STATEMENT OF BASIS

STAR ENTERPRISE TERMINAL

PICKETT ROAD FACILITY

FAIRFAX, VIRGINIA

VAD093952935

EPA Region III
841 Chestnut Building
Philadelphia, PA 19107

April 1998

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STAR ENTERPRISE TERMINAL
PICKETT ROAD, FAIRFAX, VIRGINIA

I. INTRODUCTION

This Statement of Basis ("SB") explains the proposed remedy to cleanup the *oil* [1] release at the Star Enterprise Petroleum Distribution Terminal ("Star") located at 3800 Pickett Road, Fairfax, Virginia. The Star Terminal is owned and operated by Saudi Refining, Inc., Star Enterprise Texaco, Inc., and Texaco Refining and Marketing Inc..

In the fall of 1990, *oil* was discovered in Crook Branch near the Star Terminal. Further investigations in the ensuing months revealed that a large *oil* plume, covering about 22 acres, originated from the Star Terminal and extended onto a commercial strip and a residential area across Pickett Road. In June 1991, at the request of the Virginia Water Control Board, the United States Environmental Protection Agency ("EPA") assumed the lead agency role to manage the *oil* release. Under EPA's directions, Star installed an Interim Containment System ("ICS") to control and stabilize the *oil* plume. The ICS is a pump-and-treat system that is made up of approximately 2,000 feet of recovery trenches and 65 recovery wells. The system has been pumping water and *oil* continuously to a treatment system located at the terminal since early 1992.

The ICS was intended to be an emergency measure to contain and stabilize the *oil* plume, but not a long-term remedy to cleanup up the contamination. On April 9, 1993, EPA issued a unilateral administrative order ("UAO"), EPA Docket Number III-93-003-CW-R, which required that Star, under EPA's oversight, perform the following major tasks:

(1) Operate, maintain and monitor the existing ICS to stabilize the *oil* plume;
(2) Furnish data to EPA to conduct human health and environmental risk assessment;
(3) Submit a Supplemental Site Characterization report to EPA to characterize the extent and nature of the contamination;
(4) Develop a Corrective Action Plan ("CAP") and propose a remedy; and
(5) Implement EPA's approved remedy.

To date, Star has completed the first four tasks and is awaiting EPA's decision on the final remedy and its implementation. EPA has completed a risk assessment of the site based on data submitted by Star. EPA recommends acceptance of the proposed remedy as set forth in the

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[1] Oil, as used in this document, refers to petroleum free product. All terms in *italic* are defined in the Glossary.

CAP because it is protective of human health, welfare and the environment, and it is the best implementable alternative among all alternatives evaluated. Pursuant to the public comment requirements of the UAO, the proposed remedy as described in this SB, is subject to public comment. EPA will consider public comments before making its final decision on the remedy.

II. PROPOSED REMEDY

As a long-term remedy, EPA proposes to continue operation of the existing pump-and-treat system (ICS) in conjunction with two new components described below. The remediation goal is to restore groundwater at the site to drinking water standards as closely as technologically practicable. Section VIII provides detailed discussion of the remediation objectives, and Section XI provides detailed evaluation of the alternatives.

A. Groundwater flushing: Groundwater flushing will be accomplished by means of three lines of horizontal wells located along the commercial strip, the Common Area, and Tovito Drive. The Tovito Drive horizontal well has already been installed during the pilot testing phase and has been operating satisfactorily since then. The other two lines of horizontal wells will consist of one or more sections of wells. The exact locations will be determined in the design phase, taking into consideration the surface topography, and the locations of existing buildings and underground utilities. Tap water or treated water from the ICS treatment system will be injected into the horizontal wells to promote flushing, biodegradation and product recovery. The system will be operated by remote control from the terminal. The installation of the horizontal wells will create short-term construction disturbances in the commercial strip and the Common Area. Once installed, the operation of the horizontal wells will be silent and nearly invisible.

B. Vacuum-Enhanced Recovery (VER): VER involves applying a vacuum to existing recovery wells to enhance product recovery. The VER pilot test showed that this technology will likely be successful at some wells, but not at all wells, and any effectiveness is likely to be short-term, rather than long-term. The performance of VER is expected to reach diminishing returns relatively quickly as soon as the *oil* near the well has been depleted. Since the effectiveness of VER is expected to be short-term and vary from well to well, a flexible approach is preferable. Therefore, VER will be targeted at high oil-yielding wells based on historical bailing performance. A mobile skid-mounted VER unit or a vacuum truck will be employed and moved from well to well when the recovery rate has leveled off. There will be noise disruptions during VER operation, but the disruptions are expected to be short-term and localized. VER operation will take place in non-residential area where most high yielding wells are located. Six to eight wells have been initially identified for VER application. Final selection of wells and operational criteria will be determined in the design phase, which can be adjusted as needed based on actual performance experience.

III SITE BACKGROUND

A. Facility Description: The 18-acre Star Terminal is one of five oil distribution companies that occupy the Fairfax tank farm complex. The other companies are Colonial Pipeline Company, Amoco Oil Company, Citgo Petroleum Corporation and Old Dominion Terminal L.L.C. (formerly owned by Chevron). The Star Terminal has nine 1.3 to 2.8 million-gallon above-ground storage tanks that store gasoline, jet fuel, diesel fuel and heating oil. As Star's major distribution center in northern Virginia, the amount of fuel distributed monthly approaches 20 million gallons. In 1991, Star upgraded the truck loading rack with all above-ground piping to eliminate suspected release sources. With funding from Star, the affected community (Mantua/Stockbridge Community) hired an independent consultant, Clean Sites, to conduct a facility audit in 1992-93 to determine whether there were ongoing releases. Clean Sites concluded that there were no ongoing releases, and all potential leak sources identified in the audit were later repaired or eliminated by Star. By 1996, Star had upgraded all above-ground storage tanks with double bottoms; installed dikes around the terminal to prevent catastrophic surface releases; and removed, abandoned or replaced all underground piping and eleven small underground tanks with above-ground piping and tanks.

B. Site History: The Star Terminal was built in the early 1960's and began operation in April 1965. In September 1990, *oil* was discovered in Crook Branch near the Star Terminal. Investigation by the State Water Control Board, Fairfax County, and the City of Fairfax concluded that the *oil* originated from a storm sewer line that runs along the southern border of Star Terminal. After the first incident, numerous incidents of *oil* releases in Crook Branch and complaints of petroleum odor near storm sewer inlets at the Mantua/Stockbridge residential area were reported. At the request of the Virginia Water Control Board, EPA assumed the lead agency role in June 1991 and directed Star to investigate and respond to the *oil* releases. Subsequent investigations revealed a large underground *oil* plume that extended 2,200 feet from the Star Terminal in a northeast direction across Pickett Road onto a commercial strip and the Mantua/Stockbridge residential area. Under EPA's direction pursuant to an Administrative Order by Consent for Emergency Protective Measures ("Emergency Order"), EPA Docket Number RCRA-3-004-IT-S, September 1991, Star took emergency measures to control the *oil* plume by placing containment booms in Crook Branch, hand bailing *oil* from wells, repairing leaks in storm sewers, and began constructing the ICS in stages. The emergency construction continued through September 1992 when the ICS, in its present form, was completed. The ICS consists of 2,000 feet of interceptor trenches and approximately 65 recovery wells strategically located above the plume, around the terminal, and across the front end of the plume. The ICS pumps *oil* and contaminated groundwater continuously into a treatment system at the terminal, and has been in operation since May 1992. The scope of the Emergency Order was limited to emergency measures to contain and stabilize the *oil* plume, rather than for long-term remediation. In April 1993, EPA issued the UAO which directed Star to identify a long-term remedy. To date, Star has completed pilot testing and detailed evaluation of alternatives to remediate the site. Based on that evaluation, Star has identified a remedy as set forth in the CAP.

C. Previous Investigations: Since the release incidents of 1990, numerous investigations have been conducted to characterize the site, the extent of contamination, the risks on human health and the environment, and alternatives to abate the contamination. The volume of documents is too large to be listed here. However, EPA has maintained an Administrative Record in the Fairfax City Library of all documents relating to this site. The public is encouraged to use this information for an in-depth review. EPA has referenced the following key documents in writing this SB: Supplemental Site Characterization, December 1993; Remedial Assessment Plan, March 1994; Groundwater Infiltration Pilot Study Report, June 1995; Vacuum Enhanced Recovery Area-of-Influence Pilot Study Report, November 1995; Laboratory and Site Characterization Report, November 1995; Chevron Microbial Fence Pilot Study Report, February 1996; Mantua Microbial Fence Pilot Study Report, April 1996; Vacuum Enhanced Recovery Performance Pilot Study Report, January 1997; Analysis of Petroleum Hydrocarbon Distribution in *Smear zone* Soils; Unsaturated Zone Biodegradation Study of Fairfax Soils, 1994; Risk Assessment, Pickett Road Terminal Site, March 1998; and the Revised Corrective Action Plan, October 1997.

D. Public Participation: Three governmental jurisdictions--Fairfax County, City of Fairfax, and the Commonwealth of Virginia--are involved because the plume originated in the City of Fairfax and extended into Fairfax County. The Virginia Water Control Board requested EPA to assume the lead agency role, believing that EPA would be in the best position to deal with cross-jurisdictional issues. Because the plume has migrated beyond the terminal and has affected a commercial strip and a residential community, the site has received a high level of public attention. The affected community and local governments have actively participated in the remediation process. EPA provided a $100,000 Technical Assistance Grant to the community to hire an independent consultant to review EPA's proposed remedy, risk assessment and site investigation work. To enhance communication, EPA has contributed articles to the Mantua Community Newsletters to provide periodic updates on site activities, maintained a site telephone hotline, assigned an on-site person from the Corps of Engineers to monitor site activities and to serve as a local point of contact, scheduled public meetings to inform the community of major milestones, and briefed the Community Remediation Committee ("CRC") and the Inter-Agency Task Force ("IAG") periodically. The CRC, headed by Fairfax City Mayor John Mason, provided EPA a communication channel to local government officials and citizen groups representatives. The IAG, a work group consisting of technical representatives from the Corps of Engineers, City of Fairfax, Fairfax County and the Virginia Department of Environmental Quality, assisted EPA in the review of technical documents and issues. EPA believes that this open, full participation approach has been beneficial to the remediation process.

IV. SUMMARY OF SITE INVESTIGATION

A. Site Geology: A typical cross-section of the site consists of approximately 10 feet of unconsolidated soil and fill overlying 100 feet of semi-consolidated saprolite. Saprolite is disintegrated bedrock left in place, which becomes progressively less disintegrated with depth until unaltered bedrock is reached. Saprolite at this site is characterized by low-permeability, silty clay *matrix* interrupted with higher permeability fractures, ranging in size from a fraction of an inch to several inches wide. The distribution and size of the fractures strongly influence the overall permeability and contaminant migration pathways. The larger fractures were found to be oriented in a northeasterly direction, and a low permeability geologic contact zone was found along the southeastern boundary of the plume. It is this natural variation of the fractures that is believed to have skewed the orientation of the *oil* plume to the northeast direction.

B. Surface Water: Surface drainage has been altered by urbanization. Storm water at the site is collected by storm drains and sewers which discharge to Crook Branch. Crook Branch originates near the southeast corner of the Star Terminal and a small tributary runs along Prince William Drive within the Mantua/Stockbridge residential area. Runoff in the diked portion of the Star Terminal is pumped into an onsite retention pond, which discharges to the headwater of Crook Branch via a storm sewer in accordance with a Virginia Pollution Discharge Elimination System permit. The storm sewers at the site had altered the natural migration pathways of the *oil* plume. The *oil* release was first discovered in Crook Branch at the outfall of a sewer line which drains the Star Terminal and the abutting Fairfax City Mall area. Due to interception of the *oil* by the storm sewers via backfill, cracks and joints, the *oil* plume was prevented from extending farther south. Other storm sewers in the residential area had affected the plume by acting as preferential pathways or releasing vapor to the surface via storm inlets, resulting in complaints of petroleum odor in the past. All leaking storm sewers have now been identified, repaired and sealed. With routine inspection and maintenance, these storm sewers are not expected to cause problems in the future.

C. Groundwater: The water table matches roughly the surface topography. It slopes down gradient to the east across the majority of the site, to the southeast along the southern border of the terminal, and to the northwest in the northwest quadrant of the terminal where a topographic plateau and a water table divide exist. Depth to water table across the site ranges from 10 to 15 feet at Convento Terrace, 10 to 30 feet in the Common Area, 20 to 25 feet in the commercial strip, and 5 to 20 feet in the terminal. The seasonal fluctuation of the water table ranges from approximately 3 feet in low lying areas to approximately 10 feet in the terminal upland area. The operation of the ICS has lowered the water table and reduced the extent of natural fluctuation in impacted areas. Following the water table gradients, groundwater flows naturally towards the east across the majority of the site, towards the southeast along the southern border of the terminal, and towards the northwest in the northwest quadrant of the terminal. Flow occurs mainly along fractures, because the tight saprolite *matrix* is not very conducive to fluid flow. Despite predominantly easterly flow directions, the *oil* plume is oriented to the northeast coinciding with the orientation of the major fractures and the geologic contact zone. Recharge to groundwater occurs in all unpaved areas, but most significantly in the tank farm area. The tank farm is situated on a topographic plateau and groundwater divide, where natural soil and vegetation have been replaced by pervious fill and gravel. The tank containment berms and terminal boundary dikes further retain storm water and promote recharge.

D. Extent of Surface Water Contamination: Although *oil* from the plume had impacted Crook Branch between 1990 and 1993, it has not impacted Crook Branch since 1994 after 3,250 feet of storm sewers had been repaired, grouted, and relined between 1991 and 1994. Water samples collected from Crook Branch showed improvement in quality over time consistent with storm sewer repairs. The samples collected after 1994 showed that the creek water was essentially free of petroleum contamination, although the sediments remained contaminated. Crook Branch is a small creek with a fast water turn-over rate. The creek water tends to clean itself relatively quickly once the contamination sources have been removed. The creek sediments, however, remain contaminated with heavier hydrocarbons which tend to be soil bound. An unquantifiable fraction of that sediment contamination originated from surface runoff unrelated to the plume. Urban runoff has been, and will continue to be, a source of contamination to Crook Branch.

E. Extent of Groundwater Contaminations:

(1) *Phase Separated Hydrocarbon* Plume - The *phase separated hydrocarbon* is referred to in this document as *oil*, product or free product. The *oil* plume extends approximately 1,800 feet from the Star Terminal loading rack in a northeasterly direction, across Pickett Road and the commercial strip, onto the Stockbridge/Mantua residential area. The composition of the *oil* varies slightly from location to location, but typically consists of less than 10 percent gasoline and over 90 percent middle distillates (diesel and jet fuel). The volume of the release cannot be determined with certainty because the amount of *oil* in the subsurface cannot be measured directly. The observed thickness of *oil* in a monitoring well is a poor indicator of the true amount of *oil* in the soil, frequently overestimating the true amount by an irregular factor of 2 to 10 depending on many seasonal, hydrogeological and well construction factors. Recognizing this uncertainty, the initial volume of release has been estimated by various sources to range from 100,000 to 300,000 gallons. To date, over 36,900 gallons of *oil* have been recovered. The *oil* plume has been monitored intensively since 1991 by periodically measuring the apparent thickness of *oil* in more than 200 monitoring wells. Over the years, the lateral extent of the *oil* plume has been stable, and the overall thickness has been shrinking, which can be attributable to the operation of the ICS and hand bailing efforts. In addition to the main *oil* plume, two small oil (less than one acre) plumes were identified in the northwest quadrant of the terminal and beneath the Colonial Pipeline property. These small plumes, unlike the main plume, contain a high proportion of light distillates (gasoline) and apparently have originiated from different sources. These small plumes have migrated to the northwest and joined the Colonial Pipeline plume. Under supervision by the Virginia Department of Environmental Quality, the Colonial Pipeline Company and Star Enterprise are remediating the Colonial Pipeline plume jointly using VER technology.

(2) *Dissolved-Phase Hydrocarbon* Plume - The *oil* in the main plume is largely insoluble. Of the soluble portion of the *oil*, less than one percent consists of benzene, toluene, ethylbenzene and xylenes (*BTEX*) compounds. Less than 5 percent of these *BTEX* compounds have dissolved in groundwater, forming a *dissolved phase* plume underneath the *oil* plume. This minute fraction of *BTEX* has polluted a large volume of groundwater, rendering it unsuitable for

drinking purposes for many years. The lateral extent of the *dissolved phase* plume is larger, but typically less than 50 feet wider, than the *oil* plume. In light of the potential risks of cross contamination, relatively few deep wells have been constructed within the *oil* plume boundary for the purpose of defining the vertical extent of the *dissolved phase* plume. With limited data points, the concentrations of the *dissolved phase* constituents (*BTEX*) were observed to decrease with depth from effective saturated solubility levels to non-detectable levels within 50 feet of the *oil* water interface. Several bedrock wells were constructed downgradient of the *oil* plume boundary to determine whether the *dissolved phase* constituents might have migrated into bedrock. No significant levels of *dissolved phase* constituents were detected in these bedrock wells. It can be generalized that the extents of the *dissolved phase* plume are limited to 50 feet beyond the oil-water interface, both vertically and horizontally.

F. Extent of Soil Contamination: The *oil* is trapped in the saprolite pore spaces and fractures. A portion of the *oil* adheres to the soil grains strongly, and is immobile under gravitational force. The mobile portion of the *oil* migrates to groundwater under gravity, and once reaching groundwater, it continues to migrate laterally with moving groundwater. As the *oil* moves with groundwater and the water table fluctuates seasonally, it contaminates an ever increasing volume of soil and becomes less mobile. The *oil*-contaminated soil is referred to as the *smear zone*. The *smear zone* extends between the historical high and low water table positions except in the terminal source area, where it extends from near-surface release sources to historical low water table position. The thickness of the *smear zone* ranges from 6 to 14 feet within the terminal; 6 to 20 feet in the Commercial strip and Common Area; and 6 to 12 feet in the residential area. The *Total Petroleum Hydrocarbons (TPH)* concentration in the *smear zone* averages 750 mg/kg inside the terminal, 100 mg/kg in the northern half, and 670 mg/kg in the southern half of the plume area outside the terminal. The *oil* is more mobile in the fractures--the larger the fracture, the greater the mobility--than in the minute pore spaces. This may explain the northeasterly orientation of the *oil* plume coinciding with the principal orientation of the major fractures and the geologic contact zone. The mobile *oil* is recoverable by conventional bailing and pumping; the immobile *oil* is unrecoverable. After 36,900 gallons of *oil* have been recovered to date, the *smear zone* is left with mostly immobile *oil*, which can only be removed by non-conventional technologies.

V. SUMMARY OF HUMAN HEALTH RISK ASSESSMENT

EPA has performed a human health risk assessment to evaluate the risks posed by the site under current and hypothetical exposure scenarios. The full report, " Risk Assessment, Pickett Road Terminal Site, April 1998," is available for review in the Administrative Record.

A. Contaminants Of Concern: The nature of the petroleum products released to the subsurface at the site has been determined to consist of equal portions of diesel fuel and aviation fuel, with one to seven percent of gasoline. Concentrations of fuel oils and their derivatives are often measured as *Total Petroleum Hydrocarbons (TPH)*. Fuel oil concentrations reported as *TPH* cannot be used to assess risk, because *TPH* represents a variable mixture of chemicals to which no definitive toxicity value can be assigned. Thus, for the human health risk assessment, an indicator compound approach was utilized in which the concentrations of certain individual constituents of the hydrocarbon mixture are evaluated. These constituents include some of the most toxic components of fuel oil mixtures, insuring that a conservative estimate of risks will result. These indicator compounds described in the report as chemicals of concern (COCs) include benzene, ethylbenzene, toluene, xylene, methyl tertiary butyl ether (MTBE), and *polynuclear aromatic hydrocarbons (PAHs).*

B. Exposure Scenarios: Under current conditions, exposure to contaminants in subsurface soil and Crook Branch surface water and sediments is possible. Adult residential exposure to subsurface soil via inadvertent ingestion and dermal contact was evaluated in the risk assessment. Child residential exposure to Crook Branch surface water and sediments via inadvertent ingestion and dermal contact was also evaluated.

Under current conditions, inhalation exposure to releases from the air stripper operating on the facility property was evaluated for adult and child residents and for on- and off- facility occupational receptors. Inhalation exposure to vapors that may potentially migrate from the phase-separated hydrocarbon plume into basements was also evaluated for adult and child residents.

Groundwater beneath the plume is not currently used as a source of drinking water, but has the potential to be used for consumption. Thus, there is no current actual exposure to contaminated groundwater. Hypothetical exposure to groundwater by adult and child residents was evaluated, including ingestion, inhalation, and direct contact routes.

The EPA risk assessment adopted a fundamental exposure assumption that the current conditions will not change with time. This implies that the media concentrations will remain constant, the assumed exposure pathways will stay the same, and that the remediation system will continue to operate. In reality, the conditions are expected to improve over time because the media concentrations will continue to decline in response to active and natural remediation.

C. Risk Quantification: Based on standard EPA assumptions,[2] risks to human health were quantified. Numerical cancer and non-cancer risks are listed in Tables 1 to 5 by medium. Since

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[2] *Standard conservative exposure factors were used to quantify human health risks in accordance with: (a) "Risk Assessment Guidance for Superfund" (EPA/540/1-89/002), (b) "Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors" (EPA OSWER Directive 9285.6-03), and (c) "Dermal Exposure Assessment: Principles and Applications" (EPA/600/8-91/011B). Contaminant-specific cancer slope factors or reference doses were obtained from EPA's Integrated Risk Information System data base (1997).*

the assumptions are conservative, the true risks are likely to be less than the numerical risks indicated, and possibly could be zero.

EPA expresses cancer risk in terms of the likelihood that a person might develop cancer from exposure to contaminants from a site. For example, a risk assessment might say that a receptor has an upper bound excess cancer risk of 1 in 10,000 (also written as 1 times 10^{-4}). This conveys several facts. First, the risk is an upper bound rather than an average estimate. The true risk is likely to be less, and may be zero.

Second, the numerical estimate means that if 10,000 people received this level of exposure averaged over a 70-year lifetime, no more than one would have a probability of developing cancer. Depending on site-specific factors, EPA's threshold of acceptable cancer risk ranges from 1×10^{-6} to 1×10^{-4}, or from one in one million to one in ten thousand.

EPA expresses non-cancer health risk as a ratio, known as the Hazard Quotient (HQ), which is defined as the calculated exposure from a single contaminant in a single medium divided by a reference dose. The reference dose is the level of exposure that EPA believes can exist without adverse effect in human populations, including sensitive individuals. When the exposure equals the reference dose, the HQ is 1.0, which is EPA's threshold of acceptable non-cancer risk. The Hazard Index for a site is calculated by adding the HQs for all contaminants of concern within a medium or across all media to which a person may reasonably be exposed. Similar to cancer risk estimates, EPA's HQ values are upper bound estimates. Because the reference doses are conservative, HQ values slightly greater than one are unlikely to produce adverse effects.

TABLE 1 Estimated cancer risks and noncancer hazard indices, adult receptor, current exposure routes

RECEPTOR	MEDIUM	CANCER RISK [a]	HAZARD INDEX [a]
RESIDENTIAL ADULT	Subsurface soil	1.4×10^{-11}	8.5×10^{-7}
	Outdoor air	2.2×10^{-9}	0.0001
	Indoor air	2.5×10^{-6}	0.12
TOTALS		**2.5×10^{-6}**	**0.12**

[a]-EPA's threshold of acceptable cancer risks is between 1×10^{-4} to 1×10^{-6} (probability cancer risk of one in ten thousand to one in one million). EPA's threshold of acceptable non-cancer risk is a Hazard Index of less than or equal to one.

TABLE 2 Estimated cancer risks and noncancer hazard indices, child receptor, current exposure routes

RECEPTOR	MEDIUM	CANCER RISK[a]	HAZARD INDEX[a]
RESIDENTIAL CHILD	Crook Branch surface water and sediment	8.5×10^{-7}	0.022
	Outdoor air	2.2×10^{-9}	0.00035
	Indoor air	2.6×10^{-6}	0.4
Total		**3.5×10^{-6}**	**0.42**

[a]-EPA's threshold of acceptable cancer risks is between 1 x 10^{-4} to 1 x 10^{-6} (probability cancer risk of one in ten thousand to one in one million). EPA's threshold of acceptable non-cancer risk is a Hazard Index of less than or equal to one.

TABLE 3 Excess cancer risks and hazard indices occupational exposure (Pickett Road) to outdoor and indoor air

RECEPTOR	MEDIUM	CANCER RISK[a]	HAZARD INDEX[a]
OCCUPATIONAL-COMMERCIAL PROPERTY ON PICKETT ROAD	Outdoor air	1.6×10^{-8}	0.00093
	Indoor air	3.8×10^{-6}	0.22
Total		**3.8×10^{-6}**	**0.22**

[a]-EPA's threshold of acceptable cancer risks is between 1 x 10^{-4} to 1 x 10^{-6} (probability cancer risk of one in ten thousand to one in one million). EPA's threshold of acceptable non-cancer risk is a Hazard Index of less than or equal to one.

TABLE 4 Cancer risks and hazard indices occupational exposure (terminal property) to outdoor and indoor air

RECEPTOR	MEDIUM	CANCER RISK[a]	HAZARD INDEX[a]
OCCUPATIONAL-TERMINAL PROPERTY	Outdoor air	8.1×10^{-8}	0.0047
	Indoor air	3.2×10^{-6}	0.18
Total		**3.3×10^{-6}**	**0.19**

[a]-EPA's threshold of acceptable cancer risks is between 1 x 10^{-4} to 1 x 10^{-6} (probability cancer risk of one in ten thousand to one in one million). EPA's threshold of acceptable non-cancer risk is a Hazard Index of less than or equal to one.

TABLE 5 Estimated cancer risks and noncancer hazard indices, hypothetical exposure to groundwater

RECEPTOR	MEDIUM	CANCER RISK[a]	HAZARD INDEX[a]
RESIDENTIAL ADULT	Groundwater	2.6×10^{-3}	116
RESIDENTIAL CHILD	Groundwater	1.3×10^{-3}	214

[a]-EPA's threshold of acceptable cancer risks is between 1×10^{-4} to 1×10^{-6} (probability cancer risk of one in ten thousand to one in one million). EPA's threshold of acceptable non-cancer risk is a Hazard Index of less than or equal to one.

D. <u>Conclusions</u>: Under current exposure scenarios and for all contaminated media combined, a total cancer risk of 2.5×10^{-6} and a non-cancer Hazard Index of 0.12 were estimated for adult residents; and a total cancer risk of 3.5×10^{-6} and a non-cancer Hazard Index of 0.42 were estimated for child residents. These risk levels are within EPA's thresholds of acceptable risk.

Inhalation of outdoor and indoor air by workers in businesses along Pickett Road is associated with cancer risks of 3.8×10^{-6} and a non-cancer hazard index of 0.22. Inhalation of outdoor and indoor air by workers on the terminal property is associated with cancer risks of 3.3×10^{-6} and a non-cancer Hazard Index of 0.19. These risk levels are within EPA's thresholds of acceptable risk.

The groundwater in the plume impacted area is not currently in use, so there is no current exposure. Hypothetical use of groundwater is associated with a total cancer risk of 2.6×10^{-3} and a non-cancer Hazard Index of 116 for adults residents, and a total cancer risk of 1.3×10^{-3} and non-cancer hazard index of 214 for child residents. These risk levels exceed EPA's thresholds of acceptable risk. It is also notable that Hazard Indices for individual contaminants such as benzene and MTBE also exceeded EPA's acceptable threshold of 1.

VI. SUMMARY OF ECOLOGICAL SURVEY

In 1994, a semi-quantitative survey of the aquatic community in Crook Branch was performed by EPA. This survey was conducted to measure any changes in the *macroinvertebrate* community that might have occurred since a similar survey was conducted in 1991. Both 1991 and 1994 surveys followed EPA Rapid Bioassessment Protocol I guidance.

These surveys provided an assessment of the aquatic habitat along Crook Branch in comparison to the conditions in off-site reference stations.

Based on the collected data, the condition of the *macroinvertebrate* community in Crook Branch in 1994 had improved slightly since 1991. A greater abundance and diversity of species were observed in 1994. No petroleum product (sheen or odor) was visible in the 1994 survey as was in 1991. The condition of the *macroinvertebrate* community in 1994 was slightly more diversified in the upper reach of Crook Branch nearer the terminal than in the lower reach. The finding is indicative of overall stream impairment, which is not necessarily linked to the plume alone, but is rather common in an urban environment.

VII. CORRECTIVE ACTION ALTERNATIVES

A. Identification of Preliminary Alternatives: In November 1993, as part of the CAP development, Star submitted a Remedial Assessment Plan (RAP) to EPA that provided an overview and preliminary screening of remedial technologies. The technologies described in the RAP can be broadly divided into *ex-situ* and *in-situ* methods. *Ex-situ* methods require excavation of the contaminated soil prior to treatment or disposal. *In-situ* methods rely on treating the contaminated media in place without excavation. The RAP has provided extensive description of all *in-situ* methods that have been used or tested at other sites. The description of *ex-situ* methods was less extensive, focusing on the excavation process with recognition that oil-contaminated soil can be readily treated or disposed of offsite. One objective of the RAP was to identify Preliminary Alternatives for detailed, site-specific evaluation. Based on preliminary screening of all available technologies, EPA designated nine Preliminary Alternatives (PAs) for Star to conduct further evaluation:

(1) Vacuum Enhanced Recovery,
(2) Saturated Zone Bioremediation,
(3) Microbial Fence,
(4) Groundwater Flushing (Hydraulic Containment/Enhanced Groundwater Extraction),
(5) Bioventing,
(6) Vapor Extraction,
(7) *Aquifer* Aeration and Vapor Extraction,
(8) Natural Attenuation, and
(9) Localized *Ex-situ* Treatment Options.

B. Description of the Preliminary Alternatives (PAs):

(1) Vacuum Enhanced Recovery (VER): VER is a technique that applies a vacuum to recovery wells to enhance *oil* recovery. The vacuum increases groundwater extraction rate (by increasing the effective gradient) without depressing the water table and enlarging the *smear*

zone. The vacuum may also increase *oil* recovery from the unsaturated zone where *oil* is held in small pores by negative pressure. Furthermore, the vacuum increases vaporization of liquid *oil*, and the vapor extracted by the vacuum can be treated at the exhaust. There will be noise disruptions during VER operation, but the disruptions are short-term and localized.

(2) Saturated Zone Bioremediation: Saturated zone bioremediatioin is an engineered process to enhance natural biodegradation of hydrocarbons in the saturated zone. It relies on microorganisms to break down hydrocarbons in place with no waste streams generated. By definition, saturated zone bioremediatioin is intended to remediate soil and groundwater below the water table; however, by artificial manipulation of the water table, it may be feasible to treat soil above the water table. Hydrocarbons have been demonstrated to be biodegradable under *aerobic* conditions using indigenous soil microorganisms, provided that there are no inhibiting factors such as extreme pH or the presence of toxic chemicals to soil microorganisms. In the laboratory, the rate of natural biodegradation can be increased by ten to hundred fold by supplementing the microorganisms with oxygen and nutrients (primarily nitrogen and phosphorus depending on which one is limiting). In field application, however, the effectiveness is limited by the process to effectively deliver oxygen or nutrients to the contaminated media. Therefore, despite success in the laboratory, *in-situ* bioremediation remains difficult in many field applications. Several techniques were explored in the pilot tests to identify which one can best deliver oxygen to groundwater. These included direct *aquifer* aeration, the use of oxygen releasing compounds, and injection of oxygen-rich water. The level of disruption in operating a saturated zone bioremediation system depends on which technique is used to deliver oxygen. *Aquifer* aeration generates moderate noise due to operation of the air compressor, unless the noise is adequately controlled. Delivery of oxygen by oxygen releasing compounds and injection of oxygen-rich water in vertical and horizontal wells are quiet operations. The installation of oxygen delivery systems will create short-term construction disturbances.

(3) Microbial Fence: Microbial fence technology is a variation of saturated zone bioremediation accomplished by intensifying biological degradation of contaminants in a relatively narrow bioactive zone to cleanup groundwater before it leaves the zone. Microbial fence technology is less disruptive than site-wide saturated zone bioremediation because it is applied locally, rather than across the entire site. One other difference is that a microbial fence is intended to treat contaminated groundwater only, whereas saturated zone bioremediation can treat both soil and groundwater. A microbial fence relies on natural groundwater movement to carry contaminated groundwater into the bioactive zone. Therefore, the fence must be strategically placed to optimize capture of contaminated groundwater. Although other scenarios are possible, considerations have been given to placing a fence at the leading edge of the plume, and one to two fences across the middle of the plume to cleanup passing groundwater. Two microbial fence pilot tests were conducted to explore the effectiveness of the microbial fence concept and techniques to deliver oxygen to groundwater. The Chevron Microbial Fence test explored oxygen delivery by oxygen releasing compounds; the Mantua Microbial Fence test explored direct *aquifer* aeration. Additionally, *in-situ* oxygen uptake tests, dissolved oxygen mapping, and several laboratory tests furnished further data to evaluate bioremediation. The

level of operation disruptions depends on which technique is used to deliver oxygen No further construction disruption is anticipated if a microbial fence is to be operated at the leading edge of the plume because the installation has already been completed in the pilot test. Short-term construction disruptions are expected if additional fences are placed at other locations.

(4) Groundwater Flushing: This alternative was previously referred to as hydraulic containment/enhanced groundwater extraction. Groundwater flushing involves injecting water into the unsaturated zone to promote flushing of contaminants into the existing ICS. The source of water may be tap water or treated water from the existing ICS treatment system. Groundwater flushing must be operated in conjunction with an extraction system; otherwise, there is a risk of over elevating the water table and flushing the contaminants to unanticipated locations. The ICS is currently operating at less than 10 percent of its maximum capacity. Any increase in the extraction rate could be counterproductive because it may lower the water table below the interceptor trenches and pump intake elevations. Groundwater flushing enhances biodegradation in the saturated and unsaturated zones by introducing oxygen-rich water, and enhances the operation of the ICS by increasing the extraction rate without depressing the water table and enlarging the *smear zone*. Tap water or treated water from the existing ICS treatment system can be injected into the horizontal wells. Treated water has the advantage of having been acclimated with microorganisms, thereby speeding up the biological activities. The installation of the horizontal wells will create short-term construction disturbances. Once installed, the operation of the horizontal wells will be silent and nearly invisible.

(5) Bioventing: Bioventing is an engineered process that enhances biodegradation in unsaturated soils by injecting air to, or extracting air from, soil at a low flow rate to encourage biodegradation rather than volatilization. Bioventing degrades hydrocarbons in place and reduces air emissions and subsequent need for vapor treatment. Since the process relies on biological activities, the remediation rate is relatively slow. If good uniform air flow can be maintained, bioventing can be used to treat a large mass of soil, including soil obstructed by fixed structures; otherwise, the cleanup will not be thorough because of insufficient air flow or concentration of air flow in limited soil mass. Bioventing can also be impacted by improper soil pH or lack of moisture and nutrients in the unsaturated zone. Bioventing is difficult if it is necessary to adjust the soil pH or to add nutrients and moisture. Bioventing operation can be disruptive because the vacuum pump or blower can generate noise unless the noise is controlled. It is, however, less noisy than vapor extraction because bioventing uses lower energy input. The installation of air venting wells can create short-term construction disturbances.

(6) Vapor Extraction: Vapor extraction is a technique for removing hydrocarbon vapor from unsaturated soils by drawing air through the ground with a vacuum pump. The air flow and partial vacuum created can increase volatilization of hydrocarbons. The extracted vapor can be treated above ground and safely discharged. Vapor extraction differs from bioventing in that air is drawn at a high rate to physically remove hydrocarbon vapor from the unsaturated soil. It is effective in removing volatile and semi-volatile hydrocarbons, but not heavier hydrocarbons. If the residual hydrocarbons are moderately volatile, the remediation rate is faster than bioventing

because vapor extraction does not depend on slow biological process. Vapor extraction has been applied favorably to gasoline spilled sites due to volatility of gasoline compounds. If good uniform air flow can be maintained, vapor extraction can be used to treat a large mass of soil including soil obstructed by fixed structures; otherwise, the effectiveness is limited. In some situations, it may be necessary to install active or passive air inlet wells to direct air flow, or to seal the surface to reduce air leaks. Vapor extraction operation can be disruptive because the vacuum pump or blower can generate moderate level of noise, unless the noise is effectively controlled. The installation of air extraction or inlet wells will also create short-term construction disturbances.

(7) *Aquifer* Aeration and Vapor Extraction: Air sparging, an *aquifer* aeration technique, involves injecting compressed air below the water table to promote volatilization of trapped and *dissolved phase* hydrocarbons. Air sparging is often used in conjunction with vapor extraction. The combination of the two technologies extends the remediation effectiveness to both the saturated and unsaturated zones. If good uniform distribution of air can be maintained in the saturated zone, *aquifer* aeration can be an effective technology to remediate groundwater; otherwise, the effectiveness is limited due to poor aeration distribution. *Aquifer* aeration should be applied after adequate removal of free product; otherwise, it may lead to foaming of free product, resulting in enlargement of the *smear zone* and potential increase in *dissolved phase* contamination. A vapor extraction system should be operated simultaneously with an air sparging system; otherwise, there is a risk of *oil* vapor migration to unanticipated locations. To ensure that all escaped vapor will be captured, a vapor extraction system is often designed to operate at greater capacity than the accompanying sparging system. *Aquifer* aeration and vapor extraction is an energy intensive operation. It can generate moderate level of noise due to operation of air blowers and vacuum pumps unless the noise is effectively controlled. There will be short-term construction disruptions due to installation of air extraction and air sparging wells.

(8) Natural Attenuation: Natural attenuation is not a remediation technology, but a naturally occurring phenomenon. Natural attenuation may include biodegradation, sorption, dilution, dissolution, volatilization and other natural processes that eliminate or retard the migration of contaminants. Biodegradation is the most important natural attenuation process because it actually destroys the contaminants. For this reason, natural attenuation is sometimes referred to as passive biodegradation. All hydrocarbons are biodegradable, including heavier constituents commonly resistant to active remediation. Natural attenuation does not require the addition of oxygen or nutrients as in the case of active bioremediation. Since natural attenuation generates no waste streams or contaminated soil, it is both economical and non-disruptive. On the negative side, natural attenuation is typically slow. Without active remediation, natural attenuation alone may take hundreds of years to completely degrade the contaminants. Natural attenuation is appropriate only if active remediation is not needed and no receptors are affected, or when active remediation has already reached diminishing returns or technological limitations and no longer capable of performing any better than natural attenuation. EPA has concluded that active remediation is needed at this site and will not accept natural attenuation as a sole remedy. Natural attenuation was retained as a PA because it plays an important role regardless of what

remedy is selected, and natural attenuation will continue to degrade hydrocarbons long after active remediation has been completed. Eventually, all active remediation will reach technological limitations. At that time, natural attenuation will continue to further cleanup the contaminated media.

(9) Localized *Ex-situ* Treatment Options: *Ex-situ* treatment options require excavation of contaminated soil prior to treatment offsite. Once removed, hydrocarbon-contaminated soil can be treated successfully by a range of options such as incineration, low temperature thermal desorption, asphalt mixing, *ex-situ* bioremediation or disposal in landfills. Offsite landfill disposal moves the contaminated soil from one place to another without treatment, which may be constrained by landfill capacity or disposal restrictions. Offsite treatment is preferable to offsite landfill disposal because the former option destroys the contaminants and eliminates long-term liability. Offsite treatment is more thorough and effective in destroying soil contaminants than comparable *in-situ* treatment. On the negative side, *ex-situ* options cannot remove soil from under buildings and underground utilities; it is costly and highly disruptive if large volumes of soil with low contaminant concentrations must be treated. The removal activities may pose short-term health risks due to release of fugitive vapor and dust. Therefore, EPA has ruled out *ex-situ* treatment options for site-wide application. Nevertheless, localized *ex-situ* options may be appropriate for expeditiously removing soil hot spots which cannot be treated effectively in place. Soil hot spots are defined as highly contaminanted soils that may pose substantial risks to human health or the environment.

VIII. REMEDIATION REQUIREMENTS

The UAO identifies four remediation requirements ("Requirements") which state that the cleanup must: (1) Be protective of human health, welfare and the environment; (2) Eliminate, to the maximum extent practicable, any discharge of *oil* and hazardous substances and/or the disposal of solid waste at or from the Facility; (3) Prevent, to the maximum extent practicable, the threat of any discharge of *oil* and hazardous substances and/or the disposal of solid wastes from the Facility; and (4) Cleanup *oil*, hazardous substances and solid wastes at the site, sufficient to achieve and comply with all applicable federal, state and local requirements. Each Requirement is described in detail below:

A. Requirement (1): EPA's risk assessment provides the primary basis for establishing the remediation standards for the contaminated media. The contaminated media evaluated in EPA's risk assessment include soil, groundwater, indoor air, outdoor air, sediments and surface water in Crook Branch. For each of these media, EPA estimated the cancer and non-cancer risk levels. EPA's risk assessment concludes that, under current conditions, none of the contaminated media at the site--soil, groundwater, indoor air, surface water and sediments in Crook Branch--pose risks above EPA's health-based standards. However, groundwater is a potential source of drinking water at the site. Therefore, under a hypothetical use scenario, site groundwater poses risks above EPA's health-based standards.

(1) Groundwater Standards

The Superfund and RCRA Corrective Action programs share a common goal of restoring contaminated groundwaters to a quality consistent with their current or reasonably expected future uses. Since the groundwater at the site has the potential value to be used for consumptive purposes, EPA requires that site groundwater be restored to drinking water standards.

> The Preamble to the Proposed Subpart S to 40 CFR 264 states that: "Potentially drinkable groundwater would be cleaned up to levels safe for drinking throughout the contaminated plume, regardless of whether the water was in fact being consumed."[3]

> The National Contingency Plan for the Superfund program, NCP §300.430(a)(1)(iii)(F), states that: "EPA expects to return usable ground waters to their beneficial uses wherever practicable, within a time frame that is reasonable given the particular circumstances of the site."

Petroleum hydrocarbons are made up of hundreds of constituents; however, scientists found only a small subset of these constituents that pose risks to human health. It is not necessary nor feasible to measure every one of these constituents to determine whether the medium is contaminated with petroleum and at what level of risks. An indicator approach is commonly used to make that determination. The presence or absence of certain indicator constituents indicate the presence or absence of other constituents. Additionally, a treatment technology that is effective in removing certain indicator constituents will likely be effective in removing other constituents. Based on the chemicals of concern identified in EPA's risk assessment, EPA selects the following constituents as indicator parameters: benzene, toluene, xylenes, ethylbenzene and benzo(a)pyrene. The standards promulgated pursuant to the Safe Water Drinking Water Act, or Maximum Contaminant levels (MCLs), for these parameters are listed below:

Benzene:	5 parts per billion (ppb)
Toluene:	1,000 ppb
Ethylbenzene:	700 ppb
Xylenes:	10,000 ppb
Benzo(a)pyrene:	0.2 ppb

The above parameters were selected on the basis that they are among the most toxic and soluble petroleum constituents; they provide adequate representation of the full range of volatile and semi-volatile petroleum constituents; standards for these parameters have been established

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[3] *"Corrective Action for Solid Waste Management Units at Hazardous Waste Management Facilities, " 55 FR 30798-30884, July 27, 1990, Proposed Rules, is currently used as guidance in the RCRA Corrective Action program.*

pursuant to the Safe Water Drinking Water Act; and their occurrence suggests the presence of petroleum contamination.

In addition to meeting the drinking water standards for the *dissolved phase* constituents, EPA will require Star to continue product removal activities until such time that Star can demonstrate that it is safe to terminate the activities partially or entirely. Under extremely wet conditions, several homes located near the front end of the plume are susceptible to groundwater seepage into basement due to a shallow water table condition. Although the likelihood of such an occurrence has been reduced due to operation of the ICS, EPA considers that even a momentary seepage of *oil* into basements is unacceptable because *oil* is flammable and can pose a fire hazard. EPA's guidance[4] recommends that free product be removed to less than 0.01 foot or to certain minimum recovery rates practicable.

(2) Soil, Sediments and Surface Water Standards

EPA's risk assessment determined that, under current conditions, the contaminated soil, sediments and surface water at the site do not pose risks above EPA's health-based standards. Since these media concentrations have already met EPA's health based standards, EPA concludes that it is unnecessary to establish remediation standards for soil, sediments and surface water.

EPA recognizes that contaminated soil at the site can transfer contaminants to groundwater. Therefore, to achieve groundwater cleanup, commensurate remediation of soil is needed. However, EPA has determined that it is unnecessary to establish separate remediation standards for soil for the purpose of achieving groundwater clean-up for the following reason:

> The level of groundwater contamination is linked to the level of soil contamination because groundwater is in contact with the contaminated soil (the *smear zone*) throughout the site. The linkage can be estimated quantitatively from the constituent partition coefficients. Because of this linkage, groundwater concentrations are good indicators of soil concentrations. Therefore, for the purpose of remediating groundwater, it would be redundant to establish two separate standards. If groundwater has not met standards, soil remediation has not reached completion. Furthermore, it is much simpler to monitor the trend of groundwater concentrations over time and space than to measure that for soil.

The remediation standards established here are based on a fundamental assumption adopted in EPA's risk assessment--that the current conditions will not change over time. This

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[4] *EPA Underground Storage Tank guidance document, EPA 510-R-96-001, "How to Effectively Recover Free Product At Leaking Underground Storage Tank Site, A Guide For State Regulators," September 1996.*

implies that the media concentrations will remain constant, the assumed exposure pathways will stay the same, and that the containment/remediation system will continue to operate.

The conditions are expected to improve over time because the media concentrations will continue to decline in response to active and passive remediations. At some point, EPA may determine that it is appropriate to shut down the system partially or entirely if Star can demonstrate that such actions will not pose unacceptable risks. Until such time is reached, EPA will require Star, among other measures, to continue operation of the containment/remediation system and maintenance of the storm sewers.

With remediation measures in place, EPA does not believe conditions should change for the worse. However, in the highly unlikely event that conditions do get worse, or if the exposure pathways are changed, EPA may decide to revise the media remediation standards that have been established.

(3) Points of Compliance

The points of compliance define the locations of measurement to determine whether the remediation standards are met. Based on the EPA's risk assessment, EPA concludes that groundwater is the only medium that requires remediation. The points of compliance apply to both free-phase and dissolved-phase plumes in groundwater.

The Preamble to the Proposed Subpart S to 40 CFR 264 states that groundwater throughout the contaminated plume area must be returned to drinking water standards. Thus, the points of compliance apply to all areas within the plume boundaries under current conditions.

EPA recognizes that free product thickness, and groundwater concentration to a lesser degree, can vary substantially over time and space. Even with the most thorough cleanup, groundwater standards may still be exceeded at isolated locations and time even though the overall quality has met the standards. EPA will require Star to demonstrate compliance by showing that the constituent concentrations have met groundwater standards statistically, and that such compliance can be sustained for a minimum of three years after system shut down.

B. Requirement (2): Requirement (2) states that existing releases at or from the facility must be eliminated to the maximum extent practicable. Technological limitations will be considered in determining whether "maximum extent practicable" has been achieved in cleanup of existing releases.

Studies have shown that petroleum hydrocarbons are biodegradable in the natural environment provided that no inhibitive factors exist. Inhibitive factors may include extreme pH, a highly *anaerobic* environment, or the presence of toxic chemicals to soil microorganisms. Pilot tests conducted at this site confirmed that natural biodegradation of hydrocarbons is occurring at a slow pace and that natural biodegradation can be accelerated by engineered processes. EPA believes that the groundwater cleanup standards are achievable; however, considering the extent of contamination and the inaccessibility of the contaminated media in many areas, it may take an extended time frame to meet the standards.

EPA's guidance[5] provides a contingency strategy for Star to petition for a Technical Impracticability (TI) determination. The TI contingency strategy does not signal that Star can reduce its efforts to pursue aggressive groundwater restoration. Star must implement the remedy to the maximum extent technologically practicable before considering TI petitioning.

EPA expects that the plume will shrink further as the remediation progresses. Since some areas are expected to be remediated faster than others, and some part of the system may reach technological limitations earlier than the others, Star may request a TI determination in whole or for part of the remediation system in accordance with the provisions contained in EPA's guidance[5].

EPA does not believe that it is feasible to make a reasonable TI determination until after the remedy has been implemented for a sufficient period of time. The site characterization and pilot test data are too limited in scope and duration to make such a determination. To request a TI determination, Star shall present a minimum of five years of remedy performance data to support its TI petition.

Any TI petition developed by Star shall be in accordance with EPA's guidance[5] and shall provide evidence to support a demonstration that the following conditions are met:

(1) The efficiency of the remediation system in reducing the contaminant mass or concentration has leveled off. Further operation of the remediation system is no longer practical from an engineering perspective because the efficiency of the remediation system may not be significantly different from that achievable by natural attenuation, or the gain from further operation is no longer significant relative to the efforts. Star must demonstrate that this leveling off effect is not due to inadequate design, construction or operation of the remediation system, but attributable to inherent technological limitations.

(2) Termination of the remediation/containment system in whole or part will not pose unacceptable risks to human health or the environment considering that the "current conditions" assumption used in the risk assessment will no longer be valid due to the proposed shut down.

(3) Termination of the remediation/containment system in whole or part will not lead to spreading of free product into previously uncontaminated areas. Star must be able to

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[5] *EPA's Directive 9234.2-25, Guidance for Evaluating the Technical Impracticability of Ground-water restoration, Interim Final, September 1993.*

demonstrate that the boundary of the *free phase* plume has stabilized naturally without the need to further operate the remediation/containment system in whole or part.

C. Requirement (3): Requirement (3) states that new and ongoing releases must be prevented to the maximum extent practicable. Technological limitations will be considered in determining whether "maximum extent practicable" has been achieved in preventing new and ongoing releases. No remediation effort would be effective if releases are on going and new releases are not adequately prevented.

A facility leak audit conducted by Clean Sites between 1992 and 1993, under supervision of the Oversight Committee,[6] concluded that none of the aboveground bulk storage tanks was leaking; minor potential leaks were identified in two underground storage tanks, nine underground drain lines and one aboveground pipeline segment. Star took actions to eliminate all potential leaks identified in the audit by repairing the leaks, removing the items from service, or upgrading the items to prevent future leaks.

Under a 1993 Consent Order between Star Enterprise and the Virginia Department of Environmental Quality (VADEQ), Star has completed the following tasks: (a) retrofitting all above-ground bulk storage tanks with double bottoms, (b) constructing dikes along the facility perimeter to prevent catastrophic surface releases, (c) retrofitting, removing or relocating all underground tanks and piping to above ground, and (d) implementing other measures required by VADEQ, both structural and non-structural, to minimize new releases. The facility trench/well barrier system, a component of the interim containment system installed during the emergency phase, is effective in containing not only the existing releases, but also any new releases that may occur if all other measures fail.

EPA has determined that there is no evidence of any ongoing releases, and that efforts to prevent new releases have been maximized. EPA concludes that Requirement (3) has been achieved to the maximum extent practicable, and does not require further action at this time other than requiring Star to continue current efforts as part of the final remedy.

D. Requirement (4): Requirement (4) states that all applicable federal, state and local clean-up requirements must be identified. Fairfax County and the City of Fairfax have not established clean-up standards. Virginia has established clean-up standards for its hazardous waste and underground storage tank programs. EPA's clean-up requirements as set forth in this section have met or exceeded Virginia's clean-up standards.

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[6] *An ad hoc Oversight Committee comprising of representatives from Fairfax citizens, EPA, Star Enterprise, Virginia Department of Environmental Quality, Fairfax County and City of Fairfax was formed to investigate whether there was evidence of any on going releases from the facility. Clean Sites was hired by the Committee to conduct the leak audit. The results of the audit were issued in a March 1993 report entitled, "Task 1 Final Report--Inventory and Assessment of Existing Facilities at the Star Enterprise Pickett Road Facility."*

IX. EVALUATION CRITERIA

The UAO has established seven criteria for the evaluation of the alternatives, which are described below. An in-depth discussion of these criteria can be found in EPA's guidance document, "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (USEPA 1989)." The seven criteria were used to select the PAs in the initial screening phase, and to further rank them in the detailed pilot study phase. The goal is to identify a PA, or a combination of PAs, that will best perform at this site and at the same time will be fully implementable.

A. Technical Feasibility: This criterion addresses all technical aspects of implementing the remedy such as the ability to construct and operate the remedy, the reliability of the technology, flexibility of the technology to accommodate future modifications, and the ability to monitor the effectiveness of the technology.

B. Implementability: This criterion addresses all non-technical aspects of implementing the remedy such as the ability to obtain permits or approval from regulatory agencies, and the availability of capacity, equipment or specialized resources to perform the work.

C. Predicted Effectiveness and Efficiency: These criteria address the predicted performance of the technology. Effectiveness refers to the ability to progress towards the remediation goal, and efficiency refers to the rate of or how fast it can progress towards that goal. The efficiency of a technology is not necessarily constant. An efficient technology today may become less efficient in the future as remediation progresses.

D. Technological Limitations: This criterion addresses the inherent performance limitation of a technology. Technological limitations will be considered in determining whether "maximum extent practicable" has been achieved.

E. Capital and Operation Costs: Capital costs refer to the design and construction costs of the remedy. Operation costs refer to long-term operation costs of the remedy.

F. Estimated Time to Meet Remediation Requirements: This criterion addresses the estimated time frame to reach the remediation goal or some milestones of that goal. It is rarely possible to predict with a high degree of certainty the remediation time frame until the remedy has been implemented for some time. For the purpose of comparing performance, a best estimate of the relative time frame would be adequate.

G. Potential Short-Term and Long-Term Interference with Public Welfare: This criterion addresses public disruptions associated with implementation of the remedy such as noise and traffic disruptions. Typically, short-term interference is associated with construction of the remedy, whereas long-term interference is associated with its operation.

X. PILOT STUDIES

A series of pilot tests was conducted to evaluate the PAs. Major findings and EPA's evaluation of the results are summarized below. For a detailed description of the test methods and results, readers are encouraged to review the original pilot test reports included in the Administrative Record.

A. Laboratory and Site Characterization Studies: These studies consist of five laboratory experiments and two field tests to evaluate bioremediation and *oil* distribution in the *smear zone*.

(1) Hydrocarbon Distribution Study: This study measured *oil* distribution in the *smear zone* soils. The results show that *oil* is distributed non-uniformly between the saprolite *matrix* (uniform area) and fractures. Generally, but not consistently, the concentration of *oil* in the fractures is greater than that in the adjoining *matrix*. Among the most *oil*-contaminated samples, less than 10 percent of the pore spaces is occupied by *oil*, with the remainder occupied by air and water. Unlike *oil* floating on surface water, *oil* in the subsurface does not exist as a continuous thickness of liquid and does not fully saturate the soil pore spaces. The most contaminated soil samples at this site were saturated with less than 10 percent of *oil* dispite the fact that several feet of *oil* may be measurable in the adjacent monitoring wells. Thus, the apparent *oil* thickness observed in a monitoring well is a poor indicator of the true amount of *oil* in the surrounding soil.

(2) In-situ Oxygen Uptake Study: This test measured oxygen consumption rate, which is an indicator of biological activities, by injecting air into the unsaturated zone at different locations. The results show that air flow distribution in the unsaturated zone is highly irregular, concentrating in a few unpredictable flow paths.

(3) Dissolved Oxygen Mapping: Dissolved oxygen in groundwater averaged 1.3 mg/l within the *oil* plume, and 3.5 mg/l outside the *oil* plume. For comparison, water quality criteria for surface water typically require a minimum of 5 mg/l oxygen. The data suggest that groundwater within the *oil* plume is slightly *aerobic* and natural biodegradation is occurring at a very slow rate due to low oxygen concentrations. Outside the *oil* plume, the oxygen concentrations are relatively high for groundwater, suggesting that natural biodegradation is occurring at a faster pace and apparently is effective in limiting the extent of the *dissolved phased* plume.

(4) Microbial Enumeration and Microbial Stimulation Studies: These laboratory experiments confirmed the presence of viable microbial populations, and that the rate of biodegradation can be enhanced by adding oxygen and a small amount of nitrogen.

(5) Unsaturated Zone Biodegradation Study: This laboratory experiment showed that adding nitrogen has a greater effect in enhancing biodegradation than adding phosphate, if oxygen is in unlimited supply.

(6) Slurry Phase Respirometry Study: This test measured oxygen demand under laboratory conditions. The test results indicate that oxygen demand from non- *BTEX* hydrocarbons in the soil is high. This oxygen demand competition from non- *BTEX* hydrocarbons reduces oxygen availability to degrade target *BTEX* compounds and as a result, a very long treatment time is needed to accomplish thorough cleanup.

B. Groundwater Infiltration Pilot Study: This test evaluated artificial groundwater recharge to enhance the performance of the ICS. The results indicate that the horizontal well is effective in recharging the *aquifer*, raising the local water table, and flushing the saturated and unsaturated zones. Groundwater flushing enhances the operation of the ICS by increasing the extraction rate without depressing the water table and enlarging the *smear zone*. Since the injected water is rich in oxygen, the oxygenated water enhances natural biodegradation in the saturated and unsaturated zones. The *zone of influence* created by the horizontal well is large in comparison to all other technologies tested at this site. Within the *zone of influence*, the *BTEX* concentrations were reduced by over 85 percents after five months of flushing and the reduced concentrations appear to be sustainable in the *bounce-back* study.

C. Mantua Microbial Fence Pilot Study: This test evaluated the feasibility of using a microbial fence to stop *BTEX* migration. A gravel-filled trench fitted with air sparging and vapor extraction wells was constructed at the front end of the plume. Since vacuum extraction and air sparging techniques were used, this test also provided data to evaluate three other PAs-- vacuum extraction, bioventing, and *aquifer* aeration/vacuum extraction. The following results were observed:

(1) *BTEX* levels declined in, and downgradient of, the trench but rose unexpectedly upgradient of the trench; and

(2) All other biochemical indicator parameters were either unaffected or responded erratically . For example, no noticeable changes in dissolved oxygen, carbon dioxide, pH and conductivity levels were observed downgradient of the trench, but biochemical oxygen demand and chemical oxygen demand levels rose unexpectedly inside the trench during air sparging operation. EPA is uncertain of the exact causes despite Star's attempt to explain these unexpected responses.

D. Chevron Microbial Fence Pilot Study: This test evaluated the use of oxygen releasing compounds to promote biodegradation. Magnesium peroxide was introduced in a supply well, and *BTEX*, DO, pH, microbial populations, among other parameters, were monitored at and downgradient of the supply well. A large reduction in *BTEX* and a substantial increase in DO and pH were observed at the supply well, but no changes were detected immediately downgradient of the supply well. These observations suggest that the *zone of influence* is extremely limited. Furthemore, the reduction of *BTEX* in the supply well may not necessarily be attributable to biological activities because the pH at the supply well was elevated to above 9.5, an extreme pH condition for viable biological activities.

E. Vacuum Enhanced Recovery (VER) Pilot Study: This test evaluated the effectiveness of increasing product recovery by applying a vacuum to recovery wells. This test was conducted at two separate wells in the Common Area. At the first well, a large increase in *oil* recovery (130 gallons) was observed initially, but the performance was not sustainable at a later time. At the second well, no increase in *oil* recovery was observed. At both wells, a large increase in water flow rate was observed by applying the vacuum. The flow rate increase is proportional to the magnitude of vacuum applied and matches theoretical predictions. The *zone of influence* can be measured by two different methods--based on vacuum level response or water level response. In either method, the *zone of influence* is proportional to the magnitude of vacuum applied, and is skewed to the northeast. The *zone of influence* ranges from 10 to 200 feet depending on the measurement method and orientation.

F. Soil Vapor Extraction Pilot Tests. Two tests, not planned as a part of the master pilot test plan, were conducted in 1993 and 1996. The first test was conducted at the southeast corner of the former Chevron Terminal. A single vapor extraction well was operated and the vacuum *zone of influence* was measured. The results show that the vacuum *zone of influence* ranges between 20 to 55 feet, and the amount of vapor extracted was small. A second test was conducted in 1996 at four locations--Common Area, loading rack, southeast and southwest corners of the Star Terminal. The vacuum zones of influence were small, ranging from 5 to 30 feet depending on locations and direction of measurement.

G. Air sparging Pilot Test: This test, not planned as a part of the master pilot test plan, was conducted in 1993 at the southeast corner of the former Chevron Terminal. Air was sparged into a single well and the dissolved oxygen (DO) influence was measured. The DO *zone of influence* was small, ranging from 6 to 16 feet depending on the direction of measurement.

XI. EVALUATION OF ALTERNATIVES

EPA's evaluation of the PAs and recommendations are presented below. Based on site-specific pilot test data and other relevant information, the PAs were compared against the seven evaluation criteria. The objective is to identify a PA or a combination of PAs that will best perform at the site, and at the same time be fully implementable without undue technical or administrative constraints.

A. Vacuum Enhanced Recovery:

(1) Technical Feasibility: The VER technology is technically feasible if it is applied on a localized basis. It is technically infeasible to apply VER on a site-wide basis because it is necessary to retrofit the entire ICS with VER. A site-wide VER system is difficult to operate and maintain because it can lose vacuum and effectiveness quickly if a leak occurs somewhere in the system, which is difficult to locate and repair. Application of VER using a vacuum truck or a portable skid-mount unit is highly flexible. It is easy to operate, maintain and relocate from well

to well except in difficult-to-reach areas. It can be applied to ICS and non-ICS wells individually. Its operation can be modified easily based on operation experience. Among all PAs evaluated, mobile VER is the most flexible technology.

(2) Implementability: No significant implementation issues have been identified. If VER must be applied to wells in private properties, access agreements from the owners will be required. Since nearly all target VER wells are located in the terminal or public areas, no access restrictions are anticipated.

(3) Predicted Effectiveness and Efficiency: Based on the VER pilot test results, the effectiveness of VER in increasing *oil* recovery is well-specific and short-term. It will likely be successful at some wells, but not at all wells. If the application is successful, the efficiency in increasing *oil* recovery will likely be high initially, but will level off relatively quickly. VER increases total fluid flow rate (water with more or less *oil*) consistently without depressing the water table and enlarging the *smear zone*. Theoretically, an increase in the total fluid flow rate will increase *oil* recovery, provided that a source of mobile *oil* is intercepted by the well. Once this *oil* is depleted, the efficiency will drop off. The effectiveness and efficiency vary from well to well depending on whether the VER well has intercepted a continuous source of mobile *oil*.

(4) Technological Limitations: Technological limitation will be indicated by a leveling off effect of the amount of *oil* recovered. It varies from well to well and is difficult to predict.

(5) Capital and Operation Cost: Based on Star's estimates, the capital cost of mobilizing a VER unit per well is between $4,000 to $7,000, and the operation cost is about $5,000 per week. The capital cost is the lowest among all PAs because no permanent construction is required.

(6) Estimated Time to Meet Remediation Requirements: The efficiency of VER operation varies from well to well and operation time. The time to reach leveling-off effect is expected to be relatively short, probably less than one month.

(7) Potential Short-Term and Long-Term Interference with Public Welfare: There will be short-term noise and aesthetic disruptions during VER operation; however, most disruptions are in non-residential areas.

Recommendation: EPA recommends implementation of mobile VER on selected, high yielding wells based on past bailing performance record. Between six to eight target wells have been identified initially; they are located in the commercial, Common and terminal areas. Since mobile VER is a flexible technology, final selection of target wells and operation protocol will be determined and modified as appropriate based on actual operation experience.

B. Saturated Zone Bioremediation:

(1) Technical Feasibility: The construction and operation of a conventional well or trench based oxygen/*nutrient* delivery system may not be technically feasible in areas obstructed by buildings or fixed structures. Horizontal wells offer a technically feasible alternative to effectively deliver oxygen or *nutrient* enriched water to difficult-to-reach areas.

(2) Implementability: Permits must be obtained from Fairfax County or the City of Fairfax for the construction of a system to deliver oxygen and nutrients to the subsurface. Approval must be obtained from VADEQ for the injection of *nutrient*s-amended water.

(3) Predicted Effectiveness and Efficiency: The laboratory pilot studies have demonstrated that the residual hydrocarbons at the site are fully biodegradable, and no inhibition factors exist except for low ambient groundwater oxygen contents. This offers opportunity to enhance biodegradation by artificially replenishing groundwater with oxygen. The effectiveness and efficiency of saturated zone bioremediation depends on the ability to effectively deliver oxygen to groundwater. Both air sparging and the use of oxygen releasing compounds were experimented at this site. The experiments failed to demonstrate the effectiveness of either method, because the oxygen *zone of influence* created is extremely small, requiring impractically close spacing of oxygen supply wells. The horizontal well test, however, demonstrated that it was feasible to deliver oxygen-rich water to a large area effectively, including areas obstructed by fixed structures.

(4) Technological Limitations: Two major technological limitations were identified: (a) It is difficult to deliver oxygen uniformly to groundwater. Even with the best oxygen delivery system installed, some portions of the *aquifer* are inaccessible, relying on slow rate of oxygen *diffusion* to remediate these inaccessible zones; and (b) there is high oxygen demand competition from non- *BTEX* hydrocarbon compounds. Less than 1 percent of the hydrocarbon compounds at this site are *BTEX*; the remaining 99 percent compete with *BTEX* for oxygen. This reduces the availability of oxygen to degrade target *BTEX* compounds.

(5) Capital and Operation Costs: Based on Star's estimates, construction of the horizontal wells would cost $200,000 and subsequent operation would cost $100,000 per year.

(6) Estimated Time to Meet Remediation Requirements: It is not feasible to estimate accurately the remediation time frame until the system has been installed and operated for some time.

(7) Potential Short-Term and Long-Term Interference with Public Welfare: Short-term disturbances are anticipated with the construction of oxygen/*nutrient* delivery systems. Noise interference is anticipated with the operation of an air sparging system, but no noise is associated with the use of oxygen releasing compounds or operation of horizontal wells.

<u>Recommendation</u>: EPA does not recommend implementation of a dedicated saturated zone bioremediation system because it offers no advantage over a groundwater flushing system using horizontal wells which can achieve equivalent or better results with less effort.

C. <u>Microbial Fence</u>:

(1) Technical Feasibility: The construction and operation of the Mantua Microbial Fence demonstrated that this technology is highly intrusive. To take full advantage of this technology, additional fences would need to be placed between Star Terminal and the front end of the plume. It is technically infeasible to place these fences in ideal locations due to obstruction by buildings and fixed structures.

(2) Implementability: Construction permits are needed from Fairfax County, City of Fairfax and/or the Virginia Department of Transportation to install additional fences across the middle of the plume. Approval would be difficult to obtain in areas with dense underground utilities and fixed structures.

(3) Predicted Effectiveness and Efficiency: The purpose of the microbial fence technology is to create a bioactive zone where polluted groundwater that enters the zone will be cleaned up before leaving the zone. EPA is not certain whether the removal of *BTEX* in the Mantua Microbial Fence was due to microbial activities, or due to physical stripping actions. The water detention time in the trench was too short for biological activities to be the predominant mechanism. The oxygen *zone of influence* was nearly non-detectable beyond the Mantua Microbial Fence, suggesting that the bioactive zone is extremely limited. An effective bioactive zone should not be limited to the physical boundary of the trench itself. Therefore, EPA does not consider the Mantua microbial fence pilot study successful despite Star's claim to the contrary. Furthermore, EPA is concerned with the elevation of *BTEX* concentrations upgradient of the trench and elevation of BOD and COD concentrations in trench during sparging operation, regardless of Star's explanation for these aberrant responses.

(4) Technological Limitations: The limited effectiveness of the Mantua Microbial Fence may be explained by two technological limitations: (a) slow rate of natural groundwater movement to effectively distribute oxygenated water; and (b) high biological oxygen demand from non-*BTEX* hydrocarbon compounds that compete with *BTEX* for oxygen.

(5) Capital and Operation Costs: According to Star's estimates, the capital costs to install two microbial fences along Pickett Road and the Common Area would be $3 million. Operational costs for both fences would be $220,000 per year.

(6) Estimated Time to Meet Remediation Requirement: This criterion is not relevant because effectiveness of the technology has not been demonstrated.

(7) Potential Short-Term and Long-Term Interference to Public Welfare: Both the installation and the operation of additional microbial fences at Pickett Road and the Common Area are highly intrusive activities.

Recommendation: EPA does not recommend implementation of the microbial fence technology because its effectiveness has not been demonstrated, and the technology is highly disruptive.

D. Groundwater Flushing:

(1) Technical Feasibility: It is technically feasible to install horizontal wells beneath roads, buildings and woods to implement groundwater flushing. No other PA is capable of extending the remediation zone to these difficult-to-reach areas without creating extensive surface disruptions.

(2) Implementability: No non-technical implementation obstacles are identified that would preclude implementation of this technology. Permits would have to be obtained from the Virginia Department of Transportation, Fairfax County and/or the City of Fairfax to install the horizontal wells in the Common Area and in the Commercial strip. Approval would have to be obtained from VADEQ if it is necessary to inject recycled water from the ICS treatment system or to add nutrients to the water.

(3) Predicted Effectiveness and Efficiency: The horizontal well installed on Tovito Drive for the groundwater infiltration pilot study has been in operation since September 1994. The data available from this three-year-long operation demonstrated that horizontal well flushing is effective in flushing the saturated and unsaturated zones, increasing the ICS extraction rate without depressing the water table and enlarging the *smear zone*, and raising the water table along Tovito Drive to enhance hydraulic containment. Groundwater *BTEX* in the remediation zone were reduced by an average of 85 percent and to below MCLs in some wells. The ICS is presently operating at less than 10 percent of its maximum potential capacity. Without groundwater flushing, an increase in the ICS extraction rate would be counterproductive due to depression of the water table below the trench and pump intake elevations, and enlarging the *smear zone*. Groundwater flushing increases the extraction rate of ICS without depressing the water table. Additionally, groundwater flushing enhances biodegradation by delivering oxygen-rich water to impacted zones. Groundwater flushing is the only PA capable of remediating both the saturated and unsaturated zones, enhancing biodegradation and product recovery, and improving the efficiency of the ICS all at the same time. Among all PAs tested, horizontal well flushing has generated the largest remediation zone.

(4) Technological Limitations: Improperly controlled groundwater flushing may lead to migration of the plume and excessive elevation of the water table. Groundwater flushing is often operated in conjunction with an extraction system, and the two systems must be carefully managed to achieve desirable effects. Even with the best system in place, some portions of the

aquifer may not be impacted by the flushing, relying on slow rates of oxygen and contaminant *diffusion* to remediate these inaccessible zones.

(5) Capital and Operation Costs: According to Star's estimates, the capital cost of construction for five new horizontal wells would be $1.1 million, and the operation cost would be $310,000 per year.

(6) Estimated Time to Meet Remediation Requirements: It is not feasible to reliably estimate the remediation time until the system is in place and operated for some time.

(7) Potential Short-Term and Long-Term Interference: Short-term construction interference of up to 4 months is expected in the Common Area and in the commercial strip. The horizontal wells will be remotely controlled at the terminal. The operation does not generate any noise and is nearly invisible.

Recommendation: EPA recommends implementation of horizontal well flushing by installing two new lines of horizontal wells along the Common Area and the commercial strip. Groundwater flushing is recommended chiefly because it is the most effective technology among all PAs evaluated, it can remediate the saturated zone, unsaturated zone and difficult-to-reach areas, and it has generated the largest *zone of remediation* among all PAs tested.

E. Bioventing:

(1) Technical Feasibility: Bioventing technology requires installation of air venting wells in the unsaturated zone. It will be technically infeasible to install air venting wells in areas obstructed by buildings and subsurface structures. This technology is feasible for localized application only.

(2) Implementability: No non-technical constraints are identified that would preclude implementation of this technology. An air discharge permit from VADEQ may be required if air emission is expected to exceed state threshold limits.

(3) Predicted Effectiveness and Efficiency: The success of bioventing technology depends on good, uniform distribution of air flow. The *in-situ* oxygen uptake pilot study demonstrated that induced air flow in the unsaturated zone was highly irregular, concentrating in a few unpredictable flow paths. The air flow *zone of influence* was extremely small, and only a small fraction of the soil mass was treated. As a result, the effectiveness of bioventing at this site has not been demonstrated.

(4) Technological Limitations: The small *zone of influence* necessitates very close spacing of air venting wells, which is impractical. The concentration of air flow in a few preferential flow paths precludes effective remediation of a large volume of soil.

(5) Capital and Operation Costs: Star estimated the capital cost to install a localized system would be $1.9 million, and the operation cost would be $260,000 per year.

(6) Estimated Time to Meet Remediation Requirement: This criterion is irrelevant since the effectiveness of this technology has not been demonstrated.

(7) Potential Short-Term and Long-Term Interference: Construction of the air venting system would create short-term interference. Operation of the air compressor or vacuum system would generate noise unless it is adequately controlled

Recommendation: EPA does not recommend implementation of bioventing because effectiveness of this technology has not been demonstrated.

F. Vapor Extraction:

(1) Technical Feasibility: Vapor extraction technology requires installation of air extraction wells in the unsaturated zone. It will be technically infeasible to install vapor extraction wells in areas obstructed by buildings and fixed structures. This technology is feasible for localized application only.

(2) Implementability: No non-technical constraints are identified that would preclude implementation of this technology. An air discharge permit from VADEQ may be required if air emission is expected to exceed state threshold limits.

(3) Predicted Effectiveness and Efficiency: The success of vapor extraction depends on uniform distribution of induced air flow. The *in-situ* oxygen uptake pilot study indicated that the induced air flow in the unsaturated zone was highly irregular, concentrating in a few unpredictable flow paths. The vacuum enhanced recovery pilot test also demonstrated that the vacuum *zone of influence* was small. The limited *zone of influence* and concentration of air flow in a few preferential pathways suggest that only a small fraction of the soil mass can be treated. As a result, the effectiveness of vapor extraction technology has not been demonstrated at this site.

(4) Technological Limitations: The small *zone of influence* necessitates very close spacing of air extraction wells, which is impractical. The concentration of air flow in a few preferential flow paths and short-circuiting of air from the surface near the well preclude effective remediation of a large volume of soil.

(5) Capital and Operation Costs: Star estimated the capital cost to install a localized system would be $1.9 million, and the operation cost would be $260,000 per year.

(6) Estimated Time to Meet Remediation Requirement: This criterion is irrelevant since the effectiveness of this technology has not been demonstrated.

(7) Potential Short-Term and Long-Term Interference: Construction of the vacuum extraction would create short-term interference. Operation of the vacuum unit can generate noise interference unless it is adequately controlled.

Recommendation: EPA does not recommend implementation of vapor extraction because effectiveness of this technology has not been demonstrated.

G. Aquifer Aeration with Vapor Extraction:

(1) Technical Feasibility: This technology is a combination of vapor extraction and groundwater sparging to extend the remediation zone to both the saturated and unsaturated zones. Vapor extraction requires installation of air extraction wells in the unsaturated zone. Air sparging requires operation of air sparging wells in the saturated zone using new or existing wells. It will be technically infeasible to install vapor extraction wells and sparging wells in areas obstructed by buildings and subsurface structures. This technology is feasible for localized application only.

(2) Implementability: No non-technical constraints are identified that would preclude implementation of this technology. An air permit may be required from VADEQ if air emission is expected to exceed state threshold limits.

(3) Predicted Effectiveness and Efficiency: The success of air sparging requires uniform aeration of a large zone of groundwater. The air sparging operation conducted in the Mantua Microbial Fence pilot study demonstrated that the oxygen *zone of influence* was very limited--it did not extend beyond the trench itself. The unexpected elevation of *BTEX* upgradient of the Mantua Microbial Fence trench, and elevation of BOD and COD in trench, may suggest that air sparging could be counterproductive due to emulsification of *oil*. The success of vapor extraction requires uniform distribution of induced air flow in the unsaturated zone and complete capture of vapor generated by the air sparging wells. The *in-situ* oxygen uptake pilot study demonstrated that the induced air flow in the unsaturated zone was highly irregular, concentrating in a few erratic flow paths. Therefore, complete capture of induced vapor may not be feasible. The vacuum enhanced recovery pilot tests demonstrated that the vacuum zones of influence were very small. In conclusion, the combined *aquifer* aeration/vapor extraction technology has not been demonstrated to be effective at this site.

(4) Technological Limitations: The small vacuum and aeration zones of influence necessitate very close spacing of air extraction and air sparging wells, which is impractical. The erratic distribution of air flow in the unsaturated zone suggests that it may not be feasible to capture all vapor generated by the air sparging system, which may induce migration of vapor.

(5) Capital and Operation Costs: Star estimated the capital cost to install a localized system would be $2.5 million, and the operation cost would be $300,000 per year.

(6) Estimated Time to Meet Remediation Requirement: This criterion is irrelevant since the effectiveness of this technology has not been demonstrated.

(7) Potential Short-Term and Long-Term Interference: Construction of the vacuum extraction and air sparging systems would create short-term interference. Operation of the vacuum and air sparging units would generate noise unless it is adequately controlled.

Recommendation: EPA does not recommend implementation of *aquifer* aeration /vapor extraction because the effectiveness of this combined technology has not been demonstrated.

H. Natural Attenuation

(1) Technical Feasibility: Natural attenuation is not a remediation technology, but a naturally occurring phenomenon. Therefore, it is always feasible.

(2) Implementability: There are no implementation issues associated with a naturally occurring process.

(3) Predicted Effectiveness and Efficiency: Since hydrocarbons are fully biodegradable, natural attenuation is effective in ultimately eliminating all hydrocarbons. The rate or efficiency of natural attenuation is extremely low within the *oil* plume due to low groundwater oxygen concentrations, slow rate of natural oxygen replenishment, and high oxygen demand competition from non-*BTEX* hydrocarbon compounds. Outside the *oil* plume area where the oxygen concentrations are relatively high, the rate of natural attenuation is occurring at a faster pace. Natural attenuation appears to be effective in retarding the migration of *dissolved phase* constituents, thereby limiting the extent of the *dissolved phase* plume to within a short distance (generally less than 50 feet) from the *oil*-water interface.

(4) Technological Limitations: The rate of natural attenuation is extremely slow due to low ambient groundwater oxygen concentrations within the plume, high oxygen demand competition from non- *BTEX* hydrocarbon compounds, and the slow rate of natural oxygen replenishment.

(5) Capital and Operation Costs: There are no operation or capital costs associated with a natural process.

(6) Estimated Time to Meet Remediation Requirements: Without active remediation enhancement, natural attenuation will take many years, probably over a century, to remediate groundwater to drinking water standards.

(7) Potential Short-Term and Long-Term Interference: Natural attenuation is a naturally occurring process, and therefore it is completely non-intrusive.

Recommendation: EPA does not recommend natural attenuation as a sole remedy. EPA recommends active remediation until such time that the efficiency of active remediation has reached diminishing returns or technological limitations, and no longer can perform better than natural attenuation. At that time, active remediation can be terminated and natural attenuation will continue to restore groundwater to drinking water standards.

I. Localized Ex-situ Treatment Options

(1) Technical Feasibility: It is technically infeasible to conduct a site-wide excavation, but feasible on a localized basis in areas not obstructed by buildings, fixed structures and underground utilities.

(2) Implementation: No non-technical implementation obstacles are anticipated if the extent of excavation is small. Excavation and tree removal permits must be obtained from regulating jurisdictions. It would be difficult to obtain excavation permits in areas with densely distributed underground utilities and fixed structures.

(3) Predicted Effectiveness and Efficiency: Excavation is the most effective and efficient means to remove small volumes of highly contaminated soil near the surface. Excavation is often used to remove soil hot spots (defined by EPA as highly-contaminated soils posing imminent threat to human health or the environment) rapidly. EPA's risk assessment has not identified any soil hot spots. Large-scale excavation of soil at low contaminant concentrations is inefficient, particularly if the soil is located at great depth or obstructed by structures.

(4) Technological Limitations: Soil cannot be excavated from under buildings and fixed structures. The excavation and transportation activities may pose risks to human health due to release of fugitive vapor and dust unless the activities are carefully controlled. If the soil hot spots are not completely removed, the backfill may create preferential pathways for groundwater recharge, leading to accelerated migration of contaminants.

(5) Capital and Operation Costs: Excavation of large volumes of soil with low contaminant concentrations is not cost effective. Star estimated that it would cost $15 million to remove two areas of highly contaminated soils in the Common Area and within the terminal. There will be no long-term operation cost associated with excavation.

(6) Estimated Time to Meet Remediation Requirements: Excavation will instantly eliminate soil hot spots. However, unless it is applied site-wide, localized excavation alone will not restore groundwater to drinking water standards.

(7) Potential Short-Term and Long-Term Interference: Excavation is the most intrusive option among all PAs evaluated. Excavation would generate short-term noise, dust, odor and possibly traffic and utilities interruptions.

Recommendation: EPA's risk assessment has not identified any soil "hot spots" that need to be eliminated immediately. EPA does not recommend excavation.

XII. RECOMMENDATIONS

As a long-term remedy, EPA proposes to continue operation of the existing pump-and-treat system (ICS) in conjunction with two new components: groundwater flushing and vacuum enhanced recovery (VER). Based on the review of the pilot test results, EPA concludes that groundwater flushing and VER are the best performing technologies at this site, and there are no technical or administrative constraints that would preclude their implementation. There are many reasons cited in Section XI describing why groundwater flushing and VER are the best implementable technologies, and why others are not. Most importantly, groundwater flushing has generated the largest *zone of remediation* among all PAs tested. Both groundwater flushing and VER can increase the pumping rate of existing wells without depressing the water table and enlarging the *smear zone*, the former technology being effective on a site-wide basis and the latter technology on a localized basis. Groundwater flushing will be accomplished by operating three lines of horizontal injection wells installed along Tovito Drive, the Common Area, and the Commercial strip. Vacuum enhanced recovery will be accomplished by operating a mobile vacuum unit on selected, high productivity wells located in non-residential areas.

XIII. PUBLIC COMMENT PROCESS

EPA is issuing this SB to support EPA's proposal of the remedy and to satisfy the public participation requirements of the selection process. EPA encourages the public to review the Administrative Record to gain a comprehensive understanding of the site conditions and rationale for proposing the remedy. The Administrative Record can be reviewed at the Fairfax City Library located at:

Fairfax City Regional Library - Virginia Room
3915 Chain Bridge Road
City of Fairfax, Virginia 22031
Telephone: 703-246-2123

On April 22, 1998, at 8:00 pm, EPA will hold a public meeting at the Mantua Elementary School, Mantua Development, Fairfax County to explain the proposed remedy and to announce the beginning of a 45-day public comment period. Interested parties may submit written comments to EPA before June 7, 1998 at the following address:

> Mr. Andrew Fan
> EPA Region III
> 3WC23
> 841 Chestnut Building
> Philadelphia, PA 19107.
> Telephone: 215-566-3426

EPA will select a final remedy after considering all comments received during the public comment period. All comments that are within the scope of this decision will be considered by EPA in making its final decision. EPA may modify the proposed remedy or select a different alternative based on information and comments received from the public during the public comment period.

4-14-98
Date

John R. Pomponio, Acting Director
Waste and Chemicals Management Division

4/14/98
Date

Abraham Ferdas, Acting Director
Hazardous Site Cleanup Division

GLOSSARY

(Terms in *italic* in the text are defined in this Glossary)

Aerobic - A condition in which molecular oxygen is present. *Aerobic* metabolism is a process whereby microorganisms use oxygen as an electron acceptor to generate energy.

Anaerobic- A condition in which molecular oxygen is totally absent. *Anaerobic* metabolism is a process whereby microorganisms use chemical compounds other than oxygen as an electron acceptor to generate energy. Common alternative electron acceptors are nitrate, sulfate and carbonate.

Aquifer - An underground geologic formation, or group of formations containing useable amounts of groundwater that can supply wells and springs.

Benzene, Toluene, Ethylbenzene and Xylene (*BTEX*) - A group of volatile hydrocarbons derived from a single benzene ring. *BTEX* are moderately soluble in water and lighter fuel oils contain more *BTEX* than heavier ones. *BTEX* are toxic petroleum constituents and benzene is a known carcinogen.

Bounce Back - The reappearance of constituents in groundwater after the concentration has decreased in response to remediation.

Diffusion - The process by which both ionic and molecular species dissolved in water move from areas of higher concentrations to areas of lower concentrations.

Dissolved phase Hydrocarbons - Petroleum constituents, such as benzene, toluene, ethylbenzene and xylenes (*BTEX*), that have dissolved in groundwater. The *oil* at the site is largely insoluble. Less than 1 percent of the *oil* constituents have dissolved in groundwater, forming a large *dissolved phase* hydrocarbon plume beneath the *free phase oil* plume.

Ex-situ methods - Treatment methods that require excavation of the contaminated media prior to treatment.

Free Phase Plume or Phase Separated Hydrocarbons (PSH) - A separated *oil* phase from water as opposed to *dissolved phase hydrocarbons* in groundwater. PSH is referred to as "oil" in this document.

In-situ methods - Methods that treat the contaminated media in place.

Macroinvertebrates - A group of benthic (bottom dwelling) organisms including, but not limited to, crustacean, insect larvae, worms and mollusc. Ecologists evaluate the health of the aquatic environment by comparing the diversity and abundance of *Macroinvertebrates*.

Matrix - The basic material and/or structure of the solid in which the constituents of concern are suspended, encapsulated, or adsorbed. The soil *matrix* refers to the relatively uniform areas as opposed to the fractured areas.

Nutrient - A chemical element necessary for microorganisms and plant growth. Essential nutrients include but not limited to nitrogen, phosphorus, and potassium.

Oil - A separated oil phase from water as opposed to *dissolved phase hydrocarbons* in groundwater. Oil, as used in this document, may be referred to as *Phase Separated Hydrocarbons*, liquid phase hydrocarbons, *free phase plume*, petroleum free product or product.

Parts Per Million (ppm) - A unit of concentration of a chemical substance expressed as a ratio by weight of the chemical to the medium. One ppm is equivalent to 1 mg/kg in water or soil. In low concentrations, one ppm is almost equal to 1 mg/l in water.

Parts Per Billion (ppb) - A unit of concentration of a chemical substance expressed as a ratio by weight of the chemical to the medium. One ppb is equivalent to 1 ug/kg in water or soil. In low concentrations, one ppb is almost equal to 1 ug/l in water.

Polycyclic Aromatic Hydrocarbons (*PAHs*) - A group of semi-volatile hydrocarbons derived from multiple rings (usually of benzene type) such as naphthalene, fluorene, anthracene, pyrene or acenapthene. *PAHs* have low solubility and are found in heavier fuel oils. Some *PAHs* are probable carcinogens.

Smear zone - The soil, above or below the water table, that has been contaminated with *oil* due to migration of mobile *oil* from the release sources or due to fluctuation of the water table that carries mobile *oil*. *Oil* is defined as *free phase* hydrocarbons in this document. Only a fraction of the total amount of *oil* in the soil is mobile under gravity. At the source area, the *smear zone* typically extends from near the ground surface where the release occurred to the water table. Away from the source area, the *smear zone* typically extends between the historical high and low water table positions.

Total petroleum hydrocarbons (*TPH*) - Petroleum products are made up of complex mixtures of organic compounds called hydrocarbons. Each hydrocarbon molecule is made up of elements of hydrogen and carbon connected in chains, rings or both. *TPH* is a generic measurement of the total quantity of hydrocarbons regardless of the types.

Zone of Influence - The horizontal and vertical extent in an *aquifer* affected by the application of external stresses such as air injection or extraction, water injection or extraction, induced vacuum or engineered biodegradation through wells or trenches.

Zone of remediation - The horizontal and vertical extent in an *aquifer* that is impacted by the application of a particular remediation technology.