	Annual Costs	Life-cycle Costs*	Life-cycle Costs **
6.1.1 Obtain accurate and reliable water level measurements and develop associated potentiometric surface maps	Effectivness	$5,000	$0	$5,000	$5,000
6.1.2 Develop a groundwater flow model	Effectiveness	$50,000	$12,000	$410,000	$243,000
6.1.2b (optional) Develop a contaminant transport model	Effectiveness	$50,000	$12,000	$410,000	$243,000
6.1.3 Analyze capture zone	Effectiveness	$20,000	$4,000	$140,000	$84,000
6.1.4 Improve well-sampling program	Effectiveness	$0	$0	$0	$0
6.1.5 Monitor Well 9 for VOCs (costs incurred by city)	Effectiveness	$0	$0	$0	$0
6.2.1 Replace pumps in extraction wells	Cost reduction	$14,000	($8,500)	($241,000)	($123,000)
6.2.2 Examine city stormwater discharge policies and investigate alternative discharge locations	Cost reduction	$4,000	($60,000)	($1,796,000)	($963,000)
6.2.3 Consider replacing carbon treatment system with an air stripper	Cost reduction	$350,000	($50,000)	($1,150,000)	($456,000)
6.4.1 Excavate remaining filter cake	Gain site closeout	$500,000	$0	$500,000	$500,000
6.4.2 Maintain contaminant capture while continuing to screen alternative remedial technologies and strategies	Gain site closeout	not quantified	not quantified	not quantified	not quantified
6.4.2.3 Develop a site description for distribution to vendors of source removal technologies	Gain site closeout	$5,000	$0	$5,000	$5,000

Costs in parentheses imply cost reductions.
* assumes 30 years of operation with a discount rate of 0% (i.e., no discounting)
** assumes 30 years of operation with a discount rate of 5% and no discounting in the first year

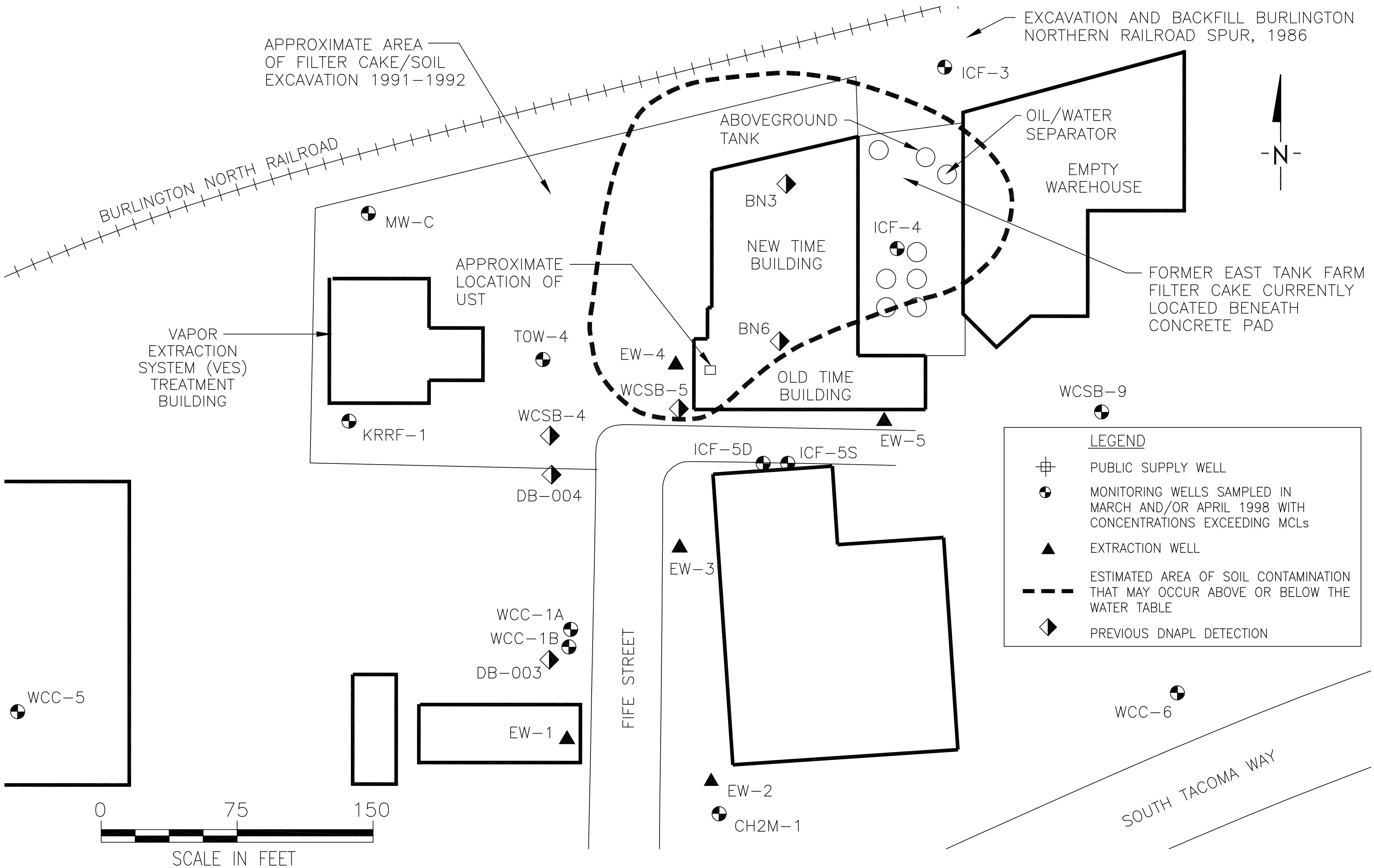
FIGURES

FIGURE 1-1. SITE LAYOUT OF THE WELL 12A OPERABLE UNIT INDICATING MONITORING WELLS SAMPLED DURING THE MARCH 1993 AND/OR APRIL 1998 MONITORING EVENTS THAT HAD CONCENTRATIONS ABOVE MCLs



(Figure compiled from Figures 1-1 and 4-7 of the Groundwater Summary Report, South Tacoma Channel/Well 12A Site, Tacoma, Washington, ICF Kaiser, December 1999).

FIGURE 1-2. LAYOUT OF THE TIME OIL PROPERTY INDICATING THE LOCATIONS OF THE GROUNDWATER EXTRACTION WELLS AS WELL AS AREAS OF CONTAMINATED SOIL, DNAPL, AND FILTER CAKE



(Note: Figure compiled from Figure 1-2 of the Preliminary Remedial Process Options Screening and Data Gaps Memorandum, Commencement Bay, South Tacoma Channel/Well 12A Superfund Site, Tacoma Washington, October 1999 and Figure 3-1 of the Groundwater Summary Report, South Tacoma Channel/Well 12A Site, Tacoma, Washington, ICF Kaiser, December 1999).

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