Case Study Abstract

Density-Driven Groundwater Sparging at Amcor Precast, Ogden, Utah

Site Name:
Amcor Precast

Location:
Ogden, Utah

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

Groundwater
- Average groundwater concentrations (mg/L) in plume area/site maximum - TPH (51/190), benzene (1.3/4.7), toluene (2.4/9.4), ethylbenzene (0.78/2.7), total xylenes (2.5/8.0), naphthalene (0.18/0.63)

Soil
- Average soil concentrations (mg/kg) in plume area/site maximum - TPH (555/1,600), benzene (2.0/7.8), toluene (1.4/2.5), ethylbenzene (5.7/19), total xylenes (37/110)

Period of Operation:
March 1992 to September 1993

Cleanup Type:
Full-scale cleanup

Vendor:
Todd Schrauf
Wasatch Env., Inc.
2251B West California Ave.
Salt Lake City, UT 84104
(801) 972-8400

SIC Code:
Not Available

Technology:
In situ Density-Driven Groundwater Sparging and Soil Vapor Extraction
- System consists of three main components - groundwater sparging system; groundwater recirculation system; and soil vapor extraction system
- Groundwater sparging was principal method of remediation; SVE was used locally

Sparging System
- Density-driven groundwater sparging - removed petroleum hydrocarbons using (1) aerobic degradation and (2) in situ air stripping; water inside the wellbore was aerated directly by injecting air at the base of the wellbore
- 12 groundwater sparging wells installed to a depth of 18 feet

Groundwater Recirculation
- 3 downgradient extraction (pumping) wells installed to a depth of 20 feet and 1 upgradient injection galley (former tank excavation backfilled with pea gravel)

SVE
- 3 vertical extraction wells located adjacent to the pumping wells
- Vapor discharged to atmosphere

Cleanup Authority:
State: Utah Department of Environmental Quality, Division of Response and Remediation (DERR)

Point of Contact:
Shelly Quick
Utah DERR

Waste Source:
Underground Storage Tanks

Type/Quantity of Media Treated:
Groundwater and Soil
- Site stratigraphy - interbedded silty sand and poorly graded fine gravel underlain by a silty clay aquitard at a depth of approximately 18 feet below ground surface
- Depth to groundwater - 5 to 11 feet; aquifer thickness (7-13 feet)
- Porosity (20-35%), hydraulic conductivity (190 ft/day)
- Aerial extent of the plume - approximately 30,000 ft^2; vertical extent of contamination - contaminants concentrated in vertical zone from approximately 5 to 11 feet below ground surface
- Estimated volume of contaminated soil - 7,000 yd^3

Purpose/Significance of Application:
Full-scale remediation of groundwater contaminated with diesel and gasoline fuels using in situ density-driven groundwater sparging and soil vapor extraction.

Density-Driven Groundwater Sparging at Amcor Precast, Ogden, Utah (Continued)

Regulatory Requirements/Cleanup Goals:
- Soil - DEQ Recommended Cleanup Levels (RCLs) - TPH - 30 mg/kg; Benzene - 0.2 mg/kg; Toluene - 100 mg/kg; Ethylbenzene - 70 mg/kg; Xylenes - 1,000 mg/kg; Naphthalene - 2.0 mg/kg
- Groundwater - BTEX and naphthalene to below MCLs; no cleanup goal for TPH in groundwater
- Air - no air discharge permit was required because air emissions were below de minimis standards of the Utah Division of Air Quality

Results:
- The cleanup goals were achieved for all contaminants of concern in both soil and groundwater

Cost Factors:
- Total Capital Cost: $156,950 (including drill/install wells and sparging system, start-up, project management)
- Total Annual Operating Cost: $62,750 (including electricity, maintenance, monitoring)

Description:
Amcor Precast in Ogden, Utah, stored gasoline and diesel fuel in three underground storage tanks. A release was discovered in 1990. An investigation in 1991 indicated that the areal extent of groundwater contamination was approximately 30,000 ft^2 and that an estimated 6,700-7,000 yd^3 of soil had been contaminated. The primary contaminants of concern were benzene, toluene, ethylbenzene, and xylenes (BTEX), naphthalene, and total petroleum hydrocarbons (TPH). A density-driven groundwater sparging system and soil vapor extraction (SVE) system were installed in January/February 1992 and operated from March 1992 to September 1993. The sparging system was used as the primary remediation technology. SVE was used locally to treat volatilized hydrocarbons, created by the air stripping process, and prevent contaminants from migrating to nearby office buildings.

With the density-driven groundwater sparging system at Amcor, water inside the wellbore was aerated by injecting air into the base of the wellbore (rather than injected under pressure) with the resulting injection air bubbles stripping contaminants from the water while increasing the dissolved oxygen content. In addition, the aeration process acted to create groundwater circulation and transport. Therefore, with this system, petroleum hydrocarbons were removed from the subsurface by (1) aerobic biodegradation resulting from the supply of oxygen to the saturated zone; and (2) in situ air stripping. The air stripped vapors are transferred to the vadose zone and are biodegraded in place. The application of density-driven groundwater sparging and SVE achieved the specified cleanup goals for both soil and groundwater. The cleanup goals for soil and for all contaminants except naphthalene in groundwater were achieved within 11 months of system operation. The cleanup goal for naphthalene in groundwater was achieved within 18 months.

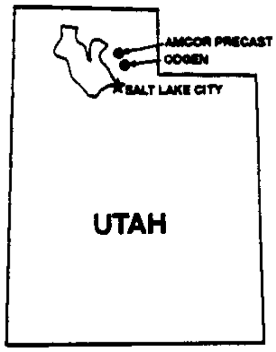
The total capital cost for this application was about $157,000 and total annual operating costs were $62,750. Air sparging is limited to contaminants that can be degraded by indigenous bacteria under aerobic conditions. Maximum sparging well air flow and groundwater wellbore circulation rates are dependent on well diameter, depth to groundwater, and the hydraulic conductivity of the formation. Therefore, longer remediation times or a greater number of sparging wells may be required in lower permeability formations.

TECHNOLOGY APPLICATION ANALYSIS

SITE

Name: Amcor Precast

Location: Ogden, Utah (directly adjacent and south of Ogden Defense Depot)



TECHNOLOGY APPLICATION

This summary addresses the field application of density-driven groundwater sparging for the *in situ* remediation of an underground storage tank release of diesel and gasoline fuels. The system was started up in March, 1992 and remediation completed in September, 1993.

SITE CHARACTERISTICS

Site History/Release Characteristics

- Amcor Precast operated three underground storage tanks at the site, used for the storage of unleaded gasoline, leaded gasoline, and diesel fuel, respectively.
- The release was discovered when the underground storage tanks were removed for permanent closure in December, 1990. The volume of the release is unknown. The exact cause of the release is also unknown, although laboratory analysis of contaminated soils from the tank excavation indicated the release consisted primarily of gasoline, with minor amounts of diesel.
- At the time of discovery and investigation (1991), the spill had an areal extent of approximately 30,000 ft^2 and had impacted an estimated soil volume of 6,700 yd^3.
- The remedial system was installed in January and February of 1992. The system was placed in to operation in March of 1992. The remediation was completed in September of 1993.

Contaminants of Concern

- The contaminants of concern were the aromatic hydrocarbons: benzene, toluene, ethylbenzene, total xylenes, and naphthalene as well as total petroleum hydrocarbons (TPH)

TABLE 1: CONTAMINANT PROPERTIES						
Property	Units	Benzene	Ethylbenzene	Toluene	o.m.p-Xylene	Naphthalene
Empirical Formula		C_6H_6	C_8H_{10}	C_7H_8	C_8H_{10}	$C_{10}H_8$
Density @ 20°C Melting Point	gm/cm^3 °C	0.88 5.5	0.87 -95	0.87 -95	0.86 to 0.88 -47.9 to 13.3	1.16 80.5
Boiling Point	°C	80.1	136.2	110.6	138.3 to 144.4	217.9
Vapor Pressure (25°C)	mm Hg	95	10	31	6.6 to 8.8	0.23, 0.87
Vapor Density (25°C)	g/L	3.19	4.34	3.77	4.34	
Henry's Law Constant	atm-m^3/mol	5.4 x 10^{-3}	0.0064 to 0.0087 (avg. 0.0072)	0.0067	0.0050 to 0.0071	0.00036 to 0.0012 (avg. 0.00061)
Water Solubility (25°C)	mg/1	1696 to 1860 (avg. 1770)	131 to 206 (avg. 174)	492 to 627 (avg. 545)	156 to 204	20.3 to 40.0 (avg. 31.0)
Octanol-Water Partition Coefficient (K_{ow})		36 to 141 (avg. 110)	1120 to 1410 (avg. 1290)	129 to 631 (avg. 417)	589 to 1580	1020 to 50,100 (avg. 2560)
Organic Carbon Partition Coefficient (K_{oc})	ml.gn	49 to 100 (avg. 81)	95,257	114,151	129 to 1580	550 to 3310 (avg. 1550)
Ionization Potential Molecular	eV gms	9.25, 9.56 78.11	8.76, 9.12 106.17	8.82 92.14	8.44 to 8.58 106.17	8.14, 8.26 128.18

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Nature and Extent of Contamination

Site investigations were conducted during the first eight months of 1991 to define the extent of soil and groundwater contamination. These investigations included soil gas surveys, drilling and sampling of soil borings, and monitor well installation and sampling. Sampling locations and plume extent are shown in Figure 1. The maximum and average concentrations of the contaminants of concern are identified in Table 2 for both soil and groundwater. Average groundwater concentrations are based on samples collected from wells MW-3, MW-4, MW-5, and MW-7, all located along the centerline of the contaminant plume. Average soil concentrations are based on samples collected from BH-3, BH-13, BH-14, and MW-5, also all located within the center of the plume. The aerial extent of the plume was approximately 30,000 ft^2. The volume of contaminated soil was estimated at 7,000 yd^3.

TABLE 2: SUMMARY OF PRE-REMEDIIATION CONTAMINANT CONCENTRATIONS						
Contaminant of Concern	Soil Concentrations (mg/kg)			Groundwater Concentrations (mg/l)		
	Site Maximum	Average in Plume Area	Cleanup Goal (RCL's)	Site Maximum	Average in Plume Area	Cleanup Goal (MCL's)
TPH	1600	556	30	190	51	Not Established
Benzene	7.8	2.0	0.2	4.7	1.3	0.005
Toluene	2.5	1.4	100	9.4	2.4	1.0
Ethylbenzene	19	5.7	70	2.7	0.78	0.7
Total Xylenes	110	37	1000	8.0	2.5	10
Naphthalene	Not Measured	Not Measured	2.0	0.63	0.18	0.020

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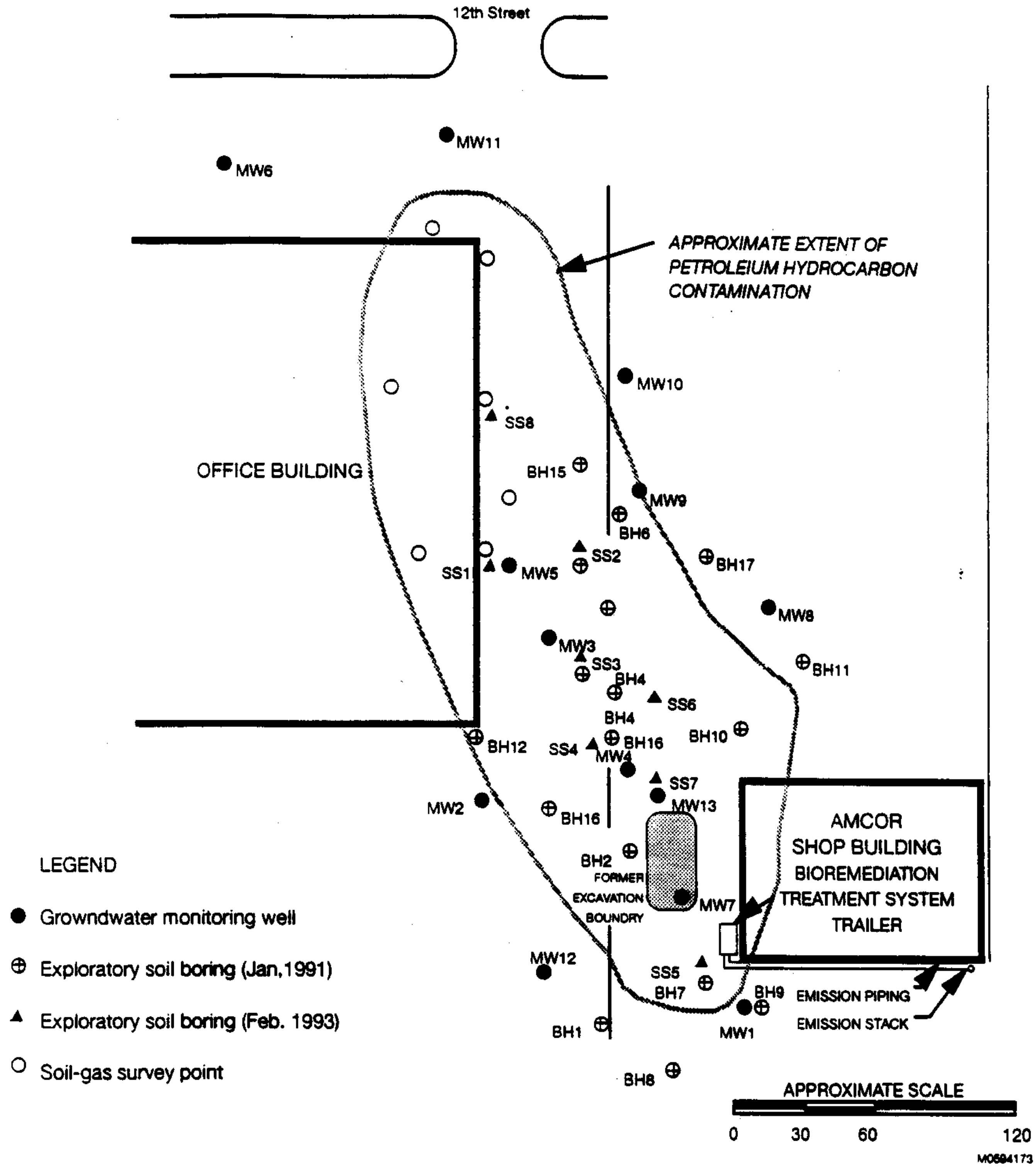

FIGURE 1. SAMPLING LOCATIONS AND PLUME EXTENT, AMCOR PRECAST

Contaminant Locations and Geologic Profiles

The distribution of dissolved groundwater contamination is presented in Figure 1. Contaminants were concentrated within a vertical zone from about 5 to 11 feet below ground surface. The site stratigraphy consisted of interbedded silty sands (SM) and poorly graded fine gravel (GP) underlain by a silty clay (CL) aquitard at a depth of about 18 feet below ground surface.

Site Conditions

- The area has an arid climate with an average ambient temperature of 58°F. The average minimum temperature is 22°F, and the average maximum temperature is 85°F.
- Precipitation averages approximately 20 inches per year, most of which occurs during the winter months.
- The direction of shallow groundwater flow is to the north-northwest.
- The elevation of the site is approximately 4260 feet above mean sea level. The site topography is flat.

Key Soil or Key Aquifer Characteristics

Key soil and groundwater parameters are presented in Table 3.

TABLE 3: KEY SOIL AND GROUNDWATER PARAMETERS

Parameter	Units	Range or Value	Comments
Soil Parameters (Prior to System Startup)			
Porosity	%	20 to 35	Estimated
Particle Density	g/cm^3	2.6 to 2.7	Estimated
Soil Bulk Density	g/cm^3	1.7 to 2.1	Estimated
Aquifer Thickness	ft	7 to 13	
Hydraulic Conductivity	ft/day	190	
Total Heterotrophic Bacteria	cfu/gm	9,300 to 3,000,000	
Total Hydrocarbon Degrading Bacteria	cfu/gm	<100 to 53,000	
Growndwater Parameters (Prior to System Startup)			
Depth to Groundwater	ft	5 to 11	Highest water table in July lowest in January
Dissolved Oxygen	mg/l	0.03 to 1.7	Background
Biological Oxygen Demand	mg/l	5.8 to 90	Proportional to contaminant level
Chemical Oxygen Demand	mg/l	9 to 300	Proportional to contaminant level
NO_3	mg/l	<0.001	
Total PO_4	mg/l	0.18 to 1.3	
TKN	mg/l	0.52 to 1.9	
TDS	mg/l	660 to 700	
Total Heterotrophic Bacteria	cfu/ml	750 to 37,000	
Total Hydrocarbon Degrading Bacteria	cfu/ml	<100 to 7,500	

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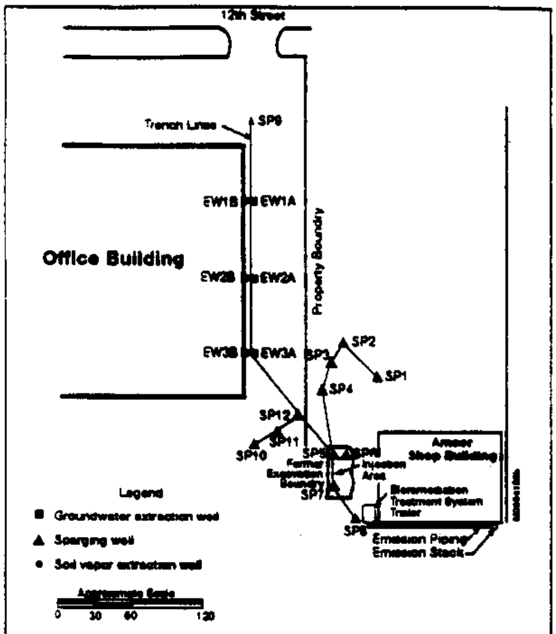
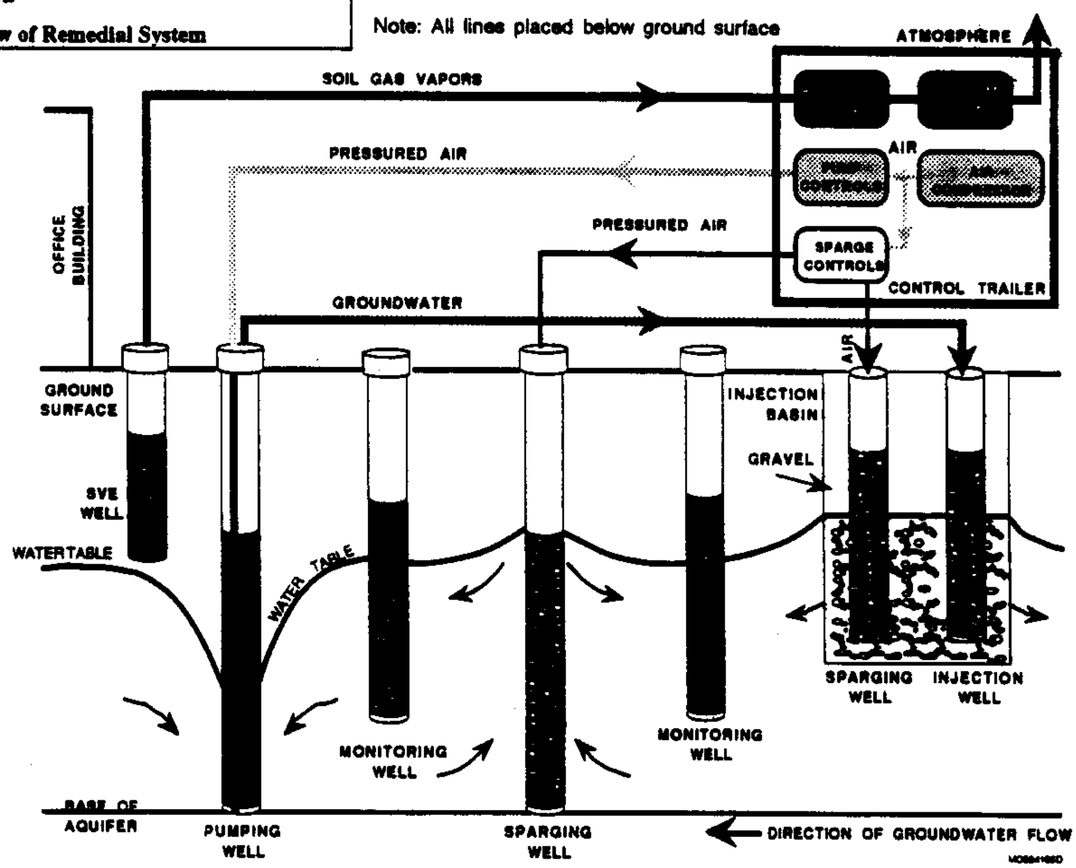
TREATMENT SYSTEM

The overall process schematic, as well as a plan view of the remedial system is presented in Figure 2 below.



Plan View of Remedial System

Figure 2. Plan View and Process Schematic Amcor Precast



Process Schematic

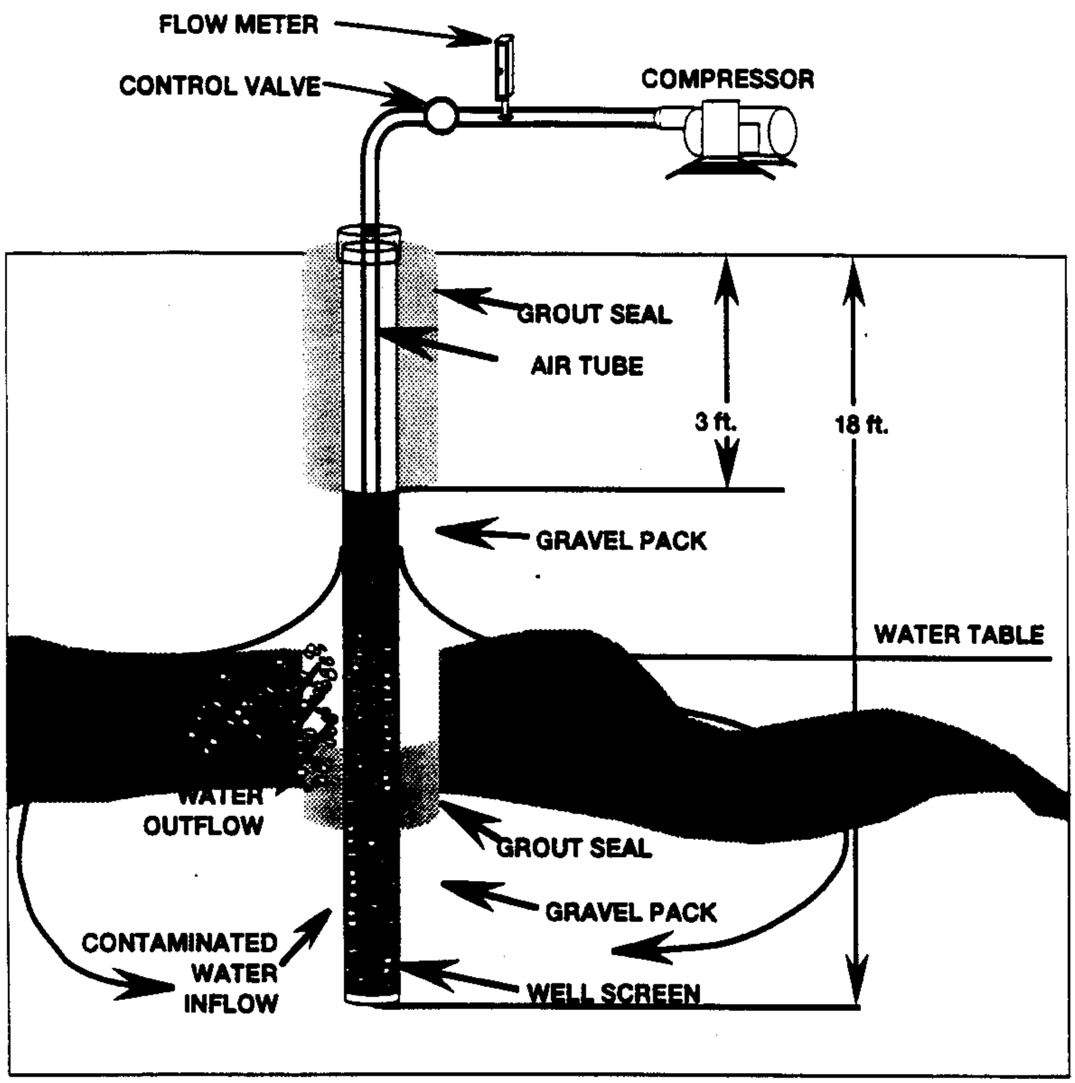


FIGURE 3. DIAGRAM OF DENSITY DRIVEN SPARGING WELL CONSTRUCTION

System Description

The system consists of three principal components: 1) a groundwater sparging system; 2) a groundwater recirculation (pumping) system; and 3) a soil vapor extraction system

- In general, groundwater sparging was the principal method of groundwater remediation employed.
- The density-driven convection system (patent pending) does not attempt to inject air into the soil pore space under pressure like a conventional air sparging system, thereby avoiding the disadvantages of pressurized injection. Instead, water inside the wellbore is aerated directly by injecting air at the base of the wellbore. As show in Figure 3 a grout seal prevents the air from escaping immediately into the formation. The injection air bubbles rise upward in the wellbore, creating a turbulent frothing action. The rising air bubbles airstrip contaminants from the water and increase dissolved oxygen content of the water (to about 10 mg/l). The aeration process also acts as a groundwater pump, pushing aerated water upward through the wellbore and out the upper well screen and drawing resident groundwater from the surrounding aquifer into the base of the well screen thus creating groundwater circulation and transport. The result is a simple small-diameter installation that is virtually maintenance free.

- Density-driven groundwater sparging removes petroleum hydrocarbons from the subsurface by two methods: aerobic biodegradation and *in situ* air stripping.
- The technology promotes aerobic biodegradation by supplying oxygen to the saturated zone via circulation of oxygenated groundwater and to the unsaturated zone via circulation of air.
- The technology promotes *in situ* air stripping by transferring dissolved contaminants from groundwater circulated through the wellbore to air bubbled upwards within the wellbore. Air stripped vapors are transferred to the vadose zone where they are biodegraded in place.
- Soil vapor extraction was used locally to protect against volatilized hydrocarbons created by the air stripping process from entering neighboring office buildings.
- Groundwater was extracted along the downgradient plume boundary and reinjected upgradient (without surface treatment) to prevent further downgradient migration of hydrocarbons below neighboring office buildings.
- The groundwater sparging system consisted of twelve groundwater sparging wells (labeled SP in Figure 2) installed to a depth of 18 feet and connected to a pressurized air supply source via underground lines. Each well was provided with a separate air injection line with flow control and meter at the air supply source.
- The groundwater recirculation system consisted of three downgradient groundwater extraction or pumping wells (labeled EWA in figure 3) installed to a depth of 20 feet and one upgradient injection gallery (former tank excavation backfilled with pea-gravel). Pressurized air supply lines for powering the extraction pumps and water lines for conducting pump discharge to the injection gallery were placed below ground. Pump controls were located at the air supply source.
- The soil vapor extraction system consisted of three vertical vapor extraction wells (labeled EWB in Figure 2) located adjacent to the downgradient pumping wells. The vapor extraction wells are connected to a knock-out tank and regenerative vacuum blower motor via underground lines. Vapors were discharged to the atmosphere via a 35-foot high emissions stack
- Pressurized air for the sparging wells and extraction pumps was supplied by a 36 cfm air compressor. The compressor, vacuum blower for vapor extraction, and associated controls were placed in a portable trailer at the site.

System Operation

- Pressurized air was introduced into the base of each sparging well via the provided air injection tube. Flow rate was controlled at the air supply source. Injected air served to create the driving force for groundwater circulation through the well; increase dissolved oxygen content of water circulated through the well to promote biodegradation in the saturated zone; transfer volatile constituents dissolved in the groundwater to the vadose zone soil gas; and provide oxygen to the vadose zone to promote biodegradation in the vadose zone.
- Pressurized air was also supplied via underground lines to operate the pneumatic groundwater extraction pumps. Extracted groundwater was delivered to the injection gallery without surface treatment. Downgradient extraction was used to prevent further downgradient migration of dissolved hydrocarbons beneath the adjacent office building.
- A vacuum draw was applied to the vapor extraction wells via underground lines attached to a vacuum blower motor. The withdrawn vapor mass was sufficiently low that direct discharge to the atmosphere was allowed. Removal of vapors from the downgradient extraction wells was used to prevent potential migration of product vapors into the neighboring office building. Detectable emissions of petroleum hydrocarbons were not measured after 60 days of system operation.

Closeup of Sparging Well Construction

The sparging well construction is shown in Figure 3 . Each sparging well was installed to a depth of 18 feet below ground surface and screened from 3 to 18 feet. The well casing consisted of schedule 40 PVC flush-coupled well casing and 0.02-inch slotted screen. Air was injected at the base of the well via 3/8-inch diameter plastic tubing.

Key Design Criteria

The key design criteria were as follows:

- Presence of site structures including an office building owned by the neighboring land owner requiring an *in situ* remediation strategy with minimal disturbance to site occupants.
- Elimination of potential product vapor migration into neighboring office building during system operation.
- Control of further downgradient migration of dissolved hydrocarbon plume beneath adjacent office building.
- Sensitivity of neighboring land owner to potential office tenant loss.
- Cost minimization for remedial system installation and operation.

Key Monitored Operating Parameters

System monitoring consisted of the following:

- Collection of air samples from the venting emissions stack and laboratory analysis for Total Petroleum Hydrocarbons (TPH) and Benzene, Toluene, Ethylbenzene, Xylene, and Naphthalene (BTEXN).
- Collection and field analysis of soil gas samples from the vadose zone (plume area and background) for carbon dioxide and oxygen.
- Measurement of field parameters for each monitoring well including water elevation, temperature and dissolved oxygen.
- Collection of groundwater samples from selected monitoring wells and laboratory analysis for TPH and BTEXN.

Monitoring was performed on a weekly basis for the first two months of system operation and monthly thereafter. Confirmatory soil sampling was conducted after eleven months of system operation to evaluate residual soil concentrations.

PERFORMANCE

Performance Objectives

- Reduce TPH and BTEXN concentrations in the site soils to below RCLs established by the Utah Department of Environmental Quality (shown in Table 4). Soil cleanup goals were based on Division of Environmental Response and Remediation recommended cleanup levels (RCLs) with a Level I (most sensitive) environmental sensitivity.
- Reduce TPH and BTEXN concentrations in the site groundwater to below federal MCLs (shown in Table 4). Adopted from the Clean Water Act. No cleanup goals exist for TPH.
- Maintain control over vapor and dissolved phase petroleum product migration.

Treatment Plan

- Maintain groundwater sparging system operation to provide oxygen to promote aerobic biodegradation of petroleum hydrocarbons.
- Maintain downgradient groundwater extraction to prevent further downgradient migration of dissolved petroleum hydrocarbons.
- Maintain downgradient vapor extraction to prevent potential product vapor migration into neighboring office building.
- Evaluate effectiveness of biodegradation by monitoring changes in dissolved hydrocarbon contaminants and bacterial activity. This activity was indicated by dissolved oxygen contents, vadose zone soil gas carbon dioxide and oxygen contents, and bacterial plate counts in groundwater.
- Evaluate effectiveness of plume containment by monitoring downgradient concentrations of dissolved petroleum hydrocarbons.
- Evaluate effectiveness of vapor migration containment by monitoring vapor extraction system emissions and petroleum vapor concentrations in neighboring office building.
- Monitor vapor emissions during system operation to verify compliance with de minimus air emissions standards established by the Utah Division of Air Quality.

Operational Performance

- Concentrations of all of the contaminants of concern were monitored in groundwater and soil to evaluate system performance.
- The following operational performance criteria were maintained during system operation:
  - Sparging well air injection rates maintained at between 60 and 100 scfh.
  - Total groundwater extraction rate (combined flow from all three extraction wells) at 10 gpm .
  - Total soil vapor extraction rate at 70 to 90 scfm.

Cumulative flow was not measured or calculated for system operation.

System inspections and maintenance were conducted at weekly intervals during system operation. The Remediation Conductor estimates that the air compressor used for sparging well and pump operation was operational over 90 percent of the system operational life. He also estimates that the vacuum blower used for vapor extraction was operational over 95 percent of the system operational life.

System downtime was attributed to the following factors:

- Two mechanical compressor failures resulting in two downtime periods of approximately of one week. A pressure modulator was subsequently installed to prevent compressor cycling to reduce compressor wear and to maintain a more constant pressure supply.
- One pneumatic pump control repair (level controls and filter replacement) resulting in downtime of approximately one week.
- Two infiltration basin overflows (three and twelve months after system startup) due to biomass buildup within the injection gallery backfill resulting in downtime of 2 to 3 days for each event.
- Several water knockout tank overfills triggering automated shut-off of the venting system, resulting in downtime of 2 to 3 days for each event.

TREATMENT PERFORMANCE

Vadose Zone Monitoring

- Measured carbon dioxide and oxygen concentrations within the vadose zone remained relatively constant thoughout the first 100 to 150 days of operation, but declined to background levels about 250 days after startup (Figure 5). These data indicate that biological activity was present within the vadose zone through 250 days of operation.
- Measured air emissions from the soil venting system declined rapidly during the initial 60 days following system start-up (Figure 6). These data indicate that physical removal of contamination through vapor extraction was not a primary mechanism in the remedial system operation.

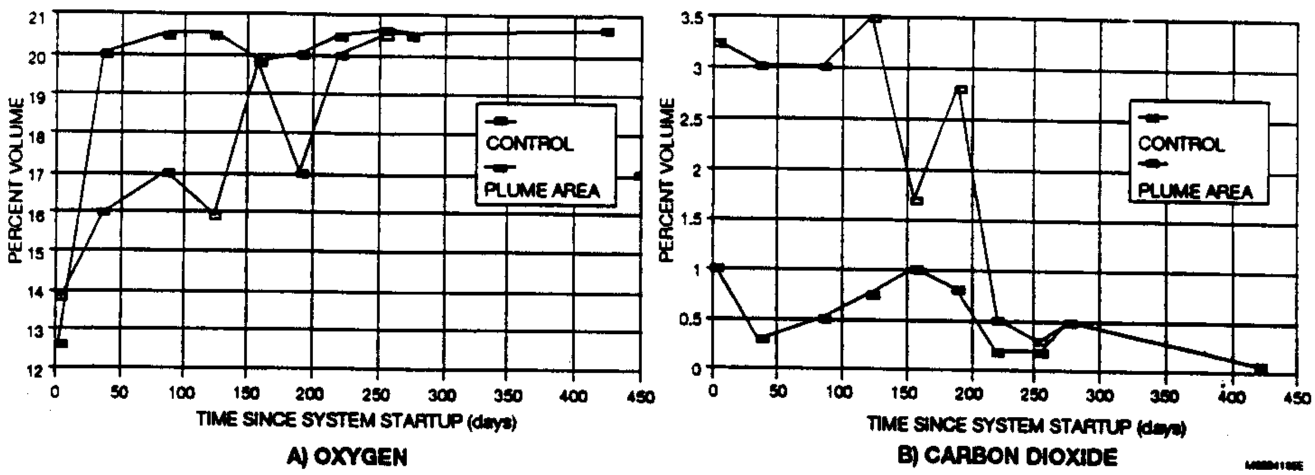


FIGURE 5. OXYGEN AND CARBON DIOXIDE SOIL GAS CONCENTRATIONS

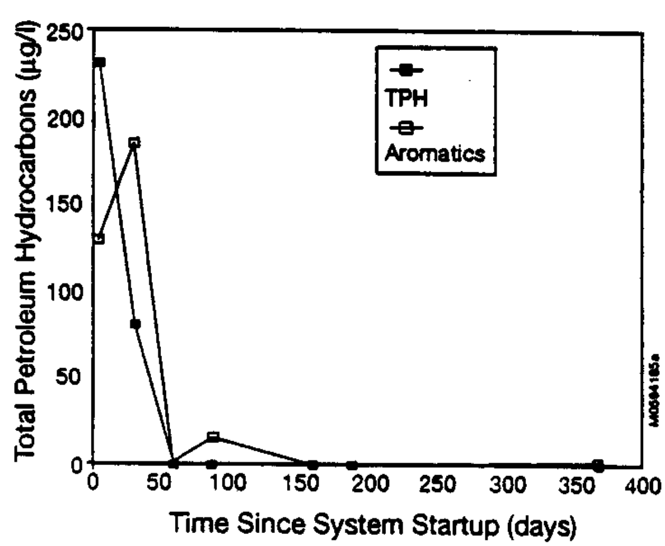


Figure 6. Emissions from Vapor Extraction System

Groundwater Monitoring

- Measurements of dissolved oxygen indicate that concentrations were generally above background levels within the immediate plume area due to the introduction of oxygen by groundwater sparging (Figure 7). These data indicate that although dissolved oxygen initially peaked about 25 days following system startup, subsequent dissolved oxygen concentrations fluctuated between 0.2 and 1.0 ppm through 280 days of operation. Dissolved oxygen was significantly higher during the remainder of system operation, presumably as a result of significant decreases in site contamination.

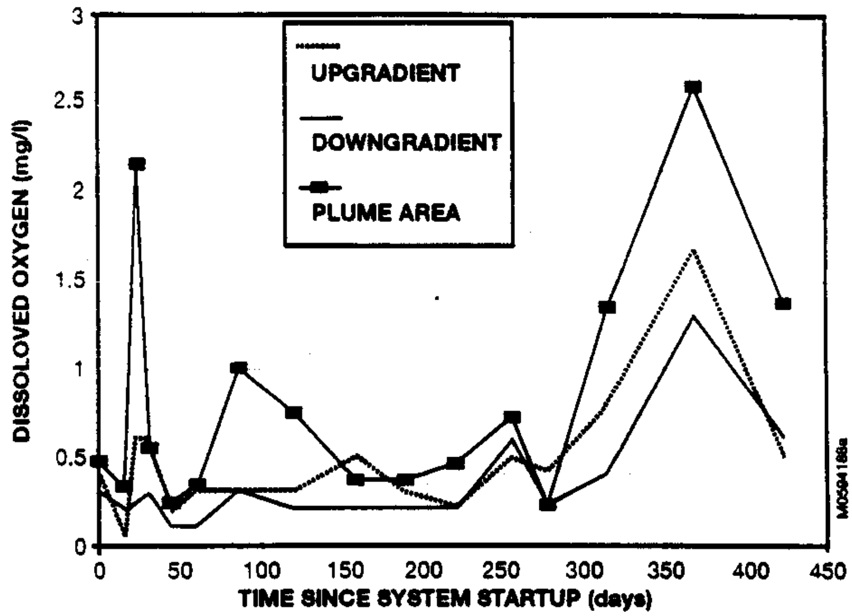


Figure 7. Oxygen Concentration in Groundwater

- Measurements of bacterial plate counts (both total heterotrophic and hydrocarbon degrading) initially increased substantially, but subsequently declined through the first 280 days of operation. These data indicate that bacterial activity was increased within the saturated zone by the groundwater sparging system operation.
- Measurements of dissolved total and aromatic hydrocarbon concentrations in groundwater show long-term declines over the life of the operating system (Figure 9). Dissolved concentrations generally exhibited the following pattern:
  - Concentrations increased over the first 30 days of operation.
  - Concentrations declined dramatically between about 30 and 100 days of operation.
  - Concentrations increased, either slightly or strongly, between about 120 and 250 days of operation.

Concentrations generally decreased steadily after 250 days of operation.

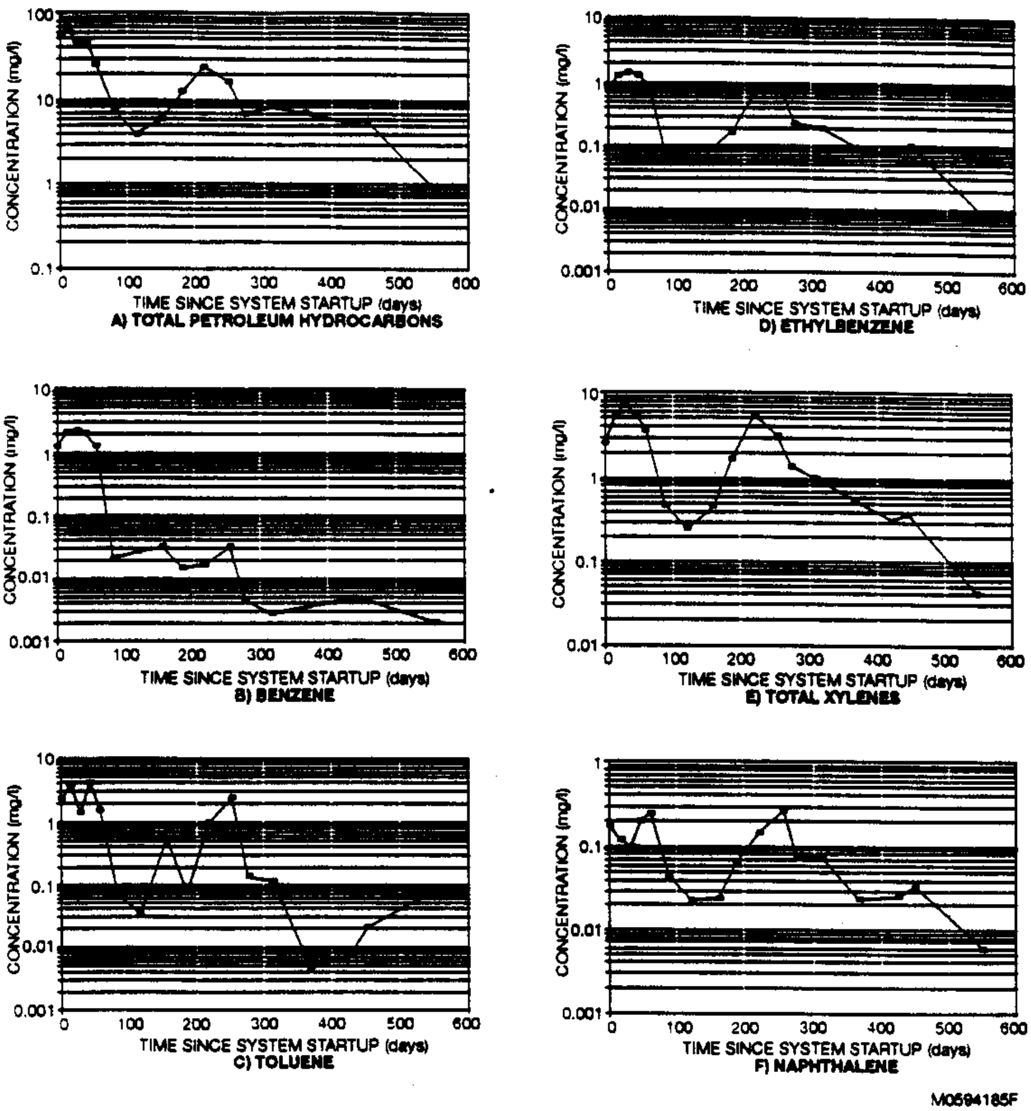


Figure 9. Petroleum Hydrocarbon Concentrations in Groundwater

- The increase in dissolved hydrocarbon concentrations over the first 30 days is probably due to disturbance of the subsurface equilibrium conditions caused by the sparging and pumping operations. Concentrations subsequently declined as microbial activity and associated biodegradation rates increased.
- The cause of the increase in dissolved hydrocarbon concentrations between 120 and 250 days of operation could be the result of any combination of the following factors: increased desorption of hydrocarbons from the site soils due to biological surfactant production and/or seasonal increase in the water table elevation; decreased microbial activity due to a seasonal drop in groundwater temperature or increased competition from non-hydrocarbon degrading bacteria.

Post Remedial Testing

Concentrations of the identified contaminants of concern in soil and groundwater at the completion of the remedial system operation are presented in Table 4. Significant reductions (typically greater than 95%) were observed for all contaminants of concern and both soil and groundwater concentrations were below the regulatory cleanup goals. Soil concentrations were measured 11 months after system startup. System operation and groundwater monitoring was continued for an additional 7 months to achieve compliance with naphthalene MCLs in all wells.

TABLE 4: SUMMARY OF POST REMEDIATION CONTAMINANT CONCENTRATIONS

Contaminant of Concern	Soil Concentrations (mg/kg)			Groundwater Concentrations (mg/l)			Cleanup Goal
	Initial	Final	%Change	Initial	Final	%Change	
Soil Concentrations (mg/kg)							
TPH	1,600	6.3	99.6	555	1.6	99.7	30
Benzene	7.8	<0.1	>98.7	2.0	<0.1	>95.0	0.2
Toluene	2.5	0.4	84.0	1.4	0.1	92.9	100
Ethylbenzene	19	0.1	99.5	5.7	<0.1	>98.2	70
Total Xylenes	110	0.8	99.3	37	0.3	99.2	1000
Naphthalene	No data	<0.1		No data	<0.1		2.0
Groundwater Concentrations (mg/l)							
TPH	190	1.3	99.3	51	0.71	98.6	Not Est.
Benzene	4.7	<0.002	>99.96	1.3	<0.002	>99.8	0.005
Toluene	9.4	0.26	97.2	2.4	0.067	97.2	1.0
Ethylbenzene	2.7	0.021	99.2	0.78	0.007	99.1	0.7
Total Xylenes	8.0	0.063	99.2	2.5	0.063	98.7	10
Naphthalene	0.63	0.010	98.4	0.18	0.006	96.6	0.020

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COST

Capital Costs

Drill and Install Wells	$ 16,000
3 extraction	
13 sparging	
6 monitor wells	
Install Groundwater and Vapor Extraction System	$ 40,300
Install Groundwater Sparging System	$ 25,750
Electrical Connections	$ 4,050
Trenching, Soil Disposal, Backfilling, Asphalting	$ 26,800
Air Compressor and Control Trailer	$ 26,800
Initial System Startup and Debugging	$ 3,000
Project Management, Construction Oversight, Regulatory Reporting and Coordination	$ 10,000
TOTAL CAPITAL COST:	**$156,950**

Annual Operating Costs

Maintenance Labor and Parts	$ 30,000
System Monitoring and Reporting	$ 30,000
Electricity (@ $0.07/kW-hr)	$ 2,750
TOTAL ANNUAL OPERATING COST:	**$ 62,750**

REGULATORY/INSTITUTIONAL ISSUES

- The Corrective Action Plan was reviewed and approved by the Utah Department of Environmental Quality (DEQ), Division of Environmental Response and Remediation (DERR).
- The Recommended Cleanup Levels for site soils were derived from DEQ guidelines for Level I environmental sensitivity (highest sensitivity). The environmental sensitivity of the site was evaluated according to the DEQ scoring system.
- The Maximum Contaminant Levels for site groundwater were derived from federal Clean Water Act regulations as adopted by the Utah DERR for underground storage tank remediations
- The Utah Division of Air Quality (DAQ) was notified of the intent to discharge volatile petroleum hydrocarbons from the vapor extraction system to the atmosphere at concentrations below *de minimus* standards established by DAQ (3,000 lbs total volatile emissions per year and 2.0 lbs of benzene per day). Because air emissions were below *de minimus* standards no air discharge permit was required.
- The Utah Division of Water Quality (DWQ) was notified of the intent to discharge contaminated groundwater to the upgradient injection gallery. An authorization-by-rule to operate the injection gallery as a Class V injection well was granted upon demonstration that the injection gallery was within the zone of influence of the downgradient extraction wells.
- Target cleanup levels (RCLs and MCLs) are presented in Table 4.

SCHEDULE

Task	Start Date	End Date	Duration
Tank Removal	12/90	12/90	1 week
Site Investigation	12/91	05/91	6 months
Remedial Investigation	06/91	08/91	3 months
CAP Preparation	09/91	10/91	2 months
CAP Approval by DERR	11/91	11/91	1 month
System Installation	01/92	02/92	2 months
System Operation	03/92	09/93	18 months

LESSONS LEARNED

Key Operating Parameters

- Stimulation of biodegradation was successful by increasing oxygen supply alone. Nutrient addition was not required at this site becouse nitrogen and phosphorous were present in the site groundwater.
- Significant air emissions associated with volatilization of contaminants by vapor extraction and air sparging was limited to the first 60 days of operation, despite the generally volatile nature of the contaminants (gasoline petroleum hydrocarbons). This is probably attributable to promotion of in situ biodegradation in both the saturated and vadose zones. Biodegradation appears to be the predominant mechanism for contaminant removal.
- Measurements of oxygen (soil gas and dissolved), carbon dioxide (soil gas), and bacterial plate counts (groundwater) all proved to be reliable and consistent indicators of biological activity and time required to reach cleanup goals. Dissolved naphthalene was an exception to these operating parameters.
- Groundwater concentrations of dissolved contaminants exhibited significant temporal fluctuations and were less reliable indicators of remedial progress than bioremediation parameters.

Implementation Considerations

- Discharge of air stripped volatile contaminants combined with moisture saturated air flow to the vadose zone permitted *in situ* biodegradation of these contaminants, greatly reducing air emissions from the vapor extraction collection points.
- Sparging wells were located at the point of groundwater reinjection and along a line of wells across the direction of groundwater flow, enhanced by the groundwater recirculation. An alternative strategy in the absence of groundwater recirculation is to space the sparging wells evenly across the entire plume area.

Technology Limitations

- Air sparging is limited to contaminants that can be degraded by indigenous bacteria under aerobic conditions. Length of system operation will be dependent upon the volatility and/or biodegradability of contaminants present. Contaminants which are sufficiently volatile to be air stripped by air sparging but are not aerobically biodegradable (chlorinated solvents for example) may be treatable by this technology with some modifications for vapor collection and treatment.
- The cost to implement air sparging is dependent upon the depth to groundwater since multiple sparging wells are required and their installation costs increases with depth.
- Maximum sparging well air flow and groundwater wellbore circulation rates are dependent upon well diameter, depth to groundwater, and formation hydraulic conductivity. Longer remediation times or a greater number of sparging wells may be required in lower permeability formations.

Future Technology Selection Considerations

- Groundwater circulation and vapor extraction were utilized for groundwater plume and product vapor containment respectively and would not generally be required as an addition to the groundwater sparging system. Subsequent groundwater sparging remediations are being successfully implemented without these additions.
- Air compressors require more maintenance and greater power draw than alternative methods of supplying air for groundwater sparging. Subsequent projects have utilized these alternative and more cost effective methods of air delivery.
- The system was able to reduce contaminant concentrations below required cleanup levels including federal MCLs and Utah RCLs. With the exception of dissolved naphthalene, all cleanup goals were achieved within 12 months of operation, the expected operational life. Reduction of dissolved naphthalene concentrations below the federal MCL of 0.020 mg/l required an additional 6 months of system operation, although the maximum dissolved naphthalene concentrations were only 0.080 mg/l after 12 months of operation. This difficulty probably is attributable to the low volatility and resistance to biodegradation of naphthalene .

SOURCES

Major Sources for Each Section

Site Characteristics:	Sections: 1, 2, 3, 4, 5, 6
Treatment System:	Sections: 7, 11
Performance:	Sections: 8, 9, 10, 11
Cost:	Sections: 7
Regulatory/institutional Issues:	Sections: 7, 11
Schedule:	Sections: 6, 7, 8, 9, 10, 11
Lessons Learned:	Sections: 10, 11

Chronological List of Sources

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3. Montgomery, John. H. and Welkom, Linda M. *Groundwater Chemicals Desk Reference*. Lewis Publishers, Chelsea, Michigan, 1990. pp. 30-31, 308-309, 398-400, 501-502, 547557.
4. Utah Division of Environmental Response and Remediation. *Estimating Numeric Cleanup Levels for Petroleum-Contaminated Soil at Underground Storage Tank Release Sites*. 1990.
5. Industrial Health Incorporated. *Site Investigation*, Amcor Precast, April 17, 1991.
6. Wasatch Environmental, Inc. *Further Site Investigation*, Release Site AGJX, Amcor Precast fueling Area. September 20, 1991.
7. Wasatch Environmental, Inc. *Amended Corrective Action Plan Proposal UST Release Site AGJX Amcor Precast*. October 10, 1991.
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REVIEW

Project Manager

The project manager has reviewed this report but he has postponed signing it until final closure of the site has been accomplished.

Regulatory Agency

This analysis accurately reflects the performance of this remediation:

[signature] - DERR x
Environmental Scientist
Utah DERR