Case Study Abstract

Pump & Treat of Contaminated Groundwater at Langley Air Force Base Virginia

Site Name:
Langley Air Force Base, IRP Site 4

Location:
Langley, Virginia

Vendor:
Not Available

SIC Code:
9711 (National Security)

Waste Source:
Underground Storage Tanks

Contaminants:
Benzene, Toluene, Ethylbenzene, Xylenes (BTEX) and Total Petroleum Hydrocarbons (TPH)

- Primary constituents of JP-4 fuel are alkanes, cycloalkanes, alkylbenzenes, indans/tetralins, naphthalenes
- Total Recoverable Petroleum Hydrocarbons - 25 to 4,100 ppb in groundwater; >100 ppm in soil
- Free product floating on groundwater has exceeded 1 ft. in thickness

Technology:
Groundwater Extraction using a Vacuum Assisted Well Point Extraction System and Aboveground Air Stripping

- Extraction - 16 vacuum extraction wells connected by a header pipe to a central vacuum system; wells extend to approximately 14 ft. below ground surface
- Extraction network has an average flow rate of 32 gpm (2 gpm per well); vacuum pump provides 24-25 in of Hg
- Separation - initial oil/water separation occurs in a vacuum decanter followed by a high efficiency oil/water separator; oil phase is sent to a storage tank
- Treatment of aqueous phase - 2 air stripping columns - Column 1 - air/water ratio of 180 and air flow of 1,440 cfm at 60 gpm; Column 2 - air/water ratio of 100 and air flow of 800 cfm at 60 gpm

Period of Operation:
Status: Ongoing
Report covers - 7/92 to 1/94

Cleanup Type:
Full-scale cleanup (interim results)

Cleanup Authority:
UST Corrective Action and
State: Virginia

Point of Contact:
Vern Bartels
Remedial Project Manager
Langley AFB

Purpose/Significance of Application:
Full-scale remediation of groundwater contaminated with fuel oil using a vacuum assisted well point extraction system and aboveground air stripping.

Type/Quantity of Media Treated:
Groundwater and Free Product

- Area of free product - about 600 ft. x 300 ft.; estimated volume of free product is 12,000 to 31,000 gallons
- Area of groundwater contamination - about 1,000 ft. x 2,000 ft.
- Properties of aquifer include pH (6.4 - 7.2), hydraulic conductivity (0.00099 - 0.002 ft/day), transmissivity (0.99 - 2.2 ft^2/day)

Regulatory Requirements/Cleanup Goals:

- Groundwater: BTEX - Benzene (1.4 ppb), Toluene (2 ppb), Ethylbenzene (1 ppb), Total Xylenes (3 ppb)
- Air Stripper Criteria for discharge: BTEX - Benzene (7 ppb), Toluene (50 ppb), Ethylbenzene (4.3 ppb), Total Xylenes (13 ppb), Lead (5.6 ppb) and TPH (1,000 ppb)
- Cleanup conducted under Virginia State Regulations and Federal Underground Storage Tank Regulations

Case Study Abstract

Pump & Treat of Contaminated Groundwater at Langley Air Force Base, Virginia (Continued)

Results:
As of 1/94:
- Floating product - appears to be largely unaffected at this time; no estimates of the amount of free product recovered are available at this time
- Air Stripper - average concentrations from air stripper are below discharge criteria

Cost Factors:
- Total Capital Costs - $569,739 (1992) (including demolition and excavation, system installation, startup, mobilization and site preparation)
- Annual Operating Costs - $216,561 (1993), $143,047 (1994) (including labor, materials, and equipment)
- An estimated total cost for completing the cleanup is not available at this time

Description:
Langley AFB has operated since 1916 as an aviation research and development facility. JP-4 fuel was stored in underground storage tanks and, in 1981, twenty-four 25,000-gallon underground fuel tanks and a fuel pipeline located at IRP Site 4 were determined to be leaking. In 1987, the tanks were abandoned by cleaning and sand-cement backfilling. Subsequent remedial investigation activities detected fuel contamination in soil and groundwater, including free product floating on the groundwater table at up to 1 foot in thickness. Primary contaminants of concern at the site are BTEX (benzene, toluene, ethylbenzene, and xylenes) and total petroleum hydrocarbons (TPH).

A groundwater pump and treat system consisting of a vacuum assisted well point extraction system, oil/water separators, and air strippers, began operating in July 1992 and was operational at the time of this report. Results to date indicate that, on average, the effluent concentration of BTEX, TRPH, and lead from the air stripper are below the discharge criteria. However, the layer of free product floating on the groundwater appears to be largely unaffected at this time. In addition, an estimate of free product recovered to date cannot be made since a sample port was not installed because of vacuum inlet conditions. It was noted that such sampling points are necessary to allow quantification of system performance.

The total capital costs for this application were about $569,700 and the annual operating costs for years 1993 and 1994 were about $216,600 and $143,000, respectively. Operational difficulties including problems with scaling, oil/water separator icing, and delays in acquiring spare parts have caused the system to be down about 51% of the time. In early 1994, adjustments to the system were made, including the use of chemical additives to prevent fouling of the system. It was noted that a roof over the treatment plant would have prevented weather-related damage and downtime (i.e., icing of oil/water separator).

TECHNOLOGY APPLICATION ANALYSIS

SITE

Langley Air Force Base
IRP Site 4
Langley AFB, Virginia

TECHNOLOGY APPLICATION

This analysis covers an effort to **pump and treat groundwater** contaminated with **JP-4 jet fuel** using a **vacuum assisted well point extraction system and above ground air stripping.** The treatment began in July 1992 and is currently ongoing. This analysis covers performance through January 1994.

SITE CHARACTERISTICS

Site History/Release Characteristics

- Langley AFB has been an aviation research and development establishment since 1916 and is the oldest continually active air force base in the U.S.
- IRP Site 4 contains twenty-four 25,000 gallon underground fuel tanks and a 6 inch JP-4 jet fuel pipeline. The tanks and pipeline were sources of leaks and were abandoned in 1987 by cleaning and sand-cement backfilling.
- Releases were first noted in 1981 and site characterization activities began in 1985. This technology application analysis presents data through January 1994 from ongoing treatment which began in July 1992.

Contaminants of Concern

The primary contaminant is JP-4 jet fuel whose principal constituents are:

Alkanes	61%
Cycloalkanes	29%
Alkylbenzenes	8%
Indans/tetralins	1.1%
Napthalenes	<1%

Indicator contaminants for the fuel mix are:

Benzene	(B)
Toluene	(T)
Ethylbenzene	(E)
Xylene	(X)

Site characterization also involved measurement of Total Recoverable Petroleum Hydrocarbons (TRPH) by EPA Method 418.1.

Contaminant Properties

Properties of contaminants focused upon during remediation are:

Property at STP*	Units	JP-4**	B	T	X***
Empirical Formula	-		C_6H_6	$C_6H_5CH_3$	$C_6H_4(CH_3)_2$
Density	g/cm^3	0.75	0.87	0.86	~0.87
Vapor Pressure	mmHg	91	95	28	10
Henry's Law Constant	$atm\,m^3/mole$	10E-4 to 10	5.6E-3	6.4E-3	7.0E-3
Water Solubility	mg/L	300	1750	535	198
Octanol-Water Partition Coefficient; K_{OW}	-	1E3 to 1E7	132	537	1830
Organic Carbon Partition Coefficient; K_{OC}	-	5E-6 to 240	83	300	240

**STP = Standard Temperature and Pressure; 1 atm, 25 °C*
*** Properties at 20°C ***Mixture of m,o and p-xylenes*

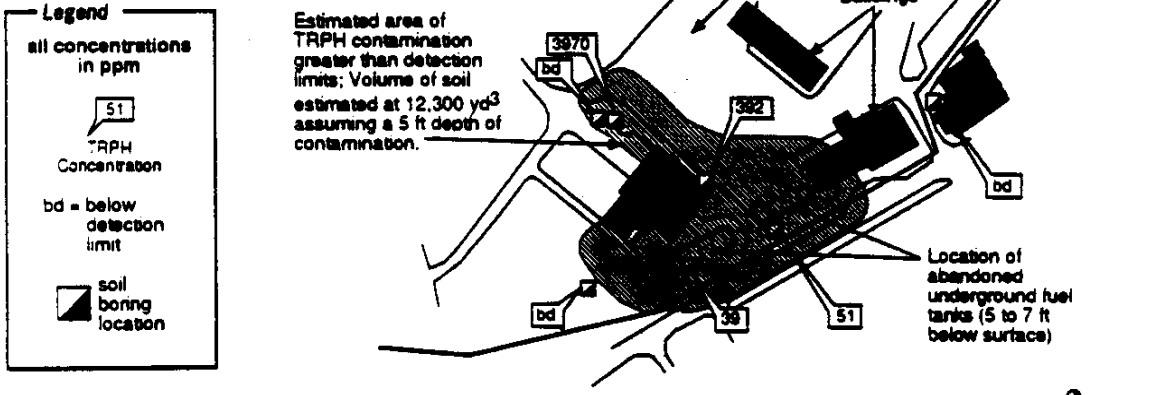
Nature & Extent of Contamination

- Fuels contamination is present in soil, as free product atop the groundwater table and dissolved in groundwater.
- Soil contamination appears to be limited to the area above the floating product and has exceeded 100 ppm TRPH in only one instance.
- Floating product has exceeded 1 foot in thickness in some locations. An oily sheen has been found in nearby estuaries.
- Significant groundwater contamination (25 to 4100 ppb TRPH) appears to be limited to locations directly beneath areas having a thick floating product layer.
- The lack of a significant groundwater gradient has minimized the potential for migration, however, underground utilities and original fuel containment facilities may have created preferential pathways for transport.

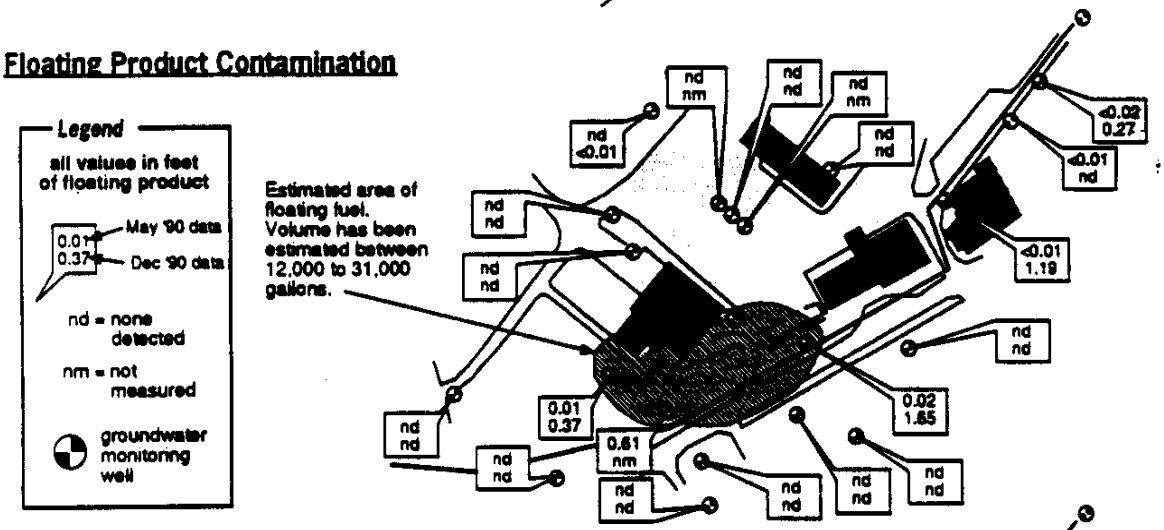
Contaminant Locations and Geologic Profiles

Remedial investigation field activities at the site have included soil and groundwater sampling and analysis, soil vapor analysis, geotechnical analyses and hydraulic conductivity measurements. Some of this data is included here to provide a general conceptual understanding of site conditions.

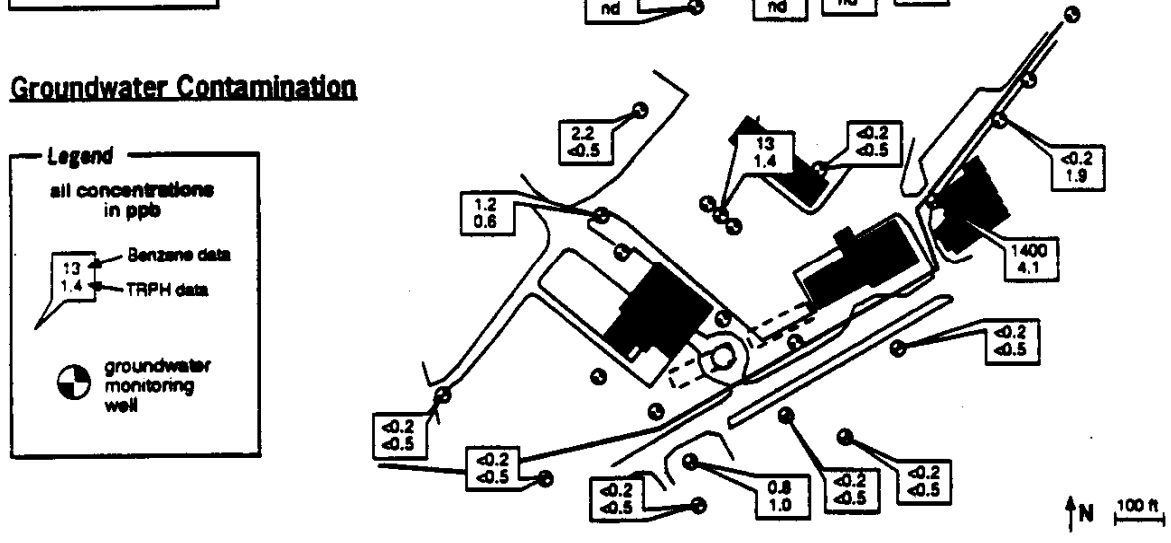
Soil Contamination & Site Layout



Floating Product Contamination

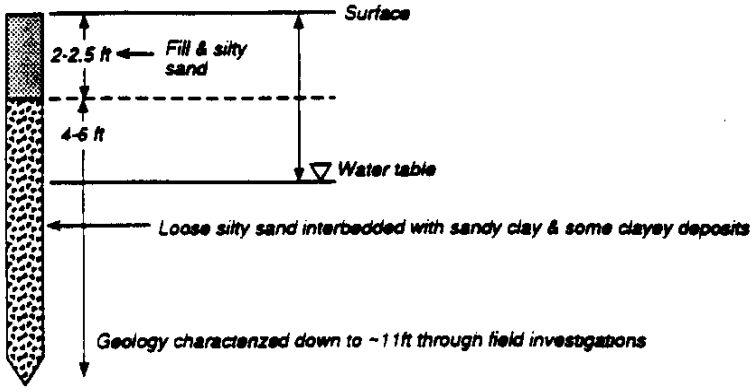


Groundwater Contamination



Contaminant Locations and Geologic Profiles (Continued)

Hydrogeologic Units



Site Conditions

- The topography of the base is very flat, showing little of no relief and ranging in elevation between 5 and 8 ft above MSL.
- Regional geology is that of an outer coastal plain characterized by a series of flat plains and intervening marine terraces.
- Land use in the nearby city of Hampton is primarily residential with 5% used by heavy or light industry. The base borders the highly environmentally sensitive Chesapeake Bay area.

Key Aquifer Characteristics

Soil Parameters (data taken from depths between 2 and 12 ft from six hand augered wells)

Property	Range
Size distributions (% passing #200 sieve)	17-28%
Liquid limits	35-39%
Plasticity index	7-11%
Water content	23.8-36.2

Groundwater Parameters (data taken during the development of six monitoring wells)

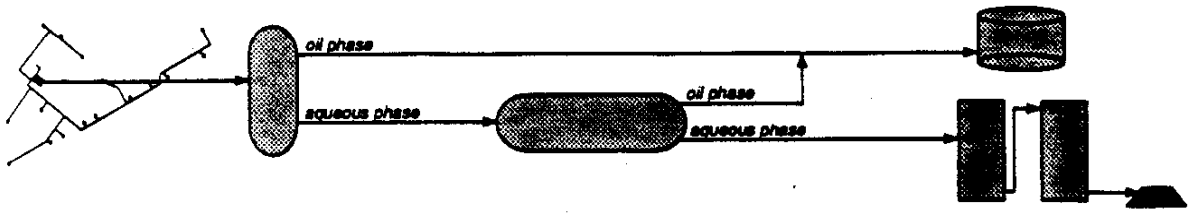
Property	Range	Comment
Specific conductance	600-700 umhos/cm	
Temperature	20-24°C	
pH	6.4-7.2	
Hydraulic conductivity	0.00099-0.002	Based on slug in/slug out Bouwer & Rice method tests performed with two wells (slug out data shown).
Transmissivity	0.99-2.2	

- The groundwater occurs in three aquifer systems (water table, upper artesian and principal artesian) within the coastal plain sediments.
- The water table aquifer, beginning at 4-6 ft below the surface, occurs within the fine sand, silts and shell beds of Pleistocene age and surficial sands of recent Holocene age.
- The upper and principal artesian aquifers begin at depths of approximately 400 and 700 ft respectively. These aquifers are assumed to be free of contamination and are not considered further in this analysis.
- Due to high chloride concentrations from salt-water intrusion, none of the aquifers beneath the base are used for drinking water supply. The water table aquifer, however, is an important source of domestic water supply for locations west of the base.

TREATMENT SYSTEM

Overall Process Schematic

Vacuum Extraction | **Separation** | **Treatment & Discharge**

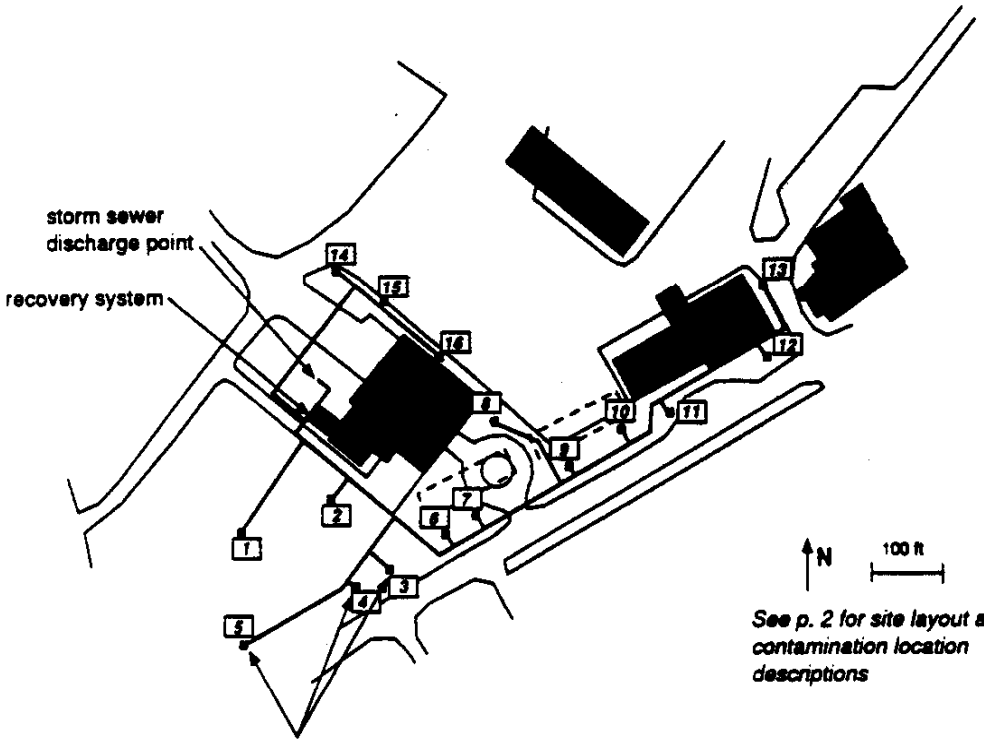


16 vacuum extraction wells are connected by a header pipe to a central vacuum system; initial separation occurs in a vacuum decanter
[detailed below and on next page]

A high efficiency oil/water separator provides a second level of oil removal
[detailed on next page]

- *Oil phase* - tank storage
- *Aqueous phase* - air stripping for a final level of VOC removal and permitted storm sewer discharge of treated effluent
[detailed on next page]

Vacuum Extraction Well Network

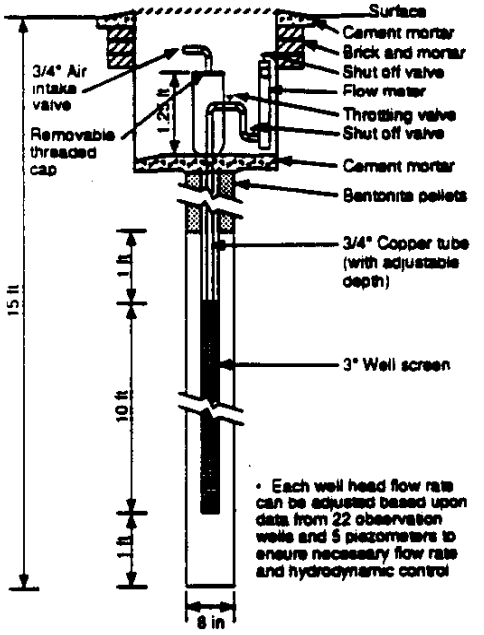


See p. 2 for site layout and contamination location descriptions

vacuum extraction wells;
each of the 16 vacuum extraction wells extends approximately 14 ft below the surface and draws an average of 2 GPM

Extraction Well Close-Up

Typical Vacuum Extraction Well



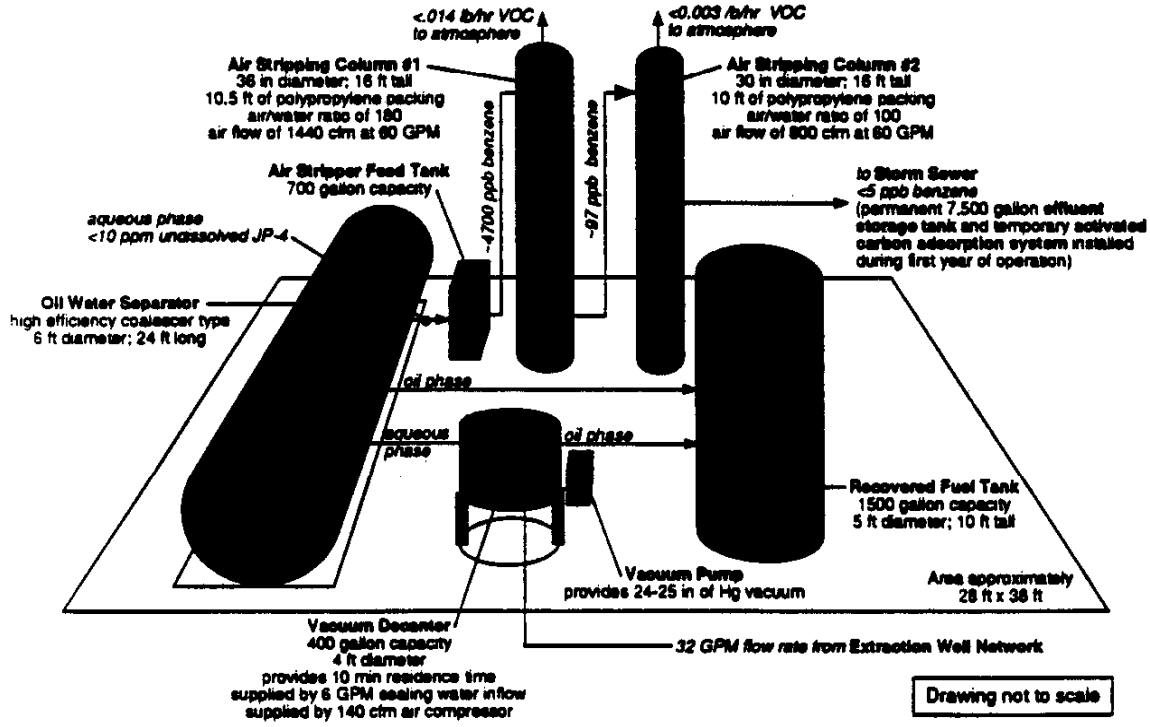
Key Design Criteria

- Maximum overlap of zones of influence of individual extraction wells within contaminated area
- Ability to create significantly increased oxygen levels in the vadose zone to enhance volatilization and biodegradation of residual soil contamination
- Ability to be installed without disturbing a complex network of existing underground utilities
- Treatment to satisfy Virginia Instream Values to allow for permitted storm sewer discharge (<5 ppb benzene from an influent of approximately 4700 ppb)
- Maximum flow of 60 GPM; Average flow of 32 GPM
- Series arrangement of air strippers for unobtrusive siting of treatment plant within air base facilities

Key Monitored Operating Parameters

- Extraction well flow rates
- Extraction well drawdown depths
- Monitoring well and piezometer location drawdown depths
- Flow to storm sewer
- Vacuum decanter vacuum pressure
- Recovered fuel tank level
- Contaminant concentrations in air stripper influent, air stripper effluent, between air stripper columns and in oil/water separator feed

Vacuum Extraction/Air Stripping Systems Schematic



PERFORMANCE

Performance Objectives

- Remove floating product atop groundwater to prevent further dissolution of contaminants (other criteria detailed in the Regulatory/Institutional section).
- Create a zone of capture that envelopes the floating product layer and prevents further migration.

Operational History

Initial operations in July 1992 resulted in discharge to the storm sewer of insufficiently treated contaminated groundwater. A notice of regulatory violation was imposed.

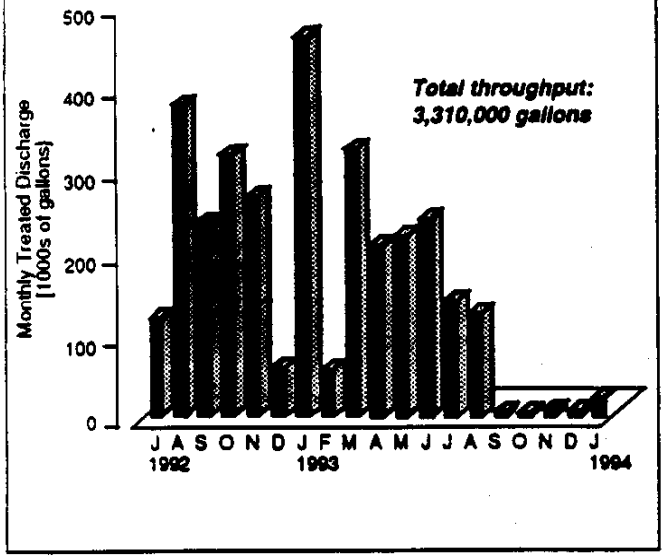
An effluent storage tank and carbon adsorption unit was procured to prevent future contaminated discharges.

Operational difficulties prevented sufficient continuous pumping to create an effective zone of capture. These difficulties are detailed below under System Downtime.

In early 1994, system adjustments permit continuous operation. These adjustments include the use of chemical additives to prevent system fouling. To date, performance data is insufficient to assess potential system effectiveness.

Operational Performance

System Throughput



System Downtime

During the period July 1992 through January 1994 the treatment system did not operate due to scheduled or forced downtime on **292 days (51% of all days)**. Causes of downtime included:

- Scaling deposits destroyed impellers, couplings and connectors on pumps. Pipe diameters have been reduced from buildup of deposits. The system was flushed and cleaned to remove iron, calcium silicate and bacterial slime buildup. A chemical additive (Betz Ente-320) was applied to recovery wells and proved effective at preventing further fouling.
- Oil/water separator icing during shut downs.
- Delays in acquiring spare pumps.
- Regulatory requirements calling for sampling of recovery wells mandated system shut down and disassembly of well extraction equipment.

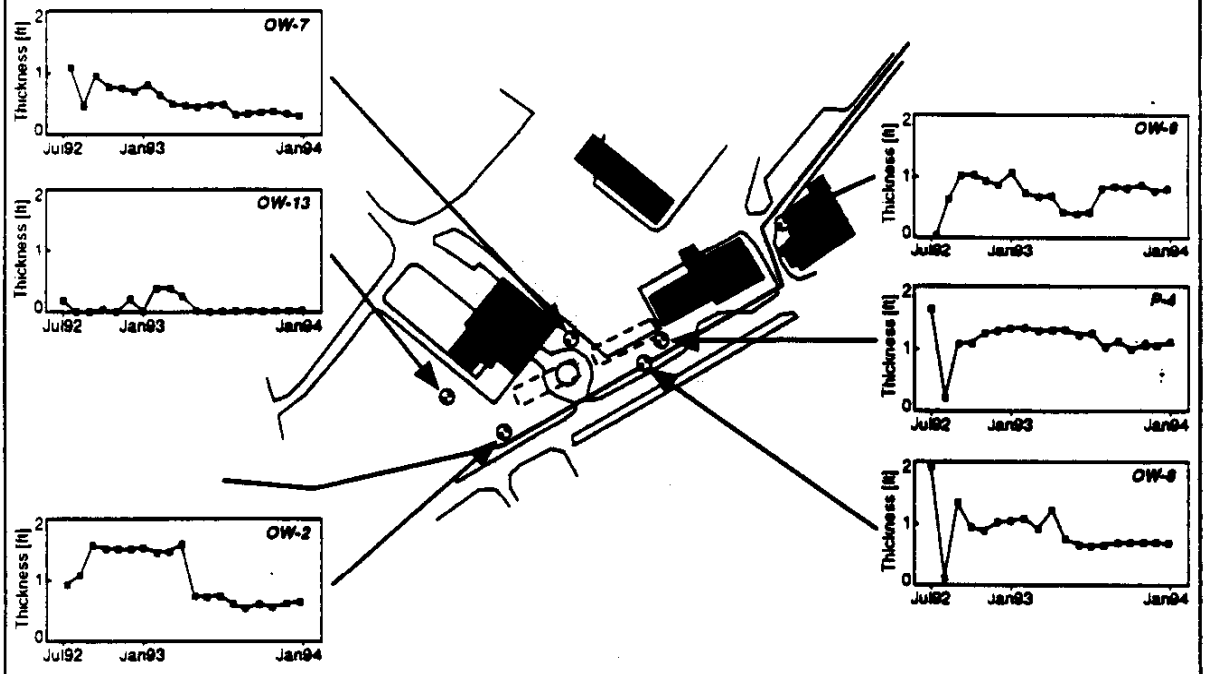
Hydrodynamic Performance

Quarterly prepared potentiometric maps of the surficial aquifer fail to indicate the influence of the treatment system to create a drawdown zone surrounding the contaminated region. Insufficient pumping duration appears to be the cause.

Treatment Performance

Effects on Floating Product Layer

Plots of floating product thickness over time at various wells containing the largest amount of fuel do not reveal overall trends. The floating layer appears largely unaffected to date.



Air Stripper Influent and Effluent

• All VOCs and targeted pollutants have been consistently treated below discharge criteria.

	Influent			Effluent		
Compound	Lo	Ave	Hi	Lo	Ave	Hi
Benzene	<5	<5	82	<5	<5	<5
Toluene	<5	<5	12	<5	<5	24
Ethylbenzene	<5	<5	150	<5	<5	<5
Xylenes	<5	<5	54	<5	<5	19
TRPH	-	-	-	<500	<500	1030
Lead	-	-	-	<1	<5	19

all concentrations in ppb

Free Product Recovered

• Currently there is no means to sample influent to the treatment system. No sample port was installed due to the vacuum inlet conditions.

• Negligible amounts of fuel have been observed in the recovered fuel tank.

COST

The U.S. Army Corps of Engineers Omaha District prepared a detailed cost estimate and specification for the treatment plant prior to procurement. That cost breakdown was pro-rated against the selected contractor's bottom-line price for system installation and start-up to arrive at the capital costs indicated below. Long-term operations and maintenance was procured via a lump-sum task order contracting mechanism. Initially estimated, contracted and final actual operating costs for the first few years of operation are presented below.

Capital Costs

Direct Costs	
Demolition & Excavation	$7,604
Horizontal Boring	5,661
Asphalt & Concrete	9,609
Screen Walls	33,560
Recovery Wells	49,403
Piezometers	8,674
Paint	593
Piping	54,537
Tanks/Equipment	111,961
Instrumentation	11,935
Electrical (Power, lighting and grounding)	24,377
Subtotal	317,914

Indirect Costs		
Mobilization & Site Preparation		21,748
Field Overhead		162,029
Other Overhead		34,048
	Subtotal	217,826
Start-up (First 90 days O&M)		34,000
	Total	**$569,739**

Operating Costs

	Year 1 (ending March 93)		Year 2 (ending March 94)		Year 3 (ending March 95)	
	Budget[a]	Actual	Budget[a]	Actual	Budget[a]	Actual
Labor	43,232	-	34,740	-	35,248	-
Materials	23,639	-	22,448	-	23,570	-
Equipment	38,535	-	2,268	-	2,365	-
Travel & Living Expenses	15,553	-	7,188	-	6,033	-
Overhead	46,916	-	34,881	-	34,965	-
Profit	9,851	-	7,339	-	7,452	-
Total	177,726	187,293[b]	108,864	112,112[b]	109,633	113,324[b]
Change Orders	0	29,268[c]	0	30,935[d]	0	Pending
Grand Total	**$177,726**	**$216,561**	**$108,864**	**$143,047**	**$109,633**	**Pending**

a - These initial budgeted amounts are taken from an Army Corps of Engineers estimate prepared in 1991 and are merely included to illustrate the probable breakdown of actual total costs among various cost elements.
b - The actual amounts are fixed priced task order sums taken agreed to by the O&M contractor
c - Necessary change orders in Year 1 included addition of an effluent storage tank and carbon adsorption unit to handle insufficiently treated flows during initial operation; system troubleshooting and optimization efforts; and laboratory analysis of effluent.
d - Necessary change orders in Year 2 included chemical flushing to remove iron, calcium and bacterial slime buildup throughout the system; analytical work; pump replacement; and oil water separator repairs.

REGULATORY/INSTITUTIONAL ISSUES

- The Corrective Action Plan was not approved by all necessary parties until well into the construction period of the system. Significant difficulties could have arisen if last minute objections were made.

- State approval of work plans significantly impacted the project schedule. Review periods over a year in duration occurred in some instances.

- To facilitate regulatory approval and maintain a project schedule, it was necessary to actively request face-to-face meetings to discuss work plans and treatment system design issues with approving agencies.

- Regulatory relief was successfully sought from the burden of sampling recovery wells in addition to monitoring wells and piezometers. Such sampling required dismantling and reassembly of recovery well apparatus.

- The treatment system was specially configured behind walls in a secure area to minimally impact operations and aesthetics at the active air base.

- Many specified materials were of foreign manufacture. Coordination with the Buy American Act was an issue.

- Cleanup was principally governed by Virginia State Regulations and Federal Underground Storage Tank Regulations 40CFR280.

Cleanup Criteria

- Concentrations of Total Petroleum Hydrocarbons in soil must be below 100 ppm in accordance with State of Virginia standards.

- Groundwater values must not rise above mean levels identified during site characterization efforts completed in 1991 of:

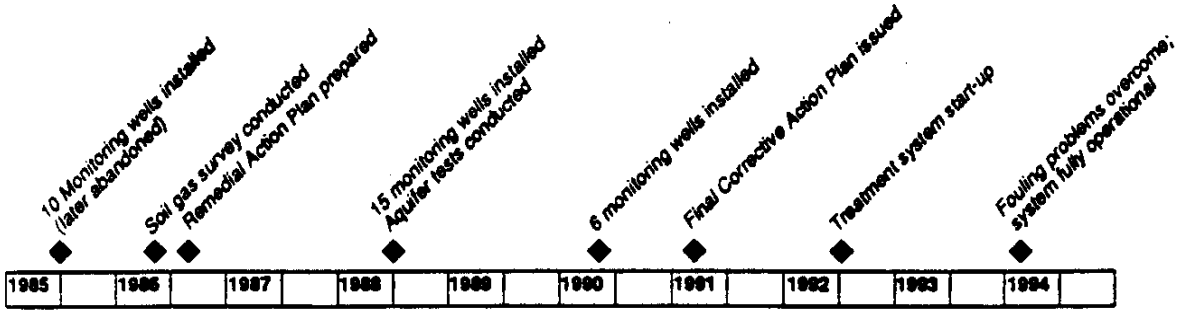
Compound	Criteria Level [ppb]	Compound	Criteria Level [ppb]
Benzene	1.4	Ethylbenzene	1
Toluene	2	Total Xylenes	3

- Virginia Instream Values were used as criteria for discharge of air stripper effluent:

Compound	Criteria Level [ppb]	Compound	Criteria Level [ppb]
Benzene	7	Total Xylenes	13
Toluene	50	Lead	5.6
Ethylbenzene	4.3	Petroleum Hydrocarbons	1000

SCHEDULE

Major Milestones



LESSONS LEARNED

Design Considerations

- Suction/vacuum pumps were designed to close to their limits at Langley to be dependable. These pumps experienced fouling and had to be replaced. Replacement parts were not readily available and spares should be specified for future systems.

- Heat tracing was inadequate and incomplete in the original design. The oil water separator experienced icing problems during periodic maintenance related shut downs.

- Sampling ports must be located at treatment plant influent to enable quantification of system performance.

- Controls must be readily accessible. At Langley, controls were located in a nearby secure area which made access more difficult.

- Operating contractor's offices must be adequately planned especially in instance where field analytical equipment requires special housing.

- The exhaust pipe on the oil water separator deflected excessively and allowed gases to be released. Adequate height and stability must be addressed in future designs for this element.

- A roof over the treatment plant would have prevented weather related damage and downtime.

- Recovery wells should be designed to allow cleaning and other maintenance without complete disassembly.

Implementation Considerations

- The Corrective Action Plan for the site must be approved by all necessary parties, in writing, in a timely manner before significant construction and design efforts are underway. Lengthy reviews of work plans impacted project schedules at Langley.

- Butt fusion welding proved to be highly expensive. An alternative method should be specified to address added connections or other system design changes in the field.

- Significant attention must be payed to early identification and prevention of conditions which may cause system fouling. Scaling of calcium silicate, iron and bacterial slime destroyed pump internals and reduced interior diameters of pipes. System flush outs and chemical additives to recovery wells were used to combat the problem.

- Recovery wells need to be periodically redeveloped.

Technology Limitations

- In this instance, a continuing series of operation problems prevented long term operation sufficient to create a zone of influence to capture and treat floating product atop the groundwater.

- Assessment of system performance was further complicated by inadequate ability to sample treatment plant influent.

Future Technology Selection Considerations

- Application of vacuum assisted pump and treat with above ground air stripping at Langley has not provided sufficient data to date to allow generalized conclusions to be made concerning the suitability of the technology at Langley or other potential locations. Much experienced has been obtained, however, on design and implementation issues involved in assuring continuous system operation. Operational difficulties have only recently been overcome at Langley and future performance data should provide a better understanding of its remediation effectiveness.

ANALYSIS PREPARATION

This analysis was prepared by:

Stone & Webster Environmental
Technology & Services

245 Summer Street
Boston, MA 02210
Contact: Bruno Brodfeld (617) 589-2767

CERTIFICATION

This analysis accurately reflects the performance and costs of the remediation:

x _____

Vern Bartels
Remedial Project Manager
Langley AFB

SOURCES

Major Sources For Each Section

Site Characteristics:	Source #s (from list below) 2, 3 and 6
Treatment System:	Source #s 1, 4, 5 and 7
Performance:	Source #s 1 and 2
Cost:	Source #s 1 and 3
Regulatory/Institutional Issues:	Source #s 1, 3 and 6
Schedule:	Source #s 1, 2, 3 and 6
Lessons Learned:	Source #s 1, 3 and personal communications with Eric Anthony Arndt, Deputy Area Engineer, Langley Resident Office, Norfolk District, Army Corps of Engineers (804) 764-2941

Chronological List of Sources and Additional References

1. Data package provided by Eric Anthony Arndt, Deputy Area Engineer, Langley Resident Office, Norfolk District, Army Corps of Engineers, March 28, 1994.

2. Data package provided by Eric Anthony Arndt, Deputy Area Engineer, Langley Resident Office, Norfolk District, Army Corps of Engineers, February 8, 1994.

3. Data package provided by S.L. Carlock, Chief, Environmental Branch, Engineering Division and Paul Dappen, Technical Manager, Army Corps of Engineers, Omaha District, November 16, 1993.

4. *Operations and Maintenance Manual (Pre-Final), for Installation Restoration Program - Site No. 4 Langley Air Force Base, Virginia*, prepared for U.S. Army Corps of Engineers, Omaha District, August 1991.

5. *Final Specifications, for Installation Restoration Program - Site No. 4 Langley Air Force Base, Virginia*, prepared for U.S. Army Corps of Engineers, Omaha District, August 1991.

6. *Final Corrective Action Plan for IRP Site 4, Langley Air Force Base, Virginia*, prepared by Law Environmental, prepared for U.S. Army Corps of Engineers, Omaha District, February 1991.

7. *Specifications (For Construction Contract) Solicitation No. DACA45 90 B 0088, Installation Restoration Work, IRP Site 4, Langley AFB, Virginia*, U.S. Army Corps of Engineers, Omaha District, July 1990.