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CITY OF OAKLAND

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June 25, 2001

JUN 28 2001

Mr. Barney Chan
Alameda County Environmental Health Services
1131 Harbor Bay Parkway
Alameda, California 94502-6577

Subject: **Evaluation of Free-Product Removal Alternatives For Petroleum Hydrocarbons Report - City of Oakland Municipal Service Center 7101 Edgewater Drive Oakland, California**

Should respond

Dear Mr. Chan:

Enclosed is your copy of the *Evaluation of Free-Product Removal Alternatives For Petroleum Hydrocarbons Report-City of Oakland Municipal Service Center 7101 Edgewater Drive Oakland, California*, dated June 2001 and prepared by our consultant, URS Corporation.

Please call me at 238-6259, if you have any questions or require additional information.

Sincerely,

Joseph A. Cotton
Environmental Program Specialist

cc: Diane Heinz, Port of Oakland

REPORT

EVALUATION OF FREE-PHASE PRODUCT REMOVAL ALTERNATIVES FOR PETROLEUM HYDROCARBONS

CITY OF OAKLAND
MUNICIPAL SERVICE CENTER
7101 Edgewater Drive
Oakland, California

Prepared for
City of Oakland
Public Works Agency
Environmental Services Division
250 Frank H. Ogawa Plaza, Suite 5301
Oakland, CA 94612

June 2001

URS
500 12th Street, Suite 200
Oakland, California 94607

51-00129010.00

URS

June 18, 2001
5100129010.00

Mr. Joseph Cotton
City of Oakland, Public Works Agency
Environmental Services Division
250 Frank H. Ogawa Plaza, Suite 5301
Oakland, CA 94612

Subject: Evaluation of Free-Phase Product Removal Alternatives, City of Oakland Municipal Service Center 7101 Edgewater Drive, Oakland, California

Reference: Consultant Assignment # CO-250-1 Environmental Consulting Services Contract

Dear Mr. Cotton:

URS Corporation (URS) is pleased to submit this evaluation report for free-phase product removal alternatives for the petroleum hydrocarbon plumes identified at the City of Oakland Municipal Service Center. The five alternatives evaluated are 1) monitored natural attenuation, 2) enhanced bioattenuation, 3) groundwater extraction and treatment, 4) additional excavation and off-site disposal, and 5) dual-phase extraction. The alternatives are evaluated based on their effectiveness, implementability, and cost. The recommended alternative is the dual-phase extraction. We can start the dual-phase extraction at Plume C within 60 days after receiving approval from Alameda County Department of Environmental Health.

The work is performed in accordance with the environmental consulting services contract signed between the City of Oakland and URS Corporation on November 20, 2000 and the consultant assignment # CO-250-1 signed on February 22, 2001. Please contact Mr. Xinggang Tong at (510) 874-3060 for questions and comments.

Sincerely,

URS CORPORATION

Xinggang Tong, Ph.D., P.E.
Project Manager

REGISTERED PROFESSIONAL ENGINEER XINGGANG TONG No. C 056202 Exp. 12/31/04 CIVIL STATE OF CALIFORNIA

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The City of Oakland Municipal Services Center (MSC) is located at 7101 Edgewater Drive, Oakland, CA (Figure 1). The site was originally part of a waterfront tidal marsh complex, which was filled between 1950 and 1971. The MSC occupies an area of approximately 17 acres. The City leased the land from the Port of Oakland for use as a corporation yard. Bordering the MSC site to the west and the north is the Martin Luther King Regional Shoreline Park. This park land is also owned by the Port of Oakland. Damon Slough is located to the north, and commercial developments are located to the east and south.

Baseline Environmental Consulting of Emeryville, CA (Baseline) has recently summarized the site history and environmental investigation and remediation results through December 2000 in the report entitled *Site History and Characterization* (Baseline, January 2001). Readers are referred to this report for details.

Free-phase petroleum hydrocarbon product has been identified at four separate locations at the MSC. They are labeled as Plumes A through D on Figure 2. This report presents the evaluation of free-phase product removal alternatives in terms of effectiveness, implementability, and cost. A preferred alternative for each free-product plume is recommended in Section 4 based on the evaluation results.

Regulations governing the investigation and remediation of fuel underground storage tanks (USTs) is contained in State of California Code of Regulations, Title 23, Chapter 16 – Underground Tank Regulations, Article 11 – Corrective Action Requirements. The primary implementation guideline of the state regulation in Alameda County is included in the *Tri-Regional Board Staff Recommendations for Preliminary Investigation and Evaluation of Underground Tank Sites* (August 1990) and associated Appendix A (August 1991). Additional guidelines are contained in an interim guidance from the State Water Resource Control Board (December 1995) and supplemental instructions from the San Francisco Bay Regional Water Quality Control Board (January 1996).

Appendix A of the Tri-Regional Board Staff Recommendations (August 1991) outlines the basic process of UST investigation and remediation. Interim remediation workplans are suggested for any specific interim actions, such as free product removal or minor soil cleanup. However, the Tri-Regional Recommendations did not recommend a specific format for such interim workplans. In the absence of specific guidelines, the evaluation of free-phase product removal alternatives presented in this report followed the federal *Guidance on conducting Non-Time-Critical Removal Actions Under CERCLA* (USEPA, August 1993), i.e., the alternatives are evaluated based on their effectiveness, implementability, and cost.

Before beginning the evaluation of free-phase product removal alternatives, it should be beneficial to first summarize the investigation results. The following information is extracted from the *Site History and Characterization* report (Baseline, January 2001).

The shallow groundwater zone is unconfined and exists within the fill materials. The fill thickness beneath the MSC site varies between about 7 and 15 feet, and the fill materials are mostly fine grained (CL and ML). The shallow zone water level varies between 5 and 10 feet below ground surface (bgs), or 0 to 5 feet above mean sea level (msl). The four free-phase petroleum hydrocarbon plumes exist on top of the shallow-zone water table. Two separate tidal studies conducted in 1995 and 1997 indicated that, except in a few isolated near-Bay areas, the site-wide shallow groundwater level is not subject to daily tidal influence. However, the shallow groundwater level fluctuates approximately 0.5 to 1.5 feet seasonally.

The direction of groundwater flow within the shallow zone is toward the southwest to the nearest shoreline along San Leandro Bay across much of the site. In the northern portion of the MSC, the flow is in a more northerly direction toward the curving shoreline and Damon Slough.

2.1 FREE-PHASE PRODUCT PLUME A

A 12,000-gallon underground storage tank (UST #6) was formerly located at the center of this plume. The UST was reportedly used for unleaded gasoline storage. However, chemical analysis indicated the impact of both gasoline- and diesel-range petroleum hydrocarbons in soil and groundwater. Approximately 1,500 gallons of a mixture of free product and groundwater was removed at the time of the UST excavation in 1997. Since then, only a minor sheen (<0.02 feet) and/or floating globules have been observed in monitoring wells TBW-3 and TBW-4. The size of the plume is approximately 30 feet by 50 feet, and the plume appears stable. [redacted] of fr[redacted]

2.2 FREE-PHASE PRODUCT PLUME B

The former UST #6 dispenser island was located at the east corner of the plume. The dispenser and associated piping were removed at the time of the UST removal in 1997. The plume, having the size of approximately 100 feet by 130 feet, extends from the former dispenser island (MW-6) southwesterly to the off-site area between monitoring wells MW-16 and MW-17 (Figure 2). The hydrocarbon composition in the free-product plume appears variable. A product sample from MW-6 (the former dispenser island location) was characterized as consisting of 95% mid-ranged hydrocarbons (e.g., diesel #2), 5% gasoline-ranged hydrocarbons, and traces of heavy-ranged hydrocarbons (e.g., heating oil #6 and coal tar oil). The product composition from MW-16 (off-site down gradient) was characterized as 50% mid-ranged hydrocarbons, 40% gasoline-ranged hydrocarbons, and 10% heavy-ranged hydrocarbons.

In April 2000, a passive skimmer was placed in MW-6 and oil absorbents were placed in MW-16. Only a few gallons of product have been removed from the two wells since the recovery operations began. In September 2000, the product thickness was measured 0.06 feet in MW-6 and only a sheen (<0.02 feet) in MW-16. The[redacted] plum[redacted]

2.3 FREE-PHASE PRODUCT PLUME C

Three former USTs were located within the plume area. UST #1 was a 5,000-gallon diesel storage tank, UST #2 a 5,000-gallon leaded gasoline tank, and UST #3 a 5,000-gallon unleaded gasoline tank. They were all removed in 1997. The free-phase product thickness was initially measured up to 0.18 foot in 1997 in one of the two monitoring wells (TBW-1 and TBW-2) located within the plume. From March through October 1998, approximately 62,000 gallons of groundwater were removed from TBW-1. Currently, oil absorbent socks are inserted into the two wells and are replaced periodically as necessary. In September 2000, the product thickness was measured 0.1 feet in TBW-1 and only a sheen in TBW-2. The size of the plume is only about 50 feet by 70 feet and the plume appears stable. The amount of free-product remaining within the plume appears limited.

2.4 FREE-PHASE PRODUCT PLUME D

Historically, two former fuel hydrant lines ran through the plume area. They were removed in 1997. The free-phase product thickness was initially measured as high as 1.45 feet in monitoring well TBW-5 in 1997. Since then, an active skimmer has removed about 320 gallons of product from the well. Chemical analysis has indicated that the product is mostly gasoline with a minor amount of mid-ranged hydrocarbons (e.g., jet fuel and kerosene). The product thickness was measured at 0.26 foot in TBW-5 in September 2000. The size of the plume is about 120 feet by 150 feet. It appears that recoverable amount of free-product still exists within the plume.

The focus here is to evaluate remedial technologies that can remove floating petroleum product from the shallow groundwater table. The five alternatives evaluated are as follows: monitored natural attenuation, enhanced bioattenuation, groundwater extraction and treatment, additional excavation and off-site disposal, and dual-phase extraction. Details of each alternative are presented below.

3.1 ALTERNATIVE 1 – MONITORED NATURAL ATTENUATION

This alternative relies on natural attenuation processes for free product reduction. Natural attenuation processes include biodegradation, adsorption, dilution, convection and volatilization. For petroleum hydrocarbons, biodegradation is frequently the dominant attenuation process. However, bioattenuation rates in many cases are limited by the availability of oxygen. This alternative may be able to remove the limited amount of free product from plume A (sheen only) within a reasonable time (on the order of years). However, it alone may require considerable time (on the order of decades) to remove free product from the other three plumes. Under this alternative, the existing wells would be monitored regularly to determine the attenuation progress.

3.2 ALTERNATIVE 2 – ENHANCED BIOATTENUATION

When oxygen is available, biodegradation of petroleum hydrocarbons in the subsurface is generally the dominant process of attenuation. In many cases, however, the availability of oxygen is limited and the subsurface is at anaerobic conditions, as it is the case at this site based on the low dissolved oxygen levels measured during groundwater sampling. This alternative will introduce oxygen to the subsurface and thus enhance the natural bioattenuation process. Oxygen can be introduced by drilling a series of borings within the plume area and by filling the boreholes with oxygen-releasing compounds (ORCs), such as magnesium peroxide (MgO_2). MgO_2 reacts with water and produces oxygen and magnesium hydroxide. Microbes in both smear zone soil and groundwater can use the oxygen and degrade petroleum hydrocarbons to carbon dioxide and water. The carbon dioxide will then react with magnesium hydroxide and convert it to magnesium carbonate, which is a good grout material. Hydrogen peroxide (H_2O_2) can also be injected into the subsurface as an ORC.

Microbes cannot attack the free-product directly. They will degrade the hydrocarbons dissolved in groundwater and adsorbed on soil particles that can be physically accessed by the microbes. Once the dissolved and adsorbed hydrocarbons are degraded, more free-product will be dissolved and adsorbed. The free-product removal rate can be limited by both the biodegradation rate and solubilization/adsorption rate. Therefore, even though this alternative will work faster than Alternative 1, it would still take a significant amount of time to remove the free-product from the subsurface (on the order of years). Under this alternative, the existing wells would be monitored regularly for the attenuation progress.

3.3 ALTERNATIVE 3 – GROUNDWATER EXTRACTION AND TREATMENT

This alternative involves groundwater extraction from selected wells or extraction trenches, treatment of the extracted water through an oil/water separator followed by two activated carbon units in series, and discharge of the treated water to either the local sewer via a POTW permit, the stormwater drain via a NPDES permit or on-site reuse. Groundwater extraction will create a cone of depression in the water table surrounding each extraction area and will thus accelerate the flow of free-product to the extraction wells and/or trenches.

Because the fill materials are mostly fine grained and the water level is relatively shallow (less than 10 feet bgs), horizontal extraction trench(es) would be far more effective than the vertical extraction wells. A horizontal extraction trench could be constructed within each of the two large plumes (B & D) and the extracted water could be combined in a single system for treatment. Plumes A and C are relatively small and each already has two wells which could be used for the extraction. Under this alternative, four to five years of extraction is estimated for plumes A and C, and a minimum of five years would be necessary for plumes B and D if a horizontal extraction trench is constructed within each of them.

The removal of highly viscous hydrocarbons, such as oil, could be facilitated by the injection of biodegradable surfactants that can emulsify the oil and thus significantly reduce its viscosity and increase its mobility.

3.4 ALTERNATIVE 4 – ADDITIONAL EXCAVATION AND OFF-SITE DISPOSAL

In addition to the soil and groundwater removed during the UST excavation, this alternative involves excavation of all remaining soils having free product and transporting them to off-site waste management facilities for treatment and disposal. Clean soil would be imported to backfill the excavation area. Floating product would be removed before backfilling.

3.5 ALTERNATIVE 5 – DUAL-PHASE EXTRACTION

Dual-phase extraction (DPE) has been successfully applied to many gasoline and diesel impacted sites since the 1980s. DPE involves the simultaneous extraction of groundwater and soil gas through the application of high vacuum to individual extraction wells. DPE achieves three remediation processes simultaneously. First, volatile compounds (100% of the gasoline and over 50% of the diesel) are vaporized under relatively high vacuum and are removed as soil gas. This action is particularly effective in removing free-phase gasoline and diesel. Second, it extracts groundwater and thus creates a cone of depression that accelerates the flow of free product to the extraction wells. The vacuum that it applied at the wellhead further facilitates the groundwater recovery. For the fined grained soils at this site, the applied vacuum has the potential to double the extraction rate that can be achieved by a conventional pumping method (Alternative 3). Third, the vapor extraction induces soil gas flow in the vadose zone and draws air into the subsurface. It supplies oxygen and enhances bioattenuation in the same way as Alternative 2. The combined actions of DPE make it one of the most cost-effective alternatives for remediation of petroleum hydrocarbon impacted sites.

Plumes A and C are small and have a limited amount of free product. Two monitoring wells exist within each plume. It is possible to implement a DPE system using the existing monitoring wells to remove free product from the two plumes within three to six months. Plumes B and D are relatively large and each has only one monitoring well located within it. Two more extraction wells would be necessary within each plume for a DPE system to effectively remove free-product from Plumes B and D within approximately one year.

The soil gas extracted would be treated through two vapor-phase activated carbon units and discharged to the atmosphere. An air permit would be required from the Bay Area Air Quality Management District (BAAQMD). The extracted groundwater would be treated through two liquid-phase activated carbon units and discharged to either the local sewer via a POTW permit, the stormwater drain via a NPDES permit or on-site reuse, such as landscape irrigation.

The five alternatives described above were evaluated for their effectiveness, implementability and cost. Detailed evaluations and comparative analyses are presented in Tables 1 through 3. For each alternative a numerical score is assigned for each evaluation criterion, with one (1) being the lowest applicable score and 10 the highest.

Numerical rankings of the five alternatives evaluated are summarized in Table 4. Both Alternative 2 – Enhanced Bioattenuation and Alternative 5 – Dual-Phase Extraction (DPE) have the highest ranking (total score 19) for Plume A. This means that either of the two alternatives could be selected as the preferred free-product removal alternative for Plume A. Alternative 5 – DPE has the highest ranking and is the preferred alternative for Plumes B, C and D. For consistent implementation across the site, Alternative 5 is also recommended for Plume A.

URS Corporation owns a mobile, trailer-mounted DPE unit that has a 10-HP liquid-ring positive displacement vacuum pump capable of achieving a flow rate of 125 inlet cubic feet per minute (cfm) and a maximum applied vacuum of 28 inches of mercury. The unit has a complete water separation system and control system. It can be applied to the plumes one at a time and rotates among the four plumes. [redacted] two [redacted] st[redacted] Field parameters obtained for the DPE operation within this plume, such as zone of vacuum influence and soil gas and groundwater yields, can be used for well placement design and gas/water treatment system adjustment at the other three plumes. A complete DPE remediation system is illustrated in Figure 3.

TABLE 1
Effectiveness Analysis of Free-Phase Product Removal Alternatives
City of Oakland Municipal Services Center, Oakland, CA
(Numerical Ranking: 1 to 10. One (10) is the lowest applicable score and 10 the highest.)

	Plume A - sheen/globules only, size approx 30' by 50'	**Plume B** - 0.06' free product, size approx 100' by 130'	**Plume C** - 0.1' free product, size approx 50' by 70'	**Plume D** - 0.26' free product, size approx 120' by 150'
Alternative 1 - Monitored Natural Attenuation	- will eventually remove the limited amount of free product, but may take years; - existing free product will continue to contribute to dissolved plume for years; - will require long term groundwater monitoring; - appears effective in protecting human health and the environment because a) plume appears stable & is not affecting sensitive receptors, b) site has been & will continue to be a service yard, c) affected area is under asphalt pavement. Numerical Score: 3	- will eventually remove the free product, but may take decades; - existing free product will continue to contribute to dissolved plume for years; - will require long term groundwater monitoring; - the free-product plume extends to off-site close to the San Leandro Bay and could potentially impact the shoreline and bay environment. Numerical Score: 1	- will eventually remove the limited amount of free product, but may take decades; - existing free product will continue to contribute to dissolved plume for years; - will require long term groundwater monitoring; - appears effective in protecting human health and the environment because a) plume appears stable & is not affecting sensitive receptors, b) site has been & will continue to be a service yard, c) affected area is under asphalt pavement. Numerical Score: 2	- will eventually remove the free product, but may take decades; - existing free product will continue to contribute to dissolved plume for years; - will require long term groundwater monitoring; - appears effective in protecting human health and the environment because a) plume appears stable & is not affecting sensitive receptors, b) site has been & will continue to be a service yard, c) affected area is under asphalt pavement. Numerical Score: 2
Alternative 2 - Enhanced Bioattenuation	- can remove the limited amount free product faster than Alternative 1, but may still take several years; - also accelerates dissolved plume remediation; - will need to monitor progress through regular groundwater sampling; - existing free product may continue to contribute to dissolved plume for a while; - as effective in protecting human health and the environment as Alternative 1. Numerical Score: 5	- can remove the free product faster than Alternative 1, but may still take years; - also accelerates dissolved plume remediation; - will need to monitor progress through regular groundwater sampling; - existing free product may continue to contribute to dissolved plume for years; - uncertain whether this alternative may stop further migration of the free product to the Bay. Numerical Score: 3	- can remove the limited amount free product faster than Alternative 1, but may still take years; - also accelerates dissolved plume remediation; - will need to monitor progress through regular groundwater sampling; - existing free product may continue to contribute to dissolved plume for years; - as effective in protecting human health and the environment as Alternative 1. Numerical Score: 4	- can remove the free product faster than Alternative 1, but may still take years; - also accelerates dissolved plume remediation; - will need to monitor progress through regular groundwater sampling; - existing free product may continue to contribute to dissolved plume for years; - as effective in protecting human health and the environment as Alternative 1. Numerical Score: 4
Alternative 3 - Groundwater Extraction & Treatment	- commonly used method for plume migration control; - accelerates floating product removal, but not effective in removing product trapped in smear zone; - also accelerates dissolved plume remediation; - will need to monitor progress through regular groundwater sampling; - requires a discharge permit for treated water. Numerical Score: 5	- will prevent further migration to the Bay; - accelerates floating product removal, but not effective in removing product trapped in smear zone; - also accelerates dissolved plume remediation; - will need to monitor progress through regular groundwater sampling; - requires a discharge permit for treated water. Numerical Score: 5	- commonly used method for plume migration control; - accelerates floating product removal, but not effective in removing product trapped in smear zone; - also accelerates dissolved plume remediation; - will need to monitor progress through regular groundwater sampling; - requires a discharge permit for treated water. Numerical Score: 5	- commonly used method for plume migration control; - accelerates floating product removal, but not effective in removing product trapped in smear zone; - also accelerates dissolved plume remediation; - will need to monitor progress through regular groundwater sampling; - requires a discharge permit for treated water. Numerical Score: 5
Alternative 4 - Additional Excavation & off-Site Disposal	- can remove almost all free product within short time; - will have short-term exposure during excavation, but can be minimized through personal protective eq.; - requires off-site treatment/disposal; - monitoring required only for dissolved plume. Numerical Score: 8	- can remove almost all free product within short time; - short-term exposure can be minimized by PPE; - difficult to excavate near shoreline, require permits; - requires off-site treatment/disposal; - monitoring required only for dissolved plume. Numerical Score: 6	- can remove almost all free product within short time; - will have short-term exposure during excavation, but can be minimized through personal protective eq.; - requires off-site treatment/disposal; - monitoring required only for dissolved plume. Numerical Score: 8	- can remove almost all free product within short time; - will have short-term exposure during excavation, but can be minimized through personal protective eq.; - requires off-site treatment/disposal; - large area excavation, underground utility interference. Numerical Score: 7
Alternative 5 - Dual-Phase Extraction	- can remove the limited free product within 3 - 6 mos; - remediates both vadose and saturated zones; - also accelerates dissolved plume remediation; - effective in protecting human health and environment; - requires both air and water treatment & discharge permits. Numerical Score: 7	- will prevent further migration to the Bay; - can remove the free product within approx one year; - remediates both vadose and saturated zones; - also accelerates dissolved plume remediation; - effective in protecting human health and environment; - requires both air and water treatment & discharge permits. Numerical Score: 6	- can remove the limited free product within 3 - 6 mos; - remediates both vadose and saturated zones; - also accelerates dissolved plume remediation; - effective in protecting human health and environment; - requires both air and water treatment & discharge permits. Numerical Score: 7	- can remove the free product within approx one year; - remediates both vadose and saturated zones; - also accelerates dissolved plume remediation; - effective in protecting human health and environment; - requires both air and water treatment & discharge permits. Numerical Score: 7

TABLE 2

Implementability Analysis of Free-Phase Product Removal Alternatives

City of Oakland Municipal Services Center, Oakland, CA

(Numerical Ranking: 1 to 10. One (1) is the lowest applicable score and 10 the highest.)

	Plume A - sheen/globules only, size approx 30' by 50'	**Plume B** - 0.06' free product, size approx 100' by 130'	**Plume C** - 0.1' free product, size approx 50' by 70'	**Plume D** - 0.26' free product, size approx 120' by 150'
Alternative 1 - Monitored Natural Attenuation	- technically implementable, no additional drilling, construction, maintenance & discharge requirements, except for purge & decon water disposal; - administratively implementable, i.e. regulatory & public approvable due to sheen/globules only; - minimal interference with facility operations; - requires site control, i.e. cover maintenance to minimize further migration risk; - requires risk management plan for future construction & development until in compliance. Numerical Score: 5	- technically implementable, no additional drilling, construction, maintenance & discharge requirements, except for purge & decon water disposal; - unclear administratively implementable due to the plume partially off-site and close to the shoreline; - minimal interference with facility operations; - requires site control, i.e. cover maintenance to minimize further migration risk; - requires risk management plan for future construction & development until in compliance. Numerical Score: 3	- technically implementable, no additional drilling, construction, maintenance & discharge requirements, except for purge & decon water disposal; - unclear administratively implementable due to the exist of recoverable free product; - minimal interference with facility operations; - requires site control, i.e. cover maintenance to minimize further migration risk; - requires risk management plan for future construction & development until in compliance. Numerical Score: 4	- technically implementable, no additional drilling, construction, maintenance & discharge requirements, except for purge & decon water disposal; - unclear administratively implementable due to the exist of recoverable free product; - minimal interference with facility operations; - requires site control, i.e. cover maintenance to minimize further migration risk; - requires risk management plan for future construction & development until in compliance. Numerical Score: 4
Alternative 2 - Enhanced Bioattenuation	- technically implementable, limited field drilling for ORC injection, but no other construction, maintenane & discharge requirments; - administratively implementable, i.e. regulatory & public approvable due to sheen/globules only; - some interference with facility operation during drilling; - requires risk management plan for future construction & development until in compliance. Numerical Score: 8	- technically implementable, limited field drilling for ORC injection, but no other construction, maintenane & discharge requirments; - unclear administratively implementable due to the plume partially off-site and close to the shoreline; - difficult to prevent further migration; - some interference with facility operation during drilling; - requires risk management plan for future construction & development until in compliance. Numerical Score: 4	- technically implementable, limited field drilling for ORC injection, but no other construction, maintenane & discharge requirments; - may be administratively implementable, because the plume appears stable; - some interference with facility operation during drilling; - requires risk management plan for future construction & development until in compliance. Numerical Score: 6	- technically implementable, limited field drilling for ORC injection, but no other construction, maintenane & discharge requirments; - may be administratively implementable, because the plume appears stable; - some interference with facility operation during drilling; - requires risk management plan for future construction & development until in compliance. Numerical Score: 6
Alternative 3 - Groundwater Extraction & Treatment	- technically implementable, use existing 2 wells for extraction, require trenching, utility connection, operation & maintenance, & water discharge; - activated carbon can be implemented quickly; - administratively implementable, i.e. regulatory & public approvable; - moderate interference with facility operations. Numerical Score: 6	- technically implementable, construct a 70-foot long extraction trench, require utility connection, operation & maintenance, & water discharge; - activated carbon can be implemented quickly; - administratively implementable, i.e. regulatory & public approvable; - moderate interference with facility operations. Numerical Score: 6	- technically implementable, use existing 2 wells for extraction, require trenching, utility connection, operation & maintenance, & water discharge; - activated carbon can be implemented quickly; - administratively implementable, i.e. regulatory & public approvable; - moderate interference with facility operations. Numerical Score: 6	- technically implementable, construct a 120-foot long extraction trench, require utility connection, operation & maintenance, & water discharge; - activated carbon can be implemented quickly; - administratively implementable, i.e. regulatory & public approvable; - moderate interference with facility operations. Numerical Score: 6
Alternative 4 - Additional Excavation & off-Site Disposal	- technically implementable, small area excavation, no long term operation & maintenance requirement; - administratively implementable, i.e. regulatory & public approvable; - major interference with facility operations. Numerical Score: 4	- technically challenging, excavate off-site in park area & near shoreline; - unclear administratively implementable due to excavation within park and near shoreline; - severe disruption to facility operations. Numerical Score: 2	- technically implementable, small area excavation, no long term operation & maintenance requirement; - administratively implementable, i.e. regulatory & public approvable; - major interference to facility operations. Numerical Score: 4	- technically implementable, large area excavation, no long term operation & maintenance requirement; - administratively implementable, i.e. regulatory & public approvable; - major disruption to facility operations. Numerical Score: 3
Alternative 5 - Dual-Phase Extraction	- technically implementable, use existing 2 wells for DPE extraction, require trenching, utility connection, operation & maintenance, air & water discharge; - existing mobile unit available for quick implement; - administratively implementable, i.e. regulatory & public approvable; - moderate interference with facility operations. Numerical Score: 6	- technically implementable, install two more wells for DPE extraction, require trenching, utility connection, operation & maintenance, air & water discharge; - existing mobile unit available for quick implement; - administratively implementable, i.e. regulatory & public approvable; - moderate interference with facility operations. Numerical Score: 6	- technically implementable, use existing 2 wells for DPE extraction, require trenching, utility connection, operation & maintenance, air & water discharge; - existing mobile unit available for quick implement; - administratively implementable, i.e. regulatory & public approvable; - moderate interference with facility operations. Numerical Score: 6	- technically implementable, install two more wells for DPE extraction, require trenching, utility connection, operation & maintenance, air & water discharge; - existing mobile unit available for quick implement; - administratively implementable, i.e. regulatory & public approvable; - moderate interference with facility operations. Numerical Score: 6

TABLE 3
Cost Analysis of Free-Phase Product Removal Alternatives
City of Oakland Municipal Services Center, Oakland, CA
(Numerical Ranking: 1 to 10. One (1) is the lowest applicable score and 10 the highest.)

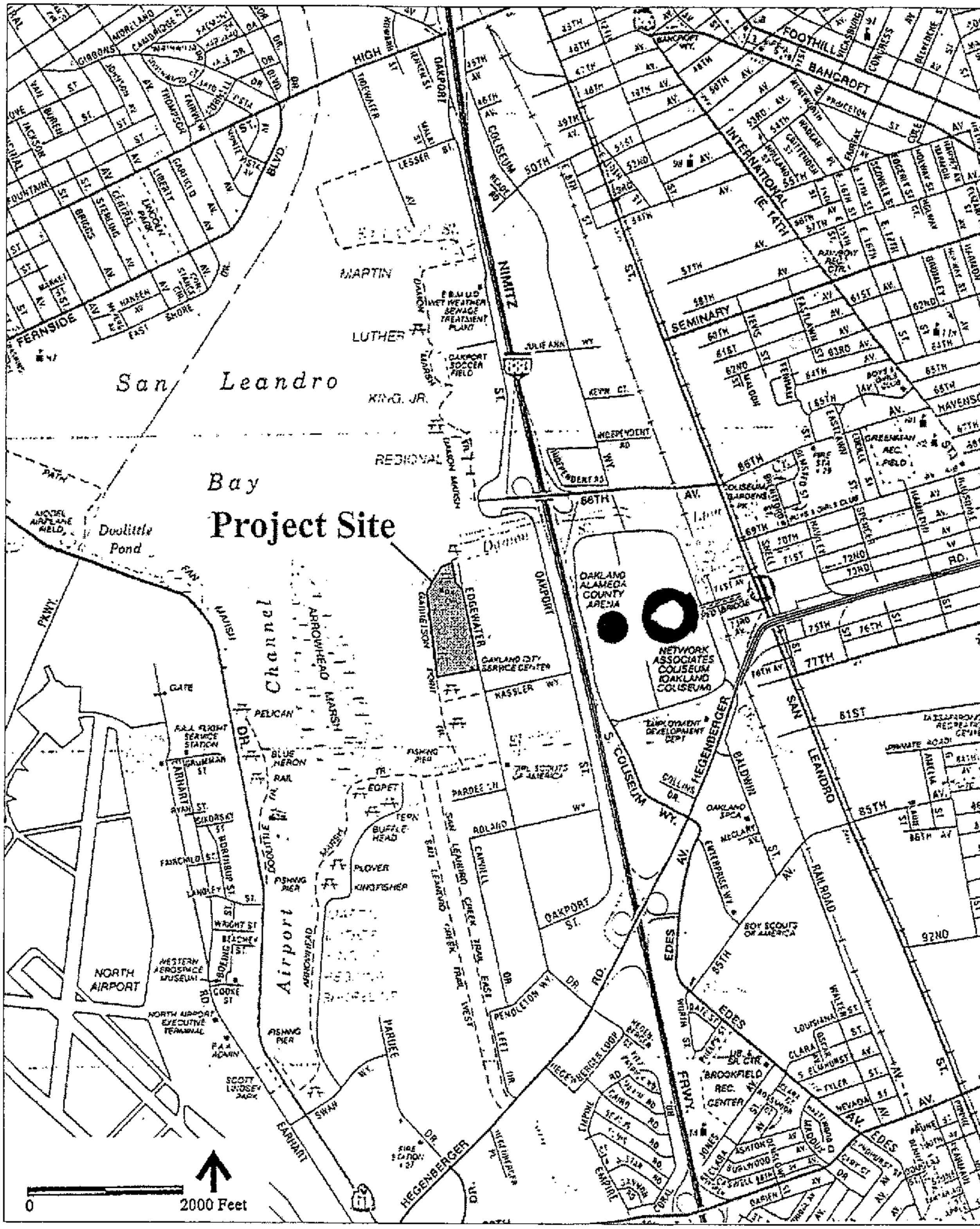
	Plume A - sheen/globules only, size approx 30' by 50'	**Plume B** - 0.06' free product, size approx 100' by 130'	**Plume C** - 0.1' free product, size approx 50' by 70'	**Plume D** - 0.26' free product, size approx 120' by 150'
Alternative 1 - Monitored Natural Attenuation	- estimate that sheen/globules will be removed within 10 years through natural attenuation; - assume 10-year semi-annual monitoring of 3 wells at $3,000 per event (sampling, analysis & reporting); - 10-year total monitoring cost would be **$60,000.**	- estimate that free-product will be removed within 20 years through natural attenuation; - assume 20-year semi-annual monitoring of 5 wells at $5,000 per event (sampling, analysis & reporting); - 20-year total monitoring cost would be **$200,000.**	- estimate that free-product will be removed within 20 years through natural attenuation; - assume 20-year semi-annual monitoring of 4 wells at $4,000 per event (sampling, analysis & reporting); - 20-year total monitoring cost would be **$160,000.**	- estimate that free-product will be removed within 20 years through natural attenuation; - assume 20-year semi-annual monitoring of 5 wells at $5,000 per event (sampling, analysis & reporting); - 20-year total monitoring cost would be **$200,000.**
	Numerical Score: 5	Numerical Score: 6	Numerical Score: 4	Numerical Score: 7
Alternative 2 - Enhanced Bioattenuation	- estimate annual ORC injection for 4 years at $7,000 per ORC injection (15' deep, 10 points injection); - assume 4-year semi-annual monitoring of 3 wells at $3,000 per event (sampling, analysis & reporting); **- 4-year total cost $52,000.**	- estimate annual ORC injection for 8 years at $16,000 per ORC injection (15' deep, 25 points injection); - assume 8-year semi-annual monitoring of 5 wells at $5,000 per event (sampling, analysis & reporting); **- 8-year total cost $208,000.**	- estimate annual ORC injection for 8 years at $7,000 per ORC injection (15' deep, 10 points injection); - assume 8-year semi-annual monitoring of 4 wells at $4,000 per event (sampling, analysis & reporting); **- 8-year total cost $120,000.**	- estimate annual ORC injection for 10 years at $16,000 per ORC injection (15' deep, 25 points injection); - assume 10-year semi-annual monitoring of 5 wells at $5,000 per event (sampling, analysis & reporting); **- 10-year total cost $260,000.**
	Numerical Score: 6	Numerical Score: 6	Numerical Score: 6	Numerical Score: 6
Alternative 3 - Groundwater Extraction & Treatment	- estimate extraction from TBW-3 & -4 at total 2 gpm for 4 years, treated by oil/water separator & activated carbon, discharge to sewer via a POTW permit; - one 30 gpm treatment system, capital and O&M costs pro-rated to four plumes based on flow rates; - pro-rated capital cost $10,000 *; - connection from wells to system $5,000; - pro-rated O&M cost $7,000 per year; - semi-annual monitoring of 3 wells at $3,000 per event; **- 4-year total cost $67,000.**	- assume construction of 70' long, 12' deep extraction trench near property fence at $25,000, pump 10 gpm for 5 years, treatment & discharge same as Plume A; - one 30 gpm treatment system, capital and O&M costs pro-rated to four plumes based on flow rates; - pro-rated capital cost $35,000 *; - connection from trench to system $5,000; - pro-rated O&M cost $25,000 per year; - semi-annual monitoring of 5 wells at $5,000 per event; **- 5-year total cost $240,000.**	- estimate extraction from TBW-1 & -2 at total 2 gpm for 5 years, treatment & discharge same as Plume A; - one 30 gpm treatment system, capital and O&M costs pro-rated to four plumes based on flow rates; - pro-rated capital cost $10,000 *; - connection from wells to system $5,000; - pro-rated O&M cost $7,000 per year; - semi-annual monitoring of 4 wells at $4,000 per event; **- 5-year total cost $90,000.**	- assume construction of 120' long, 12' deep extraction trench in middle of plume at $40,000, pump 15 gpm for 5 years, treatment & discharge same as Plume A; - one 30 gpm treatment system, capital and O&M costs pro-rated to four plumes based on flow rates; - pro-rated capital cost $45,000 *; - connection from wells to system $5,000; - pro-rated O&M cost $30,000 per year; - semi-annual monitoring of 5 wells at $5,000 per event; **- 5-year total cost $290,000.**
	Numerical Score: 4	Numerical Score: 5	Numerical Score: 7	Numerical Score: 5
Alternative 4 - Additional Excavation & off-Site Disposal	- estimate excavation area of 30' by 50' and 10'deep; - top 5' for backfill reuse and next 5' for offsite disposal; - 750 tons at $50/ton disposal and transportation cost; - 750 tons at $20/ton clean fill for backfill; - 10,000-gallon water at $0.7/gallon transport & disposal **- total cost $59,500.**	- estimate excavation area of 100' by 130' and 10'deep; - top 5' for backfill reuse and next 5' for offsite disposal; - 6,500 tons at $50/ton disposal and transport cost; - 6,500 tons at $20/ton clean fill for backfill; - 50,000-gallon water at $0.7/gal transport & disposal; **- total cost $490,000.**	- estimate excavation area of 50' by 70' and 10'deep; - top 5' for backfill reuse and next 5' for offsite disposal; - 1,750 tons at $50/ton disposal and transport cost; - 1,750 tons at $20/ton clean fill for backfill; - 20,000-gallon water at $0.7/gallon transport & disposal **- total cost $136,500.**	- estimate excavation area of 120' by 150' and 10'deep; - top 5' for backfill reuse and next 5' for offsite disposal; - 9,000 tons at $50/ton disposal and transport cost; - 9,000 tons at $20/ton clean fill for backfill; - 50,000-gallon water at $0.7/gallon transport & disposal; **- total cost $665,000**
	Numerical Score: 5	Numerical Score: 2	Numerical Score: 5	Numerical Score: 2
Alternative 5 - Dual-Phase Extraction	- estimate extraction from TBW-3 & -4 at total 3 gpm for 3-mo, soil vapor treated by carbon, water by oil/water separator & carbon, discharge to sewer; - a mobile DPE unit available for rental at $1,500/mo; - four plumes will be remediated sequentially; - pro-rated capital cost $7,000** and O&M $11,000/mo; - connection from wells to system $5,000; - one monitoring event of 3 wells at $3,000 total; **- total cost $52,500.**	- install two new wells (4" dia & 20' deep) at $10,000; - estimate one-year extraction of 5 gpm, soil gas and groundwater treatment same as Plume A; - a mobile DPE unit available for rental at $1,500/mo; - four plumes will be remediated sequentially; - pro-rated capital cost $14,000**, O&M $10,000/mo; - connection from wells to system $10,000; - two monitoring events of 5 wells at $10,000 total; **- total cost $182,000.**	- estimate extraction from TBW-1 & -2 at total 3 gpm up to 6-mo, soil gas and groundwater treatment same as Plume A; - a mobile DPE unit available for rental at $1,500/mo; - four plumes will be remediated sequentially; - pro-rated capital cost $7,000**, O&M $10,000/mo; - connection from wells to system $5,000; - two monitoring events of 4 wells at $8,000 total; **- total cost $89,000.**	- install two new wells (4" dia & 20' deep) at $10,000; - estimate one-year extraction of 5 gpm, soil gas and groundwater treatment same as Plume A; - a mobile DPE unit available for rental at $1,500/mo; - four plumes will be remediated sequentially; - pro-rated capital cost $14,000**, O&M $10,000/mo; - connection from wells to system $5,000; - two monitoring events of 5 wells at $10,000 total; **- total cost $177,000.**
	Numerical Score: 6	Numerical Score: 7	Numerical Score: 7	Numerical Score: 7

* Alternative 3 - the 30-gpm groundwater treatment system consists of one 30-50 gpm oil/water separator ($15,000), two 1,000-lb carbon units ($9,000), filter/piping/gauges/misc ($5,000), system controls/electrical connections ($20,000), secondary containment ($20,000), discharge connection ($5,000), and design/construction oversight/regulatory coordination/project management (35% of capital) for a total of $100,000.

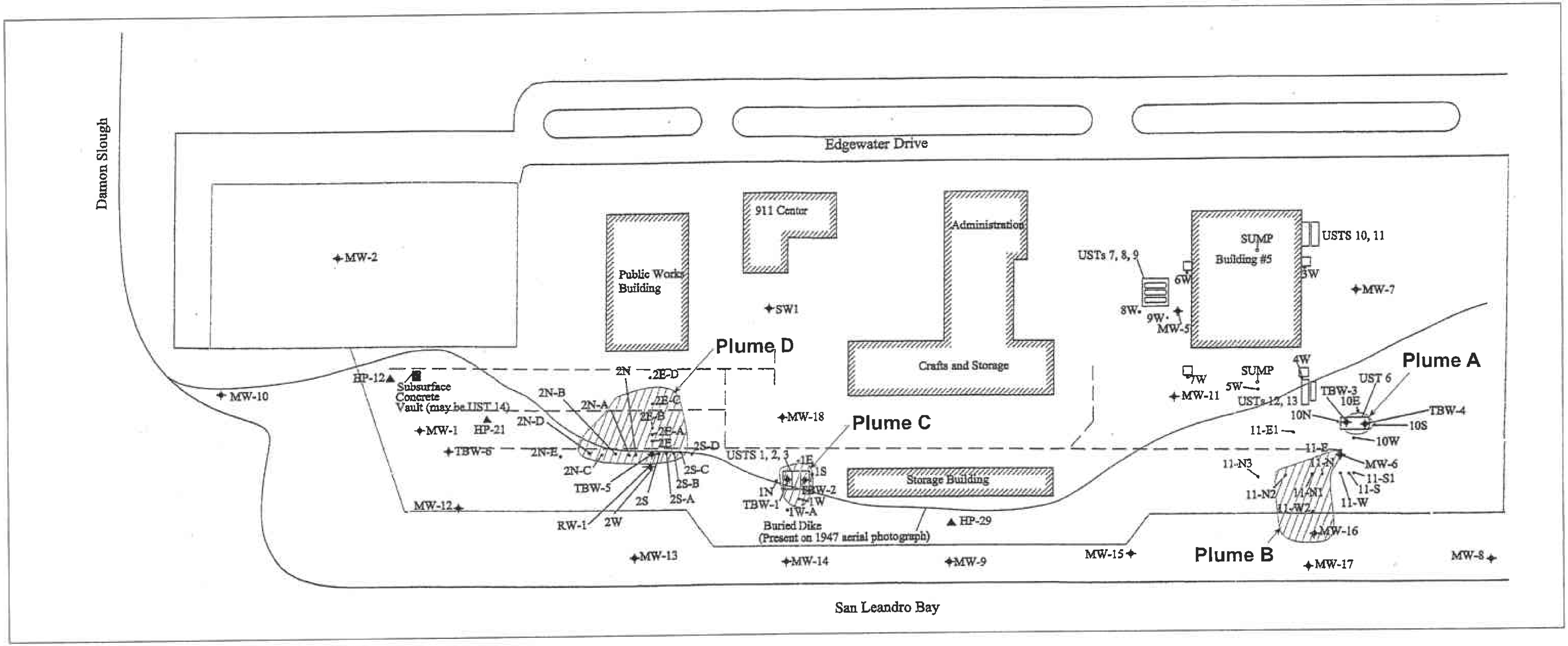
** Alternative 5 - one 5-gpm groundwater treatment system will be used sequentially for the four plumes, consisting of one 5 gpm oil/water separator ($7,000), two 55-gallon carbon units ($1,800), filter/piping/gauges/misc ($2,000), system controls/electrical connections ($10,000), plastic secondary containment ($3,000), discharge connection ($5,000), two 55-gallon gas-phase carbon units ($2,000), and other engineering costs (35% of capital) for a total of $42,000.

TABLE 4
Summary of Numerical Rankings for Free-Product Removal Alternatives
City of Oakland Municipal Services Center, Oakland, CA

	Plume A	Plume B	Plume C	Plume D
Alternative 1 -	Effectiveness: 3	Effectiveness: 1	Effectiveness: 2	Effectiveness: 2
Monitored	Implementability: 5	Implementability: 3	Implementability: 4	Implementability: 4
Natural	Cost: 5	Cost: 6	Cost: 4	Cost: 7
Attenuation	Total Score: 13	Total Score: 10	Total Score: 10	Total Score: 13
Alternative 2 -	Effectiveness: 5	Effectiveness: 3	Effectiveness: 4	Effectiveness: 4
Enhanced	Implementability: 8	Implementability: 4	Implementability: 6	Implementability: 6
Bioattenuation	Cost: 6	Cost: 6	Cost: 6	Cost: 6
	Total Score: 19	Total Score: 13	Total Score: 16	Total Score: 16
Alternative 3 -	Effectiveness: 5	Effectiveness: 5	Effectiveness: 5	Effectiveness: 5
Groundwater	Implementability: 6	Implementability: 6	Implementability: 6	Implementability: 6
Extraction &	Cost: 4	Cost: 5	Cost: 7	Cost: 5
Treatment	Total Score: 15	Total Score: 16	Total Score: 18	Total Score: 16
Alternative 4 -	Effectiveness: 8	Effectiveness: 6	Effectiveness: 8	Effectiveness: 7
Additional	Implementability: 4	Implementability: 2	Implementability: 4	Implementability: 3
Excavation	Cost: 5	Cost: 2	Cost: 5	Cost: 2
& off-Site	Total Score: 17	Total Score: 10	Total Score: 17	Total Score: 12
Disposal				
Alternative 5 -	Effectiveness: 7	Effectiveness: 6	Effectiveness: 7	Effectiveness: 7
Dual-Phase	Implementability: 6	Implementability: 6	Implementability: 6	Implementability: 6
Extraction	Cost: 6	Cost: 7	Cost: 7	Cost: 7
	Total Score: 19	Total Score: 19	Total Score: 20	Total Score: 20
Highest-ranked	Alternative 2 &	Alternative 5	Alternative 5	Alternative 5
Alternative	Alternative 5			



URS	Project No. 51-00129010.00	SITE LOCATION MAP Municipal Service Center 7101 Edgewater Drive Oakland, California	Figure 1
	Oakland MSC		



Note: USTs 4 and 5 are not shown adjacent to UST 6 (as they are shown on Figure 13) because it is unclear whether they ever existed at the site.

0 — 150 Feet

Legend

- • Boring Location (Installed in July 2000 by BASELINE)
- ⌖ Groundwater Well Location (Installed by others)
- – – – – – Former Fuel Hydrant Line
- Area of Free Product on Groundwater
- □ Waste Collection Pit
- ▭ Underground Storage Tanks
- ▲ Temporary Well Point

Municipal Service Center
7101 Edgewater Drive
Oakland, California

Base map from Figure 16 of Baseline January 2001 Report
(Site History and Characterization)

URS	Project No. 51-00129010.00 Oakland MSC	IDENTIFICATION OF FREE-PRODUCT PLUMES AND SITE FEATURES	Figure 2

51-00129010.00-00020/060601/gos.mcl

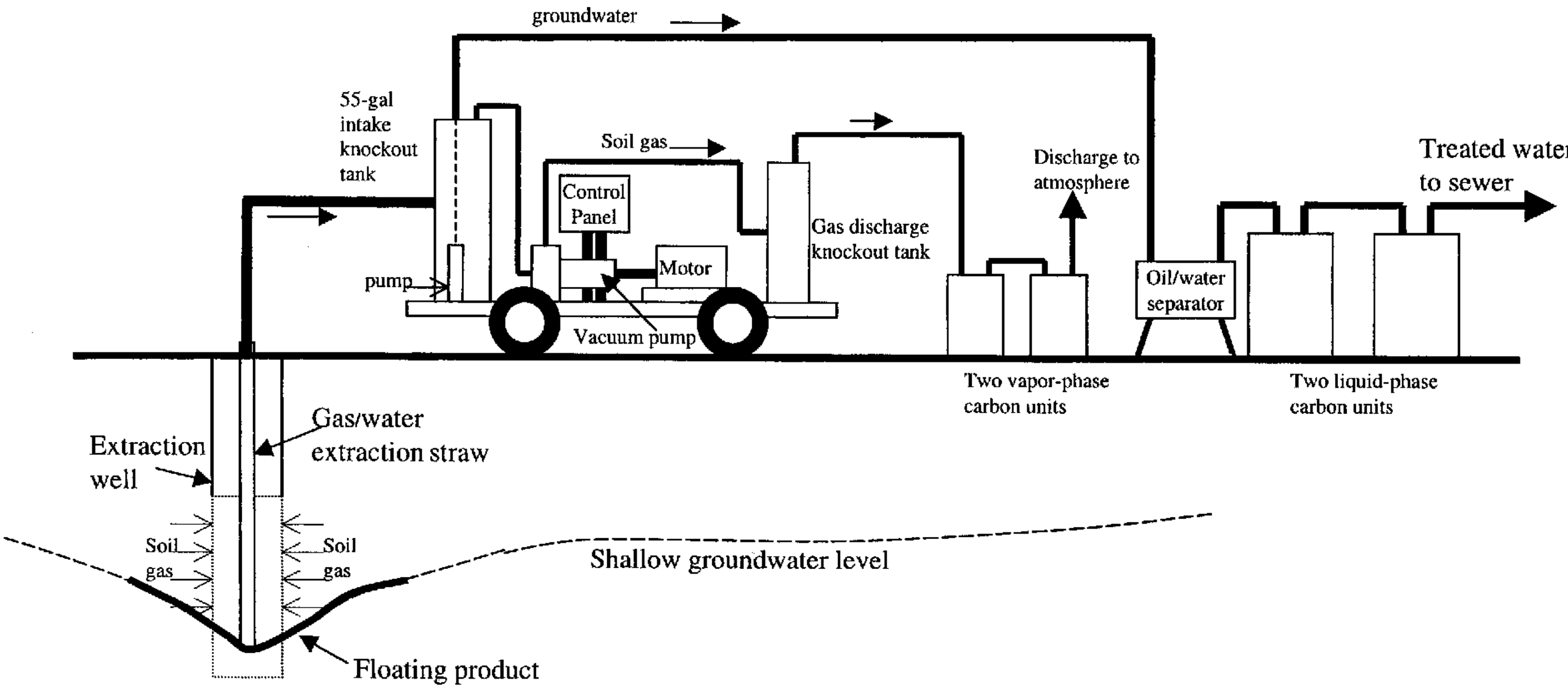


FIGURE 3
Illustration of the Recommended Free-Product Removal Alternative - Dual-Phase Extraction

URS CORPORATION