EOA, Inc.

ENVIRONMENTAL PROTECTION

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Eisenberg, Olivieri, & Associates
Environmental and Public Health Engineering

July 25, 1996

Mr. Dale Klettke
Alameda County Environmental Health Services
1131 Harbor Bay Parkway, #250
Alameda, CA 94502-6577

Re: 230 Bay Place, Oakland, CA - Transmittal of CAP feasibility screening.

Dear Mr. Klettke:

The enclosed letter report is submitted in compliance with the request contained in your letter to Bill Cox dated June 25, 1996. As requested the report evaluates a variety of alternative cleanup technologies for petroleum hydrocarbon contamination in both the saturated and unsaturated zones at the subject site. The report includes evaluation, recommendations, and the engineers estimate of a reasonable time schedule for implementation. We would like to meet with you as soon as possible to discuss the report recommendations, before proceeding with conceptual design, bidding, pre-approval by SWRCB UST Trust Fund, and implementation.

I will be following up with you by phone to discuss this letter and to confirm a date for a meeting. In the interim, if you have any questions, or wish to discuss this letter, please don't hesitate to call either me.

Sincerely,
EOA, Inc.

Don Eisenberg

Don M. Eisenberg, Ph.D., P.E.
Principal Engineer

cc: Bill Cox
Bob Cross
Rory Campbell
Andy Briefer
Kevin Graves
Gil Jensen (letter only)

1410 Jackson Street • Oakland, CA 94612 • (510) 832-2852 • Fax 832-2856

EOA, Inc.

Eisenberg, Olivieri, & Associates
Environmental and Public Health Engineering

July 25, 1996

Mr. Bill Cox
Bill Cox Cadillac
232 East 14th Street
San Leandro, CA 94577

Re: 230 Bay Place, Oakland, CA - Corrective Action Plan, Phase II

Dear Mr. Cox:

This letter, with the attached "Remedial Technologies Evaluation" and other attached information, represents the feasibility evaluation report requested in the letter dated June 25, 1996 from Alameda County Environmental Health Services. As specified in that letter, the report evaluates the feasibility and cost-effectiveness of a number of alternatives for reducing concentrations of petroleum hydrocarbons in both the saturated and unsaturated zone at the subject site, and identifies a recommended alternative or combination of alternatives. This package includes a letter which discusses the potential for some type of interim measures which could be implemented more immediately. This letter contains a time schedule for remaining tasks, including conceptual design, obtaining bids for final design and construction, obtaining pre-approval from SWRCB UST Trust Fund, and implementation. As agreed in a phone conversation with Mr. Dale Klettke of Alameda County, the conceptual design is not included in this submittal. This feasibility evaluation is submitted at this time, in order to meet the stringent time deadline imposed by the County. This document will be finalized in a subsequent report, incorporating comments from Alameda County or other involved parties, along with the development and documentation of conceptual design.

Results and Recommendations

The results of the technology screening indicate that a combination of technologies present the most effective alternative in remediating hydrocarbon impacted soil and groundwater at the site. For soil remediation in the unsaturated zone in the former parking lot area, the most effective and cost-effective approach involves additional excavation to a depth of about six feet in the vicinity of the south and east sides of the former piping leak. Additional soil borings in this area prior to excavation might be useful in refining the prediction of cost and effectiveness, but such additional investigation does not appear to be cost effective relative to basing the excavation work on evidence of pollution observed at the time of excavation. Therefore the latter approach is recommended. Effectiveness would be verified by soil sampling in the excavation walls.

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Additional excavation on the north side of the former pipe trench (toward the building) is almost certainly not cost-effective, because extensive shoring and structural support would probably be required. This conclusion needs to be verified during the conceptual and/or final design phase.

Impacted groundwater, and soils within the smear zone, would be most effectively and cost-effectively removed using active in-situ bioremediation, with groundwater extraction, aeration and nutrient addition, and re-infiltration. This alternative provides the opportunity for at least partial hydraulic control of the pollution, and perhaps for direct treatment of the recirculated groundwater. This alternative requires some additional testing to develop final design parameters, and to confirm the feasibility of re-infiltration.

Interim Remedial Action

As requested in the County's letter, the concept of implementing some type of short-term measure to enhance bio-remediation was pursued by further discussion with the bio-remediation consultants. CytoCulture, who performed the biotreatability testing concurs with the recommendation described above for active bioremediation. However, it is their opinion that the existing environment would not benefit significantly from occasional introduction of bacteria and nutrients into the existing monitoring wells.

Regenesis, a bioremediation products company that markets an oxygen release compound (ORC) for enhancing in-situ bioremediation of groundwater provided proposals for three interim alternatives using their products. The more expensive, but probably more effective alternative involves installing a grid of boreholes to 10 foot depth, with 8 foot spacing, and burying the ORC (magnesium peroxide) in the holes. To implement this for the entire area of concern would cost about $53,000. An ORC grid covering an area of 15 feet by 50 feet in the area of the former piping leak would cost about $9,000. A less attractive alternative proposed by Regenisis involves hanging ORC "socks" in the existing monitoring wells.

The alternatives using grids of boreholes appear to be costly to obtain an unknown benefit during the interim period prior to implementation of the final remedial measures. ORC "socks" in the wells are not costly, but the impact would be limited to the immediate area of the monitoring wells and would therefore interfere with obtaining representative groundwater samples. There is no certainty that the ORC addition would have any significant effect. The bioremediation experts contacted for this study had differing opinions. There is, however, some possibility that a significant benefit could be achieved, at a much lower cost than the proposed final remediation alternative. The smaller of the two borehole grid alternatives might be worth implementing, on a trial basis, if the County is willing to postpone the final design and implementation of other measures for six months to a year to evaluate the effectiveness of this approach.

Time Schedule

The following time schedule is EOA's estimate of a reasonable schedule for completion of design and implementation. This schedule could be impacted by any number of factors ranging from regulatory review time to unforeseen subsurface conditions:

Activity	Date (Week ending)	
Draft Feasibility Screening	July 26, 1996	
Follow-up meeting w County	August 2, 1996	1 week
Final Feasibility Screening and Conceptual Design	September 6, 1996	5 weeks
Obtain Bids and UST Fund Pre-approval	October 18, 1996	6 weeks
Hire Consultant, Install Well, Pump Test, Final Design	December 13, 1996	8 weeks
Obtain bids from Contractors and pre-approval	January 24, 1997	6 weeks
Hire Contractor and Install Treatment System	March 7, 1997	6 weeks

The schedule described above could be shortened by an estimated six weeks if the SWRCB UST fund and the site owner are both willing to do a single "design-build" contract for a qualified engineering firm or specialty contractor to carry out both the final design and construction of the system.

Attachments

The attachments to this letter describe and document the investigation of the feasibility and cost effectiveness for this site and the investigation of potential interim measures.

I will be following up with you by phone to discuss this letter and to identify a date for meeting with the County. In the interim, if you have any questions, or wish to discuss this letter, please don't hesitate to call me.

Sincerely,

EOA, Inc.

Don M. Eisenberg, Ph.D., P.E.
Principal Engineer

Attachments:
1) Remedial Technologies Evaluation Report
2) Letter from SCI regarding Interim Measures to Promote Biodegradation

CORRECTIVE ACTION PLAN
DEVELOPMENT REPORT
PHASE II

REMEDIAL TECHNOLOGIES EVALUATION
FORMER COX CADILLAC SITE
230 BAY PLACE
OAKLAND, CALIFORNIA

Prepared by:

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With:

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1410 Jackson Street
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July 24, 1996

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I INTRODUCTION

The purpose of this technology screening is to define potential remedial alternatives and identify the most appropriate technologies for mitigating and reducing benzene concentrations in soil and groundwater at the former Cox Cadillac facility at 230 Bay Place in Oakland, California. Various remedial technologies are currently being used to mitigate petroleum hydrocarbon contaminated soil and groundwater. The following technologies were considered viable options for further consideration for either soil and/or groundwater remediation. The "No Action" alternative was selected as a baseline technology for comparison purposes only.

Soil Remedial Technologies

- No Action
- Excavation
- Vapor Extraction
- Active In-situ Bioremediation
- Passive In-situ Bioremediation
- Dual-phase Extraction
- Bioaugmentation
- Bioventing

Groundwater Remedial Technologies

- No Action
- Active In-situ Bioremediation
- Passive In-situ Bioremediation
- Dual-phase Extraction
- Bioaugmentation
- Bioslurping
- Air Sparging/Biosparging

Each of these technologies have been qualitatively evaluated with regard to their effectiveness, implementability, and associated cost factors. The evaluation is based on a review of available literature, case studies, and limited knowledge of site-specific conditions. The following site-specific assumptions were made to assist in the evaluation of the technologies:

- benzene is the primary contaminant of concern
- shallow soils consist predominantly of clayey soils with some sand content
- subsurface foundation walls may exist
- depth to groundwater varies from 2 to 6 feet below the ground surface

- impacted vadose zone soil (soils situated above the existing groundwater level) exists within the former tank, dispenser, and pipeline area
- impacted soil also exists within the "smear" zone, zone of groundwater fluctuation, coincident with the groundwater plume
- benzene levels in groundwater are radially dispersed from source area and extend below the existing building
- nutrient, oxygen and hydrocarbon-degrading bacteria levels are low within the groundwater plume

II REMEDIAL TECHNOLOGIES SCREENING

A. No Action

The "No Action" alternative consists of not performing any remedial activities and allowing intrinsic bioremediation to reduce soil and groundwater contaminant concentrations.

1. **Effectiveness**- The effectiveness of this action is highly dependent on the presence of hydrocarbon degrading bacteria, bacteria growth, and subsurface nutrient levels. If conditions are favorable, hydraulic control is not important, and time is not a factor then this technology can be effective.

2. **Implementability**- This technology can be readily implemented.

3. **Cost Factors**- The costs associated with this technology consist of those required to monitor groundwater quality including sampling, laboratory analysis, reporting, and annual operation and maintenance of the existing monitoring wells and piezometers.

4. **Site-specific Evaluation**- According to the United States Environmental Protection Agency's guidance for conducting Remedial Investigations, the "No Action" option must be evaluated as a potential remedial action for all sites. This remedial action is retained as a baseline for which other remedial alternatives are compared. In theory, if given enough time, this alternative could be successful if hydrocarbon degrading bacteria are present in significant quantities and if subsurface conditions are favorable for continued bacterial growth. However, previous biological testing at this site indicate that neither bacterial colonies nor subsurface conditions are conducive for intrinsic degradation over a reasonable amount of time. A risk-based corrective action (RBCA) screening indicates that benzene concentrations should be reduced, and the regulatory agency has indicated that active measures are required.

B. Excavation

Excavation involves the physical removal of impacted soil. Depending on concentration levels, the soil may require treatment prior to reuse or disposal at an appropriate landfill.

1. **Effectiveness**- This technology is a very effective method of soil remediation. The source of groundwater pollution can be physically removed, provided that it can be completely identified and is accessible.

2. **Implementability**- This technology can be accomplished with readily available heavy construction equipment. Excavation adjacent to structures may require underpinning and shoring. Excavation under building floors and footings poses additional problems for implementation. Dewatering may be required prior to backfill placement.

3. **Cost Factors**- The volume of impacted soil would be the main factor in determining costs required for excavation. Costs may include equipment, labor and material costs for excavation and backfilling, soil treatment, repaving, confirmation testing, transportation, profiling, and landfill disposal fees. For deep excavations, costs for shoring, underpinning, construction dewatering, and treatment of impacted groundwater from the excavation may substantially increase overall remedial costs. Water pumped from the excavation must be tested, treated, and properly permitted prior to discharge into a Publicly Owned Treatment Works (POTW) or recycling.

4. **Site-specific Evaluation**- Excavation would be highly effective in removing impacted soil along the former product line and tank area, thereby eliminating the potential for further leaching of hydrocarbons from soil to shallow groundwater. In the immediate area of the former pipe leak, where the highest benzene concentrations was measured, excavation could extend below the water table to remove hydrocarbon-impacted soil. Such an excavation may require shoring of the existing building and dewatering of the excavation. A combination of shallow excavation and other remedial technologies would be more cost effective than a deep excavation alone, because the highest concentration in soil are in the vadose zone near the leak and in a more extensive "smear zone" at the groundwater surface. As an effective method of source removal, excavation is retained for further consideration.

C. Vapor Extraction

Vapor extraction is an effective technology in remediating soil impacted with petroleum hydrocarbons in the vadose zone. The technology utilizes the process of volatilization in order to remove hydrocarbons from soil. In a typical soil vapor extraction system, a blower is utilized to draw soil vapor from an extraction well or well network placed within the zone of soil contamination. Extracted vapor is treated to remove the hydrocarbons before the vapor is discharged to the atmosphere. Equipment for soil vapor extraction are available as packaged units from environmental remediation equipment vendors. Typical system components include piping, vapor/liquid separator, vacuum pumps, and emission control devices.

1. **Effectiveness**- This technology is a proven method of remediating soil containing petroleum hydrocarbons such as gasoline. Its effectiveness depends on the porosity of soil in the vadose zone. Higher porosity soils (i.e. sands) would allow more air flow between the pores, thereby increasing volatilization. In contrast, the presence of low permeability silty/clayey soil may restrict air flow, and limit the effectiveness of vaporizing contaminants. A vapor extraction system implemented in such conditions may be proned to "short circuiting" or development of preferential air flow pathways.

2. **Implementability**- Since the area of impacted soil is not encumbered by structures, the wells could be easily installed. However, given the highly variable soil matrix, the effective radius of influence may be relatively small.

3. **Cost Factors**- Costs associated with this technology would include the installation of appropriately screened wells, permitting, and purchase and installation of the treatment system, utility installation and service fees, and operation/maintenance costs.

4. **Site-specific Evaluation**- While vapor extraction is highly effective in removing petroleum hydrocarbons from subsurface soils, the use of this technology at this site, which has a high groundwater table and soils with heterogeneous fill and debris would not be effective. Extraction well screens would need to be installed above the groundwater table perhaps horizontally in a relatively dense grid. The close proximity of the well screens to the ground surface and the heterogeneous fill materials would allow a potential for a preferential air flow pathway (short circuiting) to develop. Also, the vast majority of pollutants (benzene) is below the water table. Even under more favorable site conditions, vapor extraction is not performed to clean-soils below the groundwater table. Vapor extraction as a stand alone technology is not retained for further consideration.

D. **Active In-situ Bioremediation**

This technology involves the use of existing aerobic or anaerobic microbial colonies to break down petroleum hydrocarbons. The hydrocarbons become an "energy source" for the microbes. Microbes under aerobic conditions are capable of degrading petroleum hydrocarbons given sufficient nutrients, such as phosphorous and nitrogen, and oxygen. Anaerobic microbes can degrade specific compounds in the absence of oxygen but this is a lengthy process, generally longer in duration than degradation under aerobic conditions.

1. **Effectiveness**- In-situ bioremediation is a proven technology in treating organic compounds such as petroleum hydrocarbons in soil and groundwater. Its effectiveness depends on the ability of the indigenous microbes to utilize added nutrients and oxygen.

2. **Implementability**- Several applications of in-situ bioremediation could be applied to the site. Land treatment is the application of this technology to surface soil. Generally, lime and nutrients are spread over the site to balance the soil pH and promote the growth of indigenous bacteria. Treated soil is then tilled to insure adequate mixing. Treated zones include two feet of tilled soil and can extend one to two feet below the tilled zone. Mixing can be accomplished by available cultivation equipment from the farming industry. Treated soil meeting remedial objectives can be removed to allow reapplication of land treatment to deeper impacted soils.

   In-situ bioremediation of groundwater involves the injection of nutrients and hydrogen peroxide into water upgradient of the plume through dedicated injection wells. The injected solution under natural hydraulic gradient would mix with the plume to provide food and oxygen for promoting growth of indigenous bacterial populations. Extraction wells or trenches are placed downgradient of the plume to capture the treated groundwater. Treated water mixed with nutrients and hydrogen peroxide would be reinjected upstream of the plume.

   Another application of in-situ bioremediation of groundwater involves the use of a proprietary compound that releases dissolved oxygen into groundwater for enhancing microbial activity. This compound can be mixed with water to create a slurry that is pumped or poured into narrow, direct-push or augered bore holes. A grid of boreholes containing the compound would be placed in or around the contaminant source area to create a highly oxygenated zone. The compound slowly releases oxygen for about six months to enhance aerobic bioremediation. This compound is also available in a filter sock that can placed within the casing of a monitoring well or piezometer. A grid of wells or piezometers could be placed within the plume for treatment. Alternatively, a line of wells or piezometers could be placed downstream of the plume to form a treatment wall.

3. <u>Cost Factors</u>- For soils, this simple technology can be implemented with available earthmoving/mixing equipment. However, for the treatment of groundwater, significant costs may be required for the design and installation of a nutrient injection and groundwater extraction system. Additional costs may be necessary to maintain and operate the system due to clogging from excessive microbial growth within system piping and injection wells.

4. <u>Site-specific Evaluation</u>- This technology can be implemented to treat soil and groundwater at this site. Active bioremediation of soil could be achieved by in-situ excavation and treatment of soil at the former product line. Extraction of groundwater, treatment and nutrient addition, and reinfiltration are the active measures which distinguishes this alternative. A recirculating system consisting of upgradient infiltration and down gradient extraction wells or trenches combined with treatment and/or nutrient addition may be an effective method of reducing the amount of hydrocarbons in groundwater. A previous study indicated that low counts of indigenous bacteria capable of degrading hydrocarbons are present in subsurface soil. The use of active bioremediation techniques may enhance microbial cultures and accelerate biodegradation. This technology will be retained for further evaluation.

E. **Passive In-situ Bioremediation**

Passive in-situ bioremediation is similar to the "No Action" alternative but requires an involved process of monitoring and evaluation. This technology is a relatively new approach in groundwater remediation that is gaining regulatory acceptance. This technology is also known as natural biodegradation or remediation by natural attenuation. The theoretical basis of passive bioremediation focuses on the concept that after source removal, the rate of natural attenuation is greater than the rate of source input, and that the contaminant plume would shrink over time due to aerobic and anaerobic degradation. The main advantage of this technology is that groundwater remediation could be conducted with minimal engineering controls and without disrupting site use.

1. **Effectiveness**- The effectiveness of this approach is dependent on factors such as bacteria growth potential, nutrient levels, volatilization, chemical degradation, redistribution, and/or adsorption to soil particle surfaces. A comprehensive monitoring program would need to be established to assess plume size and the natural attenuation rate. Mass balances must be monitored to show that bioremediation is occurring. Time frames for achieving remedial goals may be relatively long when compared with other more aggressive remedial options.

2. **Implementability**- This technology could be easily implemented at the site following source removal. A complete site characterization would be necessary to develop a conceptual site model. Such characterization would include defining the extent of contamination in groundwater and evaluating nearby receptors from a risk-based approach. Establishment of the monitoring program would include the installation of additional monitoring wells which would be sampled for specific geochemical parameters.

3. **Cost Factors**- Costs for this technology include the initial site characterization and evaluation of geochemical processes and implementation of a long term monitoring program.

4. **Site-specific Evaluation**- This technology would not control the migration of the groundwater plume. It depends highly on the ability of indigenous bacteria to naturally degrade hydrocarbon compounds in soil and groundwater over time. A study indicated that bioactivity at the site is low. Passive bioremediation with existing microbial populations would likely require an unreasonable amount of time for achieving clean up goals. This technology will not be retained for future consideration.

F. Bioaugmentation

This technology is used in conjunction with active bioremediation. Bioaugmentation consists of the addition of specialized non-indigenous microbial cultures to enhance degradation of specific contaminants. This approach is utilized in environments where contaminants are very concentrated or indigenous bacteria are unable to grow even with the addition of nutrients.

1. **Effectiveness**- The ability of non-indigenous bacteria colonies to compete and acclimate with other indigenous bacteria colonies is unclear. It is also dependent on such factors as volatilization, chemical degradation, redistribution, and/or adsorption to soil particle surfaces. During remediation, mass balances must be monitored in order to show that bioremediation is occurring.

2. **Implementability**- This technology can be easily implemented provided that an effective system could be selected to deliver non-indigenous bacteria to soil and groundwater. Such a delivery system may include injection wells or trenches. Several vendors offer proprietary microorganism-based products and that can be blended to treat specific organic compounds. Although this technology may be easily implementable, non-indigenous bacterial colonies would have to be designed to survive outside the laboratory, or conditions within the soil matrix would have to be altered for survival. In addition, government regulators may be very cautious in permitting the introduction of specialized microorganisms. Substantial proof would need to be presented to insure that the risk to human health and the environment is low.

3. **Cost Factors**- Costs would include an initial geochemical investigation and bench scale testing to design or identify an appropriate microbial colony. Additional costs would be incurred when purchasing the proprietary bacterial product. Substantial costs may be incurred if soil conditions require alteration in order to support the non-indigenous bacterial colonies.

4. **Site-specific Evaluation**- A combination of bioaugmentation and active bioremediation may be effective in degrading hydrocarbons in soil and groundwater. However, there would be significant cost associated with bioaugmentation and the needs and benefits versus indigenous microbes are not well documented. There may also be questions regarding public or regulatory acceptance. This technology will not be retained for further consideration.

G. Bioventing

Bioventing is a soil remediation technology that oxygenates subsurface to enhance bioremediation. A variant of vapor extraction, this technology uses a system to force air through subsurface soils, either by pumping air into the soil or applying a vacuum to the soil. Moving air through the soil would deliver oxygen to indigenous microbial colonies that would act to degrade the chemicals of concern. A bioventing system is operated at a much lower vacuum or pressure relative to sparging or vapor extraction so that volatilization is minimized. Several factors influencing the applicability of this technology include soil permeability characteristics, soil moisture, temperatures, total organic carbon content, additional nutrients, and the presence of other indigenous microorganisms in the subsurface soil at the site.

1. **Effectiveness**- Bioventing can be effective in enhancing bioremediation if subsurface oxygen levels are low and relatively permeable soils exists beneath the site.

2. **Implementability**- Equipment necessary to implement bioventing is commercially available and sufficient space is available to install venting wells. Equipment components would include manifold piping, a vapor/liquid separator, vacuum pumps, and emissions control devices.

3. **Cost Factors**- The costs for implementation and operation of this technology is comparable to other treatment technologies. However, additional costs may be necessary to establish a monitoring program to evaluate the effectiveness of bioventing.

4. **Site-specific Evaluation**- A previous study at the site indicated that bioactivity at the site is low due to low amounts of nutrients and indigenous microbial colonies. The absence of indigenous bacteria would limit the effectiveness of bioventing in treating impacted soils at the site. In addition, the presence of low permeable silty clayey soil may restrict air flow and prevent adequate oxygen from reaching through some portions of the contaminated soil. The presence of a high groundwater table would limit installation of the air injection wells near the soil surface. During bioventing, preferential air flow pathways may develop thus portions of the impacted soil may not be treated. In addition, groundwater would not be treated using bioventing. This technology will not be considered for further evaluation.

H. Dual-Phase Extraction

Dual-phase extraction is a technique that extracts contaminated soil vapor and groundwater from the subsurface simultaneously to remediate sites more quickly and effectively than either conventional groundwater pumping or combined soil vapor/groundwater extraction systems. This technology uses a small diameter "straw" (pipe) that is lowered into a sealed wellhead just above the static water table. A high vacuum is applied to the straw, which causes soil vapor to enter the well. At the tip of the straw, groundwater is entrained in the soil vapor as a fine mist. Both soil and water vapor passes through a knockout pot for separation. As groundwater is extracted, the static groundwater level decreases to expose previously saturated soil. The straw is then lowered to extract additional soil vapor and groundwater. A high percentage of volatile organic compounds are volatilized from groundwater during extraction at the tip of the straw. Water mist accumulating in the knockout pot is treated prior to discharge. Extracted soil vapor is treated before discharge to the atmosphere.

1. **Effectiveness**- This technology would be effective in treating both dissolved-phase contaminants in groundwater and contaminated soil in the saturated zone if site physical conditions allow the use of dual-phase extraction. Such factors to consider include the depth to the water table and the presence of permeable soils.

2. **Implementability**- This technology can be easily implemented using commercially available equipment and materials.

3. **Cost Factors**- Equipment and materials costs may be higher than other treatment methods. Frequent site visits may be necessary to reposition the groundwater extraction tube in response to groundwater fluctuations. Increased operation and maintenance costs may be incurred. The limited zone of influence created by the extraction wells may require an excessive number of well installations. Additional costs would include implementation of a monitoring program consisting of monitoring well installation, long-term analytical testing expenses, and data reduction and evaluation.

4. **Site-specific Evaluation**- The water table at the site is shallow. The use of the vapor extraction at this site would be ineffective. Extraction well screens would need to be installed above the groundwater table. The shallow placement of the well screens may lead to the development of preferential pathways (short circuiting) and creating a much smaller zone of influence. Hence, for vapor extraction, an excessive number of wells may need to be installed in order to cover the zone of impacted soils. However, this technology may be effective in containing plume migration and treating dissolved-phase contaminants in groundwater. Higher labor and materials costs may be incurred for the installation of the dual-phase extraction wells. Based on the ineffectiveness of vapor extraction, this technology will not be retained for further consideration.

I. **Bioslurping**

Bioslurping is a technology that combines bioventing and vacuum-enhanced free product recovery in an integrated technology to treat petroleum hydrocarbon contamination. This technology uses one pump simultaneously, rather than sequentially, to extract free product, groundwater, and soil vapor as a combined waste stream. Soil vapor movement through the soil enhances the oxygen content of the subsurface environment, thus stimulating microbial activity. Extraction of free product and groundwater can be controlled via a tube inserted into an extraction well. Extracted liquid passes through an oil/water separator for partitioning of water and free product. Water from the oil/water separator is treated before discharge. Free product is collected for recovery. Extracted soil vapor may require treatment before discharge to the atmosphere. The main advantage of bioslurping is that equipment expenses can be reduced by using a single pump in extracting multiple waste streams. In addition, a bioslurping system can be converted to a bioventing system once free product recovery is complete.

1. **Effectiveness**- Bioslurping may be capable of treating saturated soils at the water table by drawing down the water table slightly to allow air flow in the saturated zone. Increased oxygen levels in the saturated zone would stimulate microbial activity. This process would not be accomplished using soil vapor extraction alone. However, bioslurping is primarily for free product recovery and soil aeration. Its effectiveness in treating dissolved-phase contaminants in groundwater is essentially that of a very limited groundwater recovery system.

2. **Implementability**- This technology can be easily implemented using commercially available equipment and materials. However, its primary focus as a technology is for recovery of free product.

3. **Cost Factors**- A complete site characterization and monitoring program would necessary to establish cleanup goals and to evaluate the effectiveness of bioslurping. Equipment and materials costs are comparable to other treatment methods. Bioslurping may require a large number of wells due to the limited effectiveness of bioventing in low permeable soils at the site. In wet seasons, frequent site visits may be necessary to reposition the equipment to prevent the uptake water into the system. Increased operation and maintenance costs may be incurred during this period. Additional costs would include implementation of a monitoring program consisting of monitoring well installation, long-term analytical testing expenses, and data reduction and evaluation.

4. **<u>Site-specific Evaluation</u>**- Bioslurping was conceptually designed for enriching the oxygen content in the vadose zone and free product removal with minimal groundwater extraction. The effectiveness of using bioslurping for the extraction of dissolved-phase contaminants from groundwater is not known. Groundwater extraction and treatment by bioslurping is not expected to be effective. This technology will not be considered for future consideration.

J. Air Sparging/Biosparging

Air sparging is the introduction of air below the water table to promote biodegradation activity in groundwater. Site remediation is accomplished through the volatilization of contaminants from the aqueous phase to the gaseous phase through air injected into the water table. The introduction of air increases the oxygen content of the impacted groundwater and promotes biodegradation of groundwater contaminants. Biosparging refers to the injection of air into water table at pressures and flow necessary to deliver supplemental oxygen but not induce volatilization. The common objective in both cases of sparging is to stimulate microbial activity and contaminant degradation by delivering supplemental oxygen to impacted water.

1. **Effectiveness**- This technology is effective in treating dissolved-phase hydrocarbons in groundwater beneath the site. However, the presence of alternating layers of low and high permeable soil may inhibit the applicability of sparging at the site. Injected air may move along a preferential path of least resistance and may not develop a uniform dispersion zone.

2. **Implementability**- Sparging could be easily implemented with commercially available equipment and materials. Pilot testing would be necessary to determine and evaluate aquifer response to sparging. Some of the parameters that would be obtained during pilot testing include dissolved oxygen content, pH, nutrient availability, and the presence of indigenous bacterial.

3. **Cost Factors**- Equipment and materials costs are comparable to other treatment methods. A pilot test would be necessary to assess the applicability of sparging to the site. Additional costs would include monitoring well or piezometer installation, long-term analytical testing expenses, and data reduction and evaluation.

4. **Site-specific Evaluation**- Air sparging volatilizes contaminants in groundwater and may create uncontrolled offgasing through the vadose zone. This potential may be of concern at the site since the RBCA risk screening results highlighted benzene vapor concentration as a potential exposure pathway. Installation of a soil vapor extraction system to capture the offgases may not be effective due to short circuiting of the vapor extraction wells. However, biosparging may be effective in providing supplemental oxygen to promote bioactivity. Biosparging would be more effective when used with other bioremediation techniques such as active bioremediation and bioaugmentation. Biosparging will be retained for further evaluation.

III CONCLUSIONS

To put the technology evaluation into perspective, each technology was subjectively ranked on the basis of remedial effectiveness, ease of implementation, and capital and operational costs. A weighting factor was applied to each category (effectiveness, implementability, and cost) to account for the categories relative importance. A raw score was then obtained by summing the rankings multiplied by the weighted factor for each category. A relative score was obtained by subtracting the baseline technology weighted raw score from the total raw scores of each technology. A summary of this ranking sytem is presented in Tables 1 through 4.

Results of the technology screening indicate that a combination of technologies present the most effective alternative in remediating hydrocarbon impacted soil and groundwater at the Cox site. Impacted soil existing in the areas of the former tank, dispenser and piping would be most effectively remediated by excavation. Soil in these areas would be excavated down to the groundwater level. The excavated soils would then be aerated/treated on site and then either replaced into the excavation or disposed of at an appropriate landfill facility. At this time no additional site information would be required to complete the final design of this remedial alternative.

Impacted groundwater, and soils within the "smear" zone, would be most effectively remediated by using active in-situ bioremedial technologies. Groundwater is extracted along the downgradient plume boundary using trenches or extraction wells. The extracted water would then be aerated, and nutirents and bacteria would be added. The treated water would then be percolated into subsurface through infiltration trenches. This alternative may require the addition of carbon polishing of the treated water prior to infiltration for treatment of benzene in the groundwater. An added benefit of the extraction trenches/wells would be that at least partial hydraulic control of the plume would occur. Additional investigation consisting of the installation of an extraction well and a pump test, will be required to complete the final design of this alternative.

Table 1 Summary of Soil Remedial Alternatives, Former Cox Cadillac, 230 Bay Place, Oakland, California.

Remedial Alternative	Effectiveness	Implementability	Costs
No Action (Baseline)	Low	High	Low
Excavation	High	High	Medium
Vapor Extraction	Low	Medium	High
Active In-Situ Bioremediation	Medium	Low	High
Passive In-Situ Bioremediation	Low	Low	Low
Bioaugmentation	Medium	Low	High
Bioventing	Medium	Medium	High
Dual-phase Extraction	Low	Medium	High

Table 2 Cost-effectiveness Analysis, Soil Remedial Alternatives, Former Cox Cadillac, 230 Bay Place, Oakland, California.

Remedial Alternative	Rankings			Score
	Effectiveness	Implementability	Costs	
Weight	4	1	3	
No Action (Baseline)	-4	3	3	-4
Excavation	3	2	2	20
Vapor Extraction	-2	0	0	-8
Active In-Situ Bioremediation	2	-3	-3	-4
Passive In-Situ Bioremediation	1	-2	-2	-4
Bioaugmentation	0	-4	-4	-16
Bioventing	-1	1	1	0
Dual-phase Extraction	-3	-1	-1	-16

Notes: Rankings based on the following scale: 3 (best), 0 (average), -4 (worst)

Table 3 Summary of Groundwater Remedial Alternatives, Former Cox Cadillac, 230 Bay Place, Oakland, California.

Remedial Alternative	Effectiveness	Implementability	Costs
No Action (Baseline)	Low	High	Low
Active In-Situ Bioremediation	High	Medium	Medium
Passive In-Situ Bioremediation	Low	Medium	Medium
Bioaugmentation	Medium	Low	High
Bioslurping	Low	Low	High
Dual-phase Extraction	Medium	Low	High
Air Sparging/Biosparging	Medium	Medium	Medium

Table 4 Cost-effectiveness Analysis, Groundwater Remedial Alternatives, Former Cox Cadillac, 230 Bay Place, Oakland, California.

Remedial Alternative	Rankings			Score
	Effectiveness	Implementability	Costs	
Weight	4	1	3	
No Action (Baseline)	-3	3	3	0
Active In-Situ Bioremediation	3	0	0	12
Passive In-Situ Bioremediation	-2	1	1	-4
Bioaugmentation	1	-3	-3	-8
Bioslurping	-1	-2	-2	-12
Dual-phase Extraction	2	-1	-1	4
Air Sparging/Biosparging	0	2	2	8

Notes: Rankings based on the following scale: 3 (best), 0 (average), -3 (worst)

July 24, 1996
SCI 805.010

Mr. Don Eisenberg
EOA, Inc.
1410 Jackson Street
Oakland, California 94612

Probable Cost for Interim Remedial Action
Cox Cadillac
230 Bay Place
Oakland, California

Dear Mr. Eisenberg:

This letter transmits information regarding interim bioremedial techniques which could be implemented at the referenced site. The information presented was obtained by Subsurface Consultants, Inc. by contacting CytoCulture International, Inc. (CytoCulture) and Regenesis Bioremediation Products (Regenesis). A preliminary biotreatability study was previously performed on groundwater samples collected from the site. Results of the study indicated that biodegradation activity at the site is low and that the biodegradation of hydrocarbon contamination could be enhanced by nutrient/oxygen addition and bacteria augmentation.

CytoCulture is a local environmental company specializing in bioremediation technology. Upon his review of site data, Dr. Randall von Wedel of CytoCulture concurs that significant contaminant reduction at this site could be achieved using a well designed groundwater bioreactor system. However, he does not believe that the existing environment would benefit significantly by the introduction of dry bacteria and nutrients into existing wells. Dr. von Wedel has indicated that this type of interim measure may be ineffective because the addition of these cultures may cause biofouling in the wells which would render them useless for future monitoring events. Furthermore, Dr. von Wedel indicated that the Regional Water Quality Control Board may not permit the introduction of liquid bacteria and nutrients at the site without hydraulic control provided by groundwater extraction.

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Regenesis is a bioremediation products company that markets an oxygen release compound (ORC) for enhancing in-situ bioremediation of groundwater. Theoretically, the ORC which contains magnesium peroxide, would slowly release dissolved oxygen to groundwater to enhance natural biodegradation of contaminants. Regenesis' proposal includes installing a grid of boreholes to cover the entire benzene plume which are then filled with a slurry containing the ORC. A grid of ORC boreholes would be installed on 8-foot spacing to a depth of 10-feet over a 48 feet by 100 feet area. The approximate cost to implement this scenario would be about $53,000 ($40,000 for materials and $13,000 for installation). On a smaller scale, the OCR grid could be established only for the source area (former tank and dispenser locations) covering an area of 15 feet by 50 feet. The cost required to implement this scenario would be approximately $9,000 ($6,000 for materials and $3,000 for installation).

Regenesis also could provide "socks" containing the ORC which could be installed within existing wells at the site. However, it is expected that the radial dispersion of dissolved oxygen would be limited only to the zone immediately surrounding the wells. Placing the ORC "socks" into the monitoring wells will render the wells inappropriate for monitoring purposes while the ORC is active. Additionally, it will be difficult to assess the effectiveness of the ORC addition without additional monitoring points. The cost of the ORC "socks" and installation would be about $1000.

Please call if you have any questions.

Yours very truly,

Subsurface Consultants, Inc.

Samuel C. Won
Project Engineer

Jeriann N. Alexander
Civil Engineer 40469 (exp. 3/31/99)

SCW:JNA:sld