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July 29, 1998

Roll 68

State Water Resources Control Board
P. O. Box 944212
Sacramento, California 94244-2120

Re: *Corrective Action Plan*
3927 East 14th Street
Oakland, California

Dear Sir or Madam:

Enclosed is the *Corrective Action Plan* for Ruben Hausauer's 3927 East 14th Street, Oakland, California site. This report was prepared by ATC Associates Inc. at the request of the Ruben Hausauer and the Alameda County Health Care Services Agency in its letter dated April 22, 1998.

Very truly yours,



Tommy A. Conner

TAC:syr

Enclosure

cc: Barney Chan (w/o encl)
Alameda County Health Care Services

Gary Rogers, Ph.D. (w/encl)
Aquatic & Environmental Applications

Prepared For:

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**CORRECTIVE ACTION PLAN
FOR
NEW GENICO SITE
3927 E. 14TH STREET
OAKLAND, CALIFORNIA**

ATC PROJECT NO. 61137.0005

7/23/98


Prepared by:

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July 23, 1998



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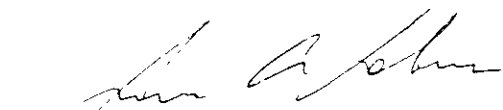

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Senior Geologist

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**CORRECTIVE ACTION PLAN
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NEW GENICO SITE
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ATC PROJECT NO. 61137.0005**

1.0 INTRODUCTION

This report has been prepared for Mr. Ruben Hausauer of Oakland, California by ATC Associates Inc. (ATC). This site-specific Corrective Action Plan (CAP) has been prepared for the New Genico site located at 3927 East 14th Street in Oakland, California (Figure 1). The CAP is related to a release from a former underground storage tank (UST) that has been removed from the site. The CAP was requested by the Alameda County Health Care Services Agency (ACHCSA) in a letter dated April 22, 1998. The CAP has been prepared in general accordance with the California Code of Regulations, Division 3, Chapter 16, Sections 2725(d), (e), (f), and (g).

The scope of work for the CAP includes the performance of a preferential pathway investigation in front of the New Genico site on 40th Avenue and an evaluation of alternatives for removal of residual contamination within groundwater to the site-specific target levels (SSTLs). The SSTLs were proposed based upon a Tier II of the Risk-Based Corrective Action (RBCA) evaluation, as described in ASTM E-1739 "*Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites.*" The results of the RBCA evaluation are provided in a August 22, 1997 report prepared by ATC: "*Well Survey, Conduit Study and ASTM Tier 2 RBCA Analysis, New Genico Site, 3927 E. 14th Street, Oakland, California*", and a supplemental letter dated May 12, 1998, prepared by ATC: "*Response to Agency Comments: ASTM Tier 2 RBCA Analysis, 3927 East 14th Street, Oakland, California*".

1.1 OBJECTIVE

The objectives of the CAP are to evaluate applicable remedial action activities for groundwater, and recommend an applicable remediation technology.

1.2 SITE DESCRIPTION

The site is presently used by the New Genico Automotive Electrical Service (Genico) to rebuild automotive parts. The facility is located on the north side of 40th Avenue in Oakland, California on the east side of Interstate I-880 (Figure 1). The site area is occupied by a warehouse-type building with offices in the front (south side) and the remainder of the building is used for rebuilding and storage of parts. The former UST was located in front of the building under the sidewalk adjacent to 40th Avenue.

2.0 SUMMARY OF SITE ACTIVITIES AND CORRECTIVE ACTION

2.1 SUBSURFACE INVESTIGATIONS

One 550-gallon capacity UST, reportedly used for the storage of waste oil, was located beneath the sidewalk in front of the New Genico facility on 40th Avenue, near the intersection of East 14th Street, in Oakland, California. Two soil borings were drilled at the site in September 1993 by John P. Cummings and Associates, and the results of this investigation were presented in a report dated September 30, 1993, entitled " Report on the Site Investigation, 3927 E. 14th Street, Oakland, California". The two borings, B-1 and B-2, were advanced at angles below the UST. They were advanced to depths of approximately 11 feet below ground surface (bgs). Soil samples were collected at depths of 4 and 7 feet bgs in each boring. Groundwater was not encountered in either boring. The soil samples were analyzed for Total Petroleum Hydrocarbons as gasoline (TPHg) and TPH as diesel (TPHd) in general accordance with Environmental Protection Agency (EPA) Method 8015 Modified; Total Oil and Grease (TOG) in general accordance with Method 5520 D&F; benzene, toluene, ethylbenzene and total xylenes (BTEX compounds) in general accordance with EPA Method 8020; and the five heavy metals: Cadmium, Chromium, Lead, Nickel and Zinc using various methods. Benzene, TPHg and Halogenated Hydrocarbons were not detected in the soil samples. Five heavy metals, TPHd, TOG, toluene, ethylbenzene and total xylenes were detected in the soil samples. The results of this soils investigation are presented in John P. Cummings & Associates', September 30, 1993 report: "*Report on the Tank Site Investigation, 3927 E. 14th Street, Oakland, CA*".

Following this initial site work, an additional soil boring was advanced at the site, adjacent to the UST, and a groundwater monitoring well, HMW-1, was installed in the boring. The results of this investigation are presented in a report prepared by John P. Cummings and

Associates, dated July 4, 1994: "*Groundwater Monitoring, 3927 E. 14th Street, Oakland, CA*". TPHg, TPHd and TOG were detected in groundwater sample collected from HMW-1.

At the request of the ACHSA additional subsurface investigation was performed at the site in August 1996. Additional data were requested by the ACHSA to evaluate whether the existing groundwater contamination detected at the site is originating at one or more sources. In response to this request, ATC conducted a soil and groundwater investigation that included the installation of three temporarily cased borings (TCBs). Soil samples were analyzed in the field to determine the location of monitoring wells. Two of these TCBs were converted into monitoring wells HMW-2 and HMW-3, shown on Figure 2. Five soil samples from the borings were analyzed for TPHg and BTEX compounds. The well HMW-1, adjacent to the former UST location was installed at an earlier date. In addition, wells associated with the site across the street (the Motor Partners site) were installed in the vicinity of the New Genico site. Water level monitoring in these wells indicated that the direction of groundwater flow beneath the site is in a generally southerly direction.

In addition, the UST was removed from the ground during the soil and groundwater investigation. ATC observed the tank excavation and collected soil samples from around the excavation following tank removal. Five post-tank-removal soil samples were analyzed for TPHg, BTEX compounds and TPHd. At the time of the tank removal, it was observed that the tank had about eight inches of product remaining.

Groundwater samples were collected from the TCBs and the monitoring wells and analysis of these samples indicated that TPHg and BTEX compounds were present. The investigation also suggested that the westerly extent of the benzene in groundwater is near well HMW-3. Furthermore, groundwater data suggested that a second, off-site, source of groundwater contamination was present and was impacting groundwater quality in the vicinity of HMW-2. This additional subsurface investigation is summarized in ATC's September 19, 1996 report: "*Soil and Groundwater Investigation, 3927 East 14th Street, Oakland, California*".

Following implementation of the additional subsurface investigation, quarterly groundwater monitoring of the wells was implemented. Results of the quarterly groundwater monitoring are summarized in Table 1. Groundwater monitoring is performed concurrently with groundwater monitoring of the leaking UST site across 40th Avenue from the site--the Motor

Partners site. A second, off-site, source of groundwater contamination is originating at the Motor Partners site, located at 1234 40th Avenue. Figure 2 shows the location of Motor Partners in relation to the site, and shows the locations of the monitoring wells associated with the investigation of the groundwater plume originating at this adjacent property.

In November 1997, in order to assess the length of the plume beneath 40th Avenue, a fourth monitoring well, HMW-4, was installed and sampled by Artesian Environmental Consultants (Artesian). HMW-4 is located downgradient of HMW-2. The location of HMW-4 is shown on Figure 2. Artesian's January 30, 1997 report: *"Groundwater Sampling Point Installation and Sampling Report, 3927 East 14th Street, Oakland, California"* describes the installation of well HMW-4. This well was incorporated into the quarterly groundwater monitoring program for the site in November 1997.

Total TPH concentrations detected in groundwater samples collected from the Motor Partners' site (TPHg and TPHd) and the New Genico site (TPHg, TPHd and TPH as motor oil (TPHmo)) in June 1998, are shown on Figure 3 and are summarized below.

<u>Well I.D.</u>	<u>Site</u>	<u>Total TPH (mg/L)</u>
HMW-1	New Genico	15.9
HMW-2	New Genico	7.3
HMW-3	New Genico	nd
HMW-4	New Genico	0.94
MW-1	Motor Partners	3.7
MW-2	Motor Partners	0.4
MW-3	Motor Partners	10
MW-4	Motor Partners	0.07
MW-5	Motor Partners	9.3

note: nd = not detected.

Groundwater flow beneath the site has been documented to be in a generally southerly direction but varies between south-southwesterly to south-southeasterly. The highest detected concentration of contaminants associated with the New Genico site is in the vicinity of HMW-1. Concentration of contaminants detected in MW-4, located about 15-feet south of HMW-1 are significantly lower than concentrations in HMW-1. For example, data from the June 1998 sampling event show that the concentration of total TPH drops off from 15.9 mg/L in HMW-1

to 0.07 mg/L in MW-4. Despite the groundwater flow direction, the analytical data suggest that the groundwater plume from the New Genico site is not migrating in a southerly direction.

2.2 CONDUIT STUDY

As part of the RBCA evaluation and this CAP, ATC performed a conduit study. The goal of the conduit study was to evaluate potential preferential pathways for groundwater flow beneath the site. Results of the conduit study are summarized below. Design plans of the subsurface sewer lines in the vicinity of the site were obtained from the Oakland Engineering Department (OED). In order to evaluate the possibility of groundwater entering the backfill around the sanitary and storm sewers, plans available at the OED were reviewed. The sanitary sewer line originates in front of the site beneath 40th Avenue and slopes towards the southwest. Storm sewer lines are not installed beneath 40th Avenue but rather begin southwest of the site on East 13th Street. Based upon the historical depth of groundwater beneath the site and typical depths of sanitary sewers, it is possible that the permeable backfill for the sewer lines may be in the saturated zone during periods of high groundwater, and during these times the groundwater plume would enter the backfill for the sewer lines.

To further investigate the possibility that the utility trenches were a preferential pathway for the groundwater plume beneath 40th Avenue, ATC interviewed municipal workers. Workers reported no evidence of sewer malfunction or petroleum hydrocarbon odor in the area of 40th Avenue.

In order to further investigate the possibility of a man-made preferential pathway in the vicinity of the former UST, ATC performed a site reconnaissance as part of this CAP. The reconnaissance was performed on July 8, 1998 to determine the location of sewer laterals from the on-site building to the sewer main. An ATC employee was accompanied by New Genico personnel during the reconnaissance. ATC did not observe any sewer cleanouts in the portion of the building that fronts on 40th Avenue. The bathroom is located at the northwestern portion of the building. What appeared to be the sanitary sewer cleanout was observed in the floor in the bathroom. This indicates that the sewer lateral from the building connects to the sewer main beneath 39th Avenue, rather than 40th Avenue. In addition, water and electricity were observed to enter the building from 39th Avenue. Our conclusion is that there is a low likelihood that there is a man-made preferential pathway in the vicinity of the former UST at the New Genico site.

2.3 SITE AND REGIONAL GEOLOGY AND HYDROGEOLOGY

2.3.1 Regional Geology

The San Francisco Bay Area, east of the San Andreas fault, is underlain by a bedrock sequence known as the Franciscan Formation. The Franciscan Formation consists of Mesozoic Era oceanic deposits that were lithified into hard sandstone, chert and greenstone. The Franciscan Formation was partly crushed and thoroughly mixed while it was subducted beneath the edge of the continent. During subduction, gabbro, and rock that later formed serpentine were incorporated in to the Franciscan Formation (USGS, 1979).

The San Francisco Bay region was divided into basins and highlands during the Cenezoic Era, and sand, clay and gravel eroded from the highlands and were deposited beneath the sea or on alluvial plains in the subsided basins. These sediments were interbedded with volcanic rocks and diatomaceous deposits. These deposits were lithified into sandstone, shale, conglomerate and chert, were folded, faulted and tilted. This Cenezioc age rock is typically not as hard as the Mesozoic Franciscan Formation (USGS, 1979).

The site is located within the Flatland Deposits of the San Francisco Bay Region of Northern California. The site is mapped to be located within medium-grained Quaternary alluvium that consists of up to 12-feet of unconsolidated, moderately sorted, moderately permeable fine sand, silt, and clayey silt with occasional thin beds of coarse sand (USGS, 1979).

2.3.2 Site Geology and Hydrogeology

Based on the work conducted during the subsurface investigations, the site geology has been interpreted to consist of young alluvium. The stratigraphic horizons encountered during advancement of the borings include a sandy or silty clay to a depth of approximately 7 to 10 feet below ground surface (bgs) which is underlain by a clayey gravel or a silty or gravely sand to about 16.5-feet bgs. The gravel and sand unit is underlain by a silty clay. Groundwater was first encountered at a depth of about 12-feet bgs during advancement of the borings for the subsurface investigations, but quickly rose to about 8-feet bgs after boring completion. The gravel and sand aquifer therefore appears to be under confined conditions. The aquifer thickness is between about 5.5 and 9.5-feet.

The monitoring wells are screened in the aquifers as follows. HMW-2 and HMW-3 are constructed with 10-foot lengths of 2-inch diameter, 0.02-inch slot, schedule 40, PVC screen. Well HMW-4 is constructed with a 10-foot length of 1.6-inch diameter, 0.01-inch slot, schedule 40 PVC prepack well screen. Well construction details for HMW-1 were not available.

Based on the groundwater elevation data obtained during the years of groundwater monitoring at the site (Table 2), the gradient for the aquifer has been interpreted. The gradient at the site has been interpreted to be directed to the south at an average magnitude of 0.013.

2.4 RECOMMENDED TARGET CLEANUP LEVELS

Target cleanup levels were obtained using the ASTM standard RBCA. The ASTM standard RBCA evaluation was performed following Standard E 1739-95 and the Tier 2 Guidance Manual for Risk Based Corrective Action published by Groundwater Services, Inc. (GSI) of Houston, Texas. The results of this analysis are summarized in ATC's reports referenced in Section 1.0. A summary of the RBCA analysis is provided below.

Subsurface soil (>3-feet bgs) and groundwater were identified as secondary sources of contamination. Soil samples collected from the walls and bottom of the excavation made during removal of the UST in August 1996 were evaluated. The averages of these concentrations are:

- 0.22 milligrams per kilogram (mg/Kg) benzene;
- 0.92 mg/Kg ethylbenzene;
- 1.9 mg/Kg toluene, and
- 10 mg/Kg total xylenes.

The potential transport mechanisms for these sources at the site are volatilization and atmospheric dispersion, volatilization and enclosed space accumulation and leaching and groundwater transport. The only identified complete exposure pathway is inhalation of vapor. Potable use of groundwater beneath the site was evaluated and eliminated as an exposure pathway because water wells were not identified within a one-half mile radius of the site and because groundwater quality in the vicinity of the site is generally degraded and would

therefore not likely be used for potable water in the foreseeable future. The site and area upgradient of the site is primarily non-residential. However, the property adjacent to the site to the south is residential and the area southeast of the site is residential. Potential receptors were identified as on-site non-residential workers and off-site occupants of residential structures.

The results of the Tier 1 RBCA analysis indicated that no further action would be required for subsurface soil contamination, and that the only constituent of concern for groundwater was benzene. Tier 2 RBCA input was selected. The target risk values for benzene were set at $1.0E-5$ for commercial exposure and $1.0E-6$ for residential exposure. For the Tier 2 RBCA evaluation, the representative concentration of benzene in subsurface soil and groundwater were 0.22 mg/Kg and 0.25 mg/L, respectively.

The site specific target levels (SSTLs) were calculated using the Tier 2 RBCA model. It was found that using a target risk of $1.0E-5$, the SSTL for benzene in groundwater is marginally higher than the above referenced representative concentration of benzene in groundwater. However, using the more conservative target risk of $1.0E-6$, the SSTL for benzene is significantly lower than the representative concentration of benzene in groundwater. Based upon this analysis, it was recommended that an interim remedial measure to reduce benzene concentrations in groundwater be performed proximate to the former New Genico UST.

3.0 SITE-SPECIFIC FEASIBILITY EVALUATION

3.1 EVALUATION OF REMEDIAL ALTERNATIVES

A survey of the applicable remedial methodologies was conducted as part of this CAP. An important consideration in reviewing these technologies was the ongoing use of the site as a automotive parts servicing facility. Feasible remedial alternatives that could be implemented without adversely affecting the activities at the site were selected for further evaluation. Another important consideration taken into account when evaluating the technologies was that they were complimentary and adaptable to changing field conditions

3.1.1 Soil Vapor and Groundwater Extraction and Treatment

Soil vapor extraction (SVE) and groundwater pump and treat were preliminarily evaluated as alternatives.

SVE is used to reduce concentrations of contaminants in source areas. SVE primarily affects concentrations of contaminants adsorbed to soil. SVE is most effective in reducing concentrations of contaminants in soils with relatively high air permeability. The soil beneath the site consists of between 7 and 10 feet of clays, underlain by a sand and gravel aquifer. Due to the low permeability of clays, and the observation that a significant source of impacted soil does not appear to exist beneath the site, SVE was not selected for further evaluation.

Groundwater pump and treat systems remove contaminants from the groundwater by pumping groundwater from extraction wells and treating the water at the surface using one or more treatment technologies. Treatment technologies appropriate for petroleum compounds include air stripping and carbon absorption. The effluent from pump and treat systems is typically discharged to a surface drainage or a sanitary sewer. In order for a pump and treat system to be effective in containing a contaminant plume, the radius of influence of the pumping well, or the capture zone of the well field, must encompass the entire plume. Pump and treat systems can also be effective in capturing free product floating on the groundwater, when present.

Pump and treat systems can remove contaminated groundwater from an aquifer, however, irreducible free product and petroleum hydrocarbons sorbed to the soil particles tend to remain. Hundreds of pore volumes of water may be required to flush the petroleum hydrocarbons off the contaminated soil particles, and/or dissolve irreducible free product. This flushing can be very slow and expensive, and may take several tens of years. Pump and treat remediation alone is now recognized as being ineffectual at reaching groundwater cleanup levels for petroleum hydrocarbons in many geologic settings (Rice, et al, 1995).

Site specific limitations to this alternative include physical constraints to locating the system. The entire site is occupied by a building. The system would have to be installed inside and would interfere with operations at the facility. The second site specific limitation for this alternative is that the plume from the New Genico site is commingling with the Motor Partners plume. Groundwater pump and treat would treat the entire plume and the mass of petroleum products removed from the subsurface would be increased due the Motor Partners site.

Due to these limitations, groundwater pump and treat is not considered a viable option for the site.

Historical case studies of fuel leak sites indicate that once a petroleum hydrocarbon source is removed, the time for passive bioremediation to reduce the dissolved petroleum hydrocarbon plume by a factor of 10 is about 1 to 3 years. Thus, once the petroleum hydrocarbon sources are removed, passive bioremediation can provide a remediation alternative that is as effective as actively engineered remediation (Rice, et al, 1995).

Cost-effectiveness of each remedial alternative is another primary factor in the selection process. For this evaluation, the following treatment remedial alternatives were deemed technologically feasible, applicable, and effective:

- Natural Attenuation / Intrinsic Bioremediation; and
- Addition of Oxygen Releasing Material.

These technologies are discussed in further detail below.

3.1.2 Natural Attenuation / Intrinsic Bioremediation

Several detailed field studies have been performed to examine indicators of intrinsic bioremediation and identify factors which significantly affect the rate and extent of bioremediation (Buscheck and others, 1993; McAllister and Chiang, 1994; Borden and others, 1995; and Buscheck and Alcantar, 1995). Through these studies, and ongoing research of the factors which control biodegradation, it is now understood that dissolved petroleum hydrocarbons in groundwater will biodegrade, without artificial enhancement, due to the presence of naturally occurring (indigenous) microorganisms. Technical protocols for implementing and monitoring intrinsic bioremediation studies in groundwater have been developed by the U.S. Air Force, Chevron Corporation, and others.

Intrinsic bioremediation, in brief, is the process of indigenous microorganisms degrading contaminants which have been released into the subsurface. The biodegradation of the contaminants is essentially an oxidation-reduction (redox) reaction where the hydrocarbon is oxidized (donates an electron) and an electron acceptor is reduced (accepts electrons). There are several compounds that can serve as electron acceptors including oxygen, nitrate, iron oxides (Fe III), Manganese (Mn IV), sulfate, and carbon dioxide (Borden and others, 1995). Aerobic microorganisms use oxygen as the electron acceptor. Anaerobic microorganisms use other

compounds such as nitrate, iron oxides (ferric iron), manganese oxide (Mn IV), sulfate, and carbon dioxide as electron acceptors.

Oxygen is the most preferred electron acceptor in groundwater because microorganisms gain more energy from these reactions; however, this process usually results in the depletion of oxygen with an increase in carbon dioxide in the subsurface. Therefore, low concentrations of dissolved oxygen and corresponding high concentrations of carbon dioxide within a hydrocarbon plume indicate biodegradation is taking place (Borden and others, 1995).

In anaerobic environments, microorganisms may use other compounds such as nitrate, ferric iron, manganese, and sulfate as electron acceptors. Thus, an increase in ferrous iron, carbon dioxide, dissolved manganese (Mn II), and perhaps sulfide, and a corresponding decrease in nitrate and/or sulfate within a hydrocarbon plume may indicate biodegradation is taking place.

Additional indicators of anaerobic biodegradation include total alkalinity, redox potential (Buscheck and O'Reilly, 1995), and methane (Borden and others, 1995). The total alkalinity of a groundwater system is indicative of the water's capacity to neutralize acid. Alkalinity results from the dissolution of rock (particularly carbonate rocks), the transfer of carbon dioxide from the atmosphere, and the respiration of microorganisms. Therefore, an increase in alkalinity within a hydrocarbon plume is potentially an indicator of bioremediation occurring (Buscheck and O'Reilly, 1995). The redox potential of groundwater generally ranges from -400 millivolts (mV) to 800 mV. Under oxidizing conditions, the redox potential of groundwater is positive while reducing conditions are negative. The redox potential inside a hydrocarbon plume should be less than that measured outside the plume (Buscheck and O'Reilly, 1995), and generally negative. Methane levels generally increase within the plume as a byproduct of the breakdown of petroleum hydrocarbons under anaerobic conditions (Borden and others, 1995).

During the past three quarterly events, groundwater samples have been collected from site wells and analyzed for ferrous iron, nitrate, sulfate, dissolved oxygen, and oxidation-reduction potential (redox). A summary of these analyses is presented in Table 3. When comparing data from well HMW-3, located upgradient of the plume, to data from well HMW-1, located within the former source area, to data from well HMW-2 located within the plume but downgradient of the former source area, the data suggests that anaerobic bioremediation processes are occurring.

Interpretation of the data allows the following conclusions:

- The similar dissolved oxygen concentrations between wells HMW-3, HMW-1 and HMW-2 suggests that aerobic bioremediation may not be occurring due to a limited oxygen environment.
- The generally reduced concentrations of sulfate, nitrate and oxidation-reduction potential in wells HMW-1 and HMW-2 are consistent with anaerobic bioremediation processes.
- The generally elevated concentrations of dissolved ferrous iron in well HMW-1, is consistent with anaerobic bioremediation processes.

Anaerobic bioremediation does reduce concentrations of petroleum hydrocarbons. However, without dissolved oxygen being continuously supplied to the plume from upgradient, the length of time for complete bioremediation can be much longer.

The cost for implementing the natural attenuation option on a yearly basis is estimated to be \$10,000. This cost includes one year of quarterly groundwater monitoring, data interpretation and report preparation. The monitoring cost includes sampling of the existing four groundwater monitoring wells, laboratory analyses, and reporting. The analytical cost includes monitoring for biological parameters.

3.1.3 Addition of Oxygen Releasing Material

Oxygen releasing material (ORM) can be used to increase the supply of oxygen to a hydrocarbon plume to significantly reduce the time required for aerobic bioremediation. By adding a significant mass of oxygen to the heart of the hydrocarbon plume, the time required for aerobic respiration of the plume can be dramatically reduced. A description of ORM source treatment applications, by REGENESIS Bioremediation Products, is included in Appendix A. *ORC® Applications Software Version 2.0* was used to calculate the mass of ORM and number of boreholes required to treat the central area of the aquifer plume. A table summarizing the results entitled *ORC Slurry Injection* is included in Appendix A. The area of highest groundwater concentrations was selected for treatment (centered around the former tank pit). Based upon a concentration of 16 ppm over a 500 square foot area, the required mass of ORM to treat the central area of the aquifer was calculated to be 408 pounds. The calculations show that the ORM should be distributed in 8 boreholes spaced on 8-foot centers.

In order to account for uncertainty in the input values for the *ORC® Applications Software*, and based upon industry experience in applying ORM, a second application of ORM may be required at the site. The need for a second application of ORM would be determined based on quarterly groundwater monitoring results for a period of approximately one year.

An order of magnitude cost estimate for the one-time addition of ORM to the aquifer is \$9,000. The cost for the addition of ORM includes permitting, drilling, and ORM usage and reporting. This cost does not include routine quarterly groundwater monitoring and sampling.

3.2 Recommended Alternative

A comparison of order of magnitude costs for the treatment alternatives was performed. The estimated costs are presented for the first year of each alternative, and cumulative costs for a period of two-years and for a period of four years.

<u>Alternative</u>	<u>First Year Cost</u>	<u>Cumulative (2-year) Cost</u>	<u>Cumulative (4-year) Cost</u>
Natural Attenuation/ Intrinsic Bioremediation (quarterly monitoring only)	\$10,000	\$20,000	\$40,000
One-time addition of Oxygen Releasing Material (including quarterly monitoring)	\$19,000	\$29,000	\$49,000
Two-time addition of Oxygen Releasing Material (including quarterly monitoring)	\$28,000	\$38,000	\$58,000

The lowest yearly and cumulative costs presented are for groundwater monitoring only. However, to achieve required regulatory levels in the site groundwater through natural attenuation only, a much longer time period may be required. For example, it may take four years or more of natural attenuation/intrinsic bioremediation to achieve regulatory levels. However, it may only take two years to achieve regulatory levels using a one or two time application of ORM. For this analysis it is estimated that it would take about two years to

achieve site closure using either the one or two time application of ORM. The cost for the one and two time application of ORM in combination with the quarterly monitoring for two years is \$29,000 and \$38,000, respectively. In comparison, the cost for four years of the natural attenuation/intrinsic bioremediation alternative is \$40,000. This order of magnitude analysis suggests that the addition of ORM would be a cost effective alternative.

Based on cost effectiveness, the anticipated short time period to achieve site closure, and the ease of implementation, the recommended alternative for site remediation consists of addition of ORM to the aquifer, with continued groundwater monitoring, including monitoring for biological parameters. ORM should be applied as a slurry injection into eight boreholes, and in accordance with the manufacturer's recommendations (see Appendix A). ORM should be placed in boreholes across the aquifer zone and the remainder of the borehole should be grouted with an approved bentonite grout. If concentrations of hydrocarbons in groundwater have not dropped to acceptable levels after a year of quarterly monitoring, a second application of ORM could be applied.

4.0 REFERENCES

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180
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19
274 ppm

Table 1. Summary of Groundwater Analytical Results, 3927 East 14th Street, Oakland, California

Monitoring Well	Sampling Date	Concentrations							
		TPHg (µg/L)	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	Xylenes (µg/L)	MTBE (µg/L)	TPHd (µg/L)	TPHmo (µg/L)
HMW1	8/22/96	7,400	1,200	170	530	490	----	ND	ND
	2/25/97	5,400	760	110	260	260	ND	2,000	ND
	5/28/97	6,600	1,100	100	290	340	130	2,000	600
	9/2/97	4,000	460	40	200	100	ND	8,700 ²	3,700 ²
	11/26/97	7,500	1,000	120	270	320	ND ¹	4,700	3,000
	3/17/98	11,000	2,100	290	600	760	1,200	ND	16,000
	6/30/98	10,000	1,300	160	390	390	160	ND	5,900
HMW2	8/22/96	6,300	170	57	370	120	----	7,400*	2,100*
	2/25/97	8,400	150	35	280	70	ND ¹	90	ND
	5/28/97	6,000	170	35	170	67	150	130	200
	9/2/97	8,000	210	30	160	90	ND ¹	450 ²	ND ²
	11/26/97	1,600	41	7.5	40	10	31 ¹	180	ND
	3/17/98	8,600	200	96	410	120	330	ND	ND
	6/30/98	7,300	180	52	240	88	170	ND	ND
HMW3	8/22/96	1,300	3	6	8	12	----	ND	ND
	2/25/97	150	ND	ND	ND	ND	ND	70	ND
	5/28/97	80	ND	ND	0.60	ND	ND	ND	ND
	9/2/97	140	ND	ND	2.1	ND	ND	ND ²	ND ²
	11/26/97	70	0.6	0.8	0.8	ND	ND	50	ND
	3/17/98	ND	ND	ND	ND	ND	ND	ND	200
	6/30/98	ND	ND	ND	ND	ND	ND	ND	ND
HMW4	11/26/97	1,600	4.2	3.1	1.7	5.9	ND	400	ND
	3/17/98	1,300	20	1.4	6.8	3.0	19	ND	ND
	6/30/98	940	17	1.5	18	2	10	ND	ND

ND - Not detectable in concentrations greater than the method detection limit.

"----" - Not analyzed.

* Laboratory notes that the concentration for diesel is estimated, due to overlapping fuel patterns.

Hydrocarbons reported as motor oil does not match the pattern of the motor oil standard.

ND¹ - Results using EPA Method 8260 to confirm analytical result.

² - Samples collected on 10/03/97.

HMW4 data and from 11/26/98 and all data from 3/17/98, obtained from Groundworks Environmental, Inc.

6/30/98 data from Kleinfelder, Inc.

**Table 2. Historical Groundwater Gauging Results, New Genico Site,
3927 East 14th Street, Oakland, California**

Monitoring Well	Sampling Date	Top of Casing Elevation (msl)	Depth to Water (ft)	Groundwater Elevation (msl)
HMW1	8/22/96	31.25	8.01	23.24
	2/25/97		5.95	25.30
	5/28/97		7.65	23.60
	9/2/97		8.56	22.69
	11/26/97		7.50	23.75
	2/9/98		3.35	27.90
	3/17/98		5.29	25.97
HMW2	8/22/96	29.43	8.71	20.72
	2/25/97		6.00	23.43
	5/28/97		7.65	21.78
	9/2/97		8.59	20.84
	11/26/97		6.82	22.61
	2/9/98		3.24	26.19
	3/17/98		4.44	24.99
HMW3	8/22/96	31.48	8.10	23.38
	2/25/97		6.00	25.48
	5/28/97		7.74	23.74
	9/2/97		8.60	22.88
	11/26/97		7.50	23.98
	2/9/98		2.34	29.14
	3/17/98		5.23	26.25
HMW4	11/26/97	28.80	7.42	21.38
	2/9/98		2.96	25.84
	3/17/98		5.72	23.08

Notes:

- 1) MSL = Mean Sea Level
- 2) Data from HMW4 and data collected on 2/9/98 and 3/17/98 were obtained from a report from Groundworks Environmental, Inc.

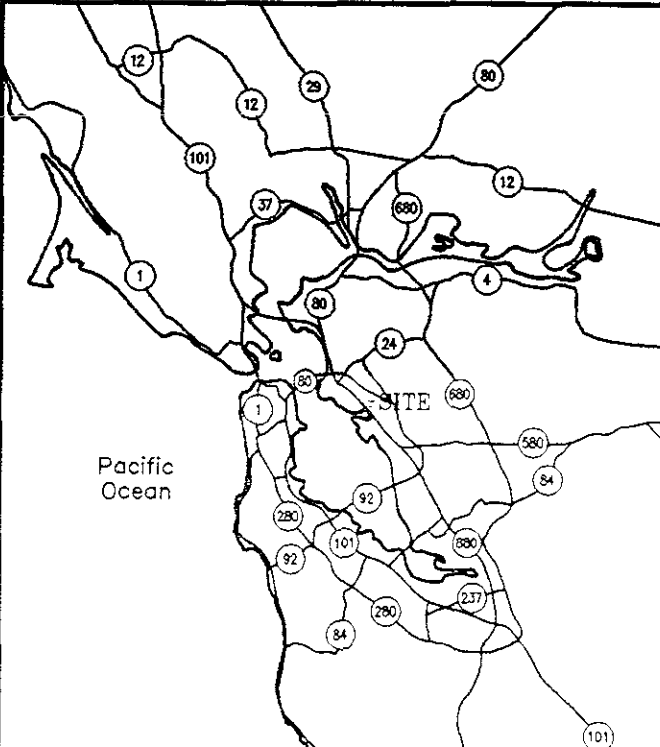
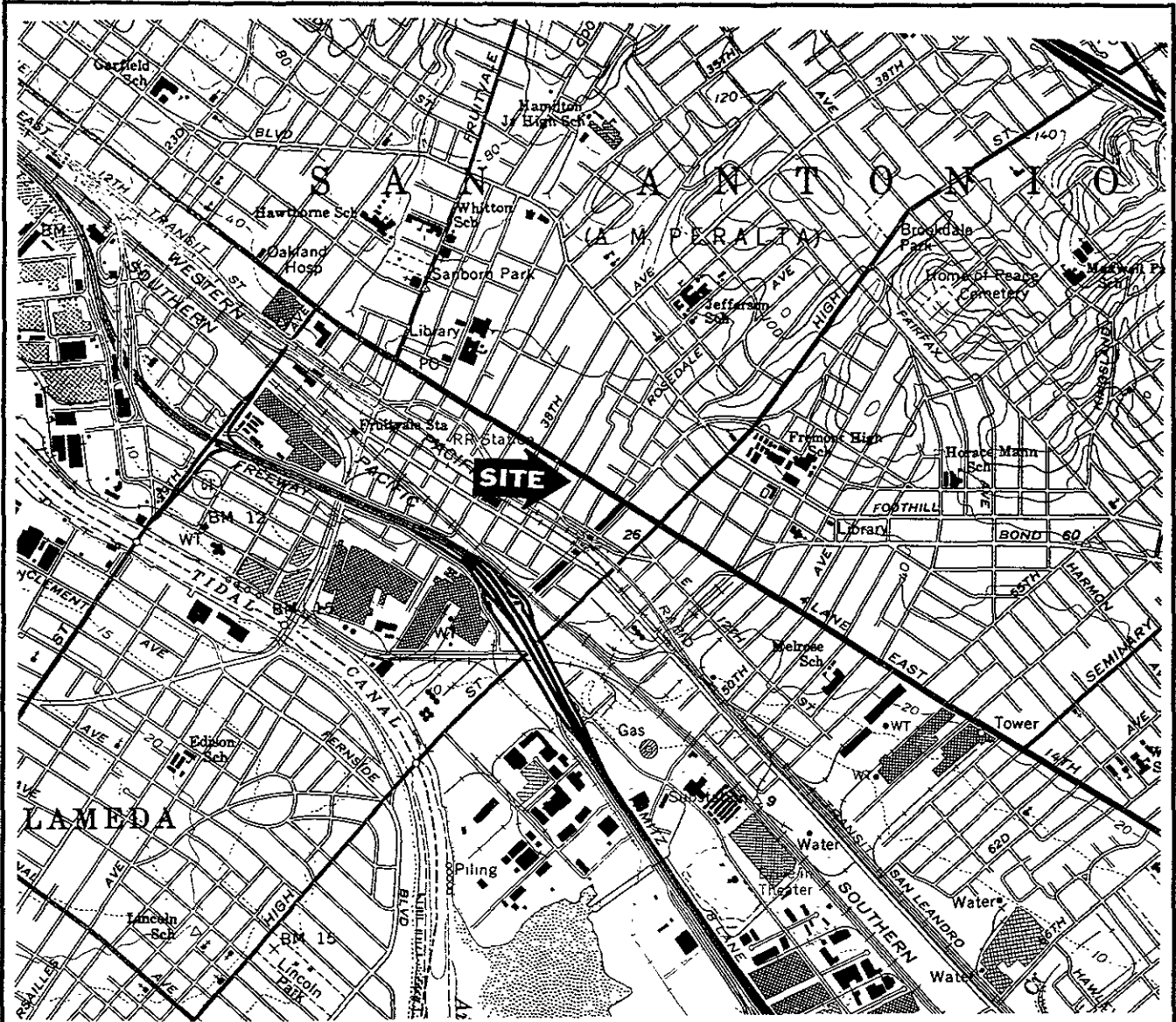
Table 3. Summary of Bioremediation Parameter Results, 3927 East 14th Street, Oakland, California.

Monitoring Well	Sampling Date	pH	Specific Conductivity (umhos/cm)	Temperature (°F)	Nitrate (mg/L)	Sulfate (mg/L)	Dissolved Oxygen (mg/L)	Redox Potential (mV)	Ferrous Iron (mg/L)
HMW1	8/22/96	----	----	----	----	----	----	----	----
	2/25/97	4.55	680	75	----	----	----	----	----
	5/28/97	7.7	810	70.4	----	----	----	----	----
	9/2/97	6.73	1074	73.4	2	12	0.24	-14.4	4.20
	11/26/97	6.93	966	70.0	0.6	ND	2.0	+105	<0.01
	3/17/98	6.16	1163	67.6	ND	0.8	0.8	-60.4	0.16
HMW2	8/22/96	----	----	----	2,100	2,100	----	----	----
	2/25/97	4.65	450	72.1	ND	ND	----	----	----
	5/28/97	7.8	480	69.4	200	200	----	----	----
	9/2/97	6.82	762	74.8	ND	0.5	0.38	+25.2	1.37
	11/26/97	6.99	731	69.8	ND	ND	2.5	+52	0.03
	3/17/98	6.62	741	66.0	ND	0.8	0.48	-50.28	0.01
HMW3	8/22/96	----	----	----	ND	ND	----	----	----
	2/25/97	5.87	390	63.3	ND	ND	----	----	----
	5/28/97	8	400	67.6	ND	ND	----	----	----
	9/2/97	6.97	669	70.9	2.2	53	0.88	+98.6	0.03
	11/26/97	6.87	665	67.8	3.5	50	1.4	+102	0.01
	3/17/98	6.43	734	65.9	1.1	43	0.63	+91.90	ND
HMW4	11/26/97	----	----	----	----	----	----	----	----
	3/17/98	6.66	769	66.3	ND	8.6	2.4	-26.67	0.12

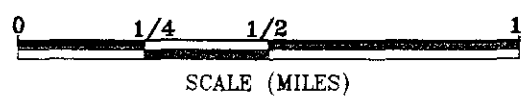
ND - Not detectable in concentrations greater than the method detection limit.

"----" - Not analyzed.

HMW4 data and data from 3/17/98 obtained from Groundworks Environmental, Inc. report.



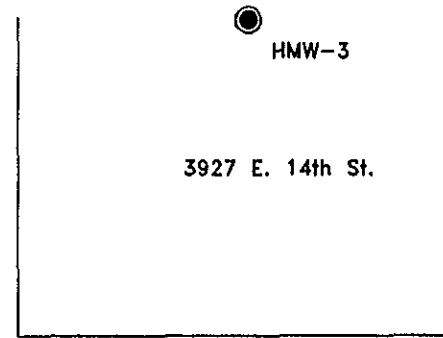
- Notes:**
- 1) All locations and dimensions are approximate.
 - 2) Base map from USGS Oakland East (1961) Quadrangle, 7.5 Minute Series Topographic. Photorevised in 1980.



ATC ASSOCIATES INC.
 Environmental, Geotechnical and Materials Professionals

SITE LOCATION MAP
 3927 E. 14TH STREET
 OAKLAND, CALIFORNIA

PROJECT NO. 61137.0005 FIGURE 1



HMW-3
3927 E. 14th St.

HMW-1

HMW-4

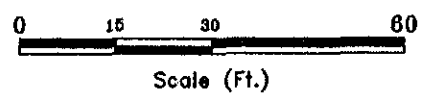
HMW-2

MW-4

40th Avenue

MW-3

MW-2



EXPLANATION

● HMW-3 Groundwater Monitoring Well (3927 E. 14th St.)

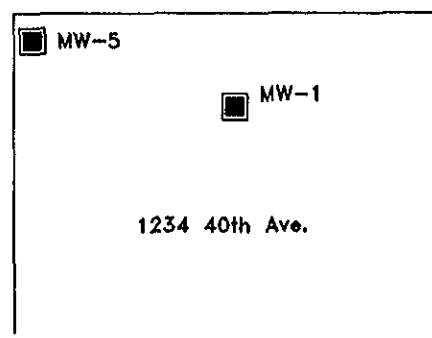
■ MW-1 Groundwater Monitoring Well (1234 40th Ave.)

—○— Designation of sanitary sewer.

—●— Designation of storm sewer.

Notes:

1. Base Map developed from survey map provided by Kier & Wright
2. Location of HMW-4 obtained from Artesian Environmental Project No.: 197-002-01 Date: 1/8/98
3. Location of MW-5 obtained from Aquatic & Environmental Applications, Project No.: 1004 Date: 3/27/98



MW-5

MW-1

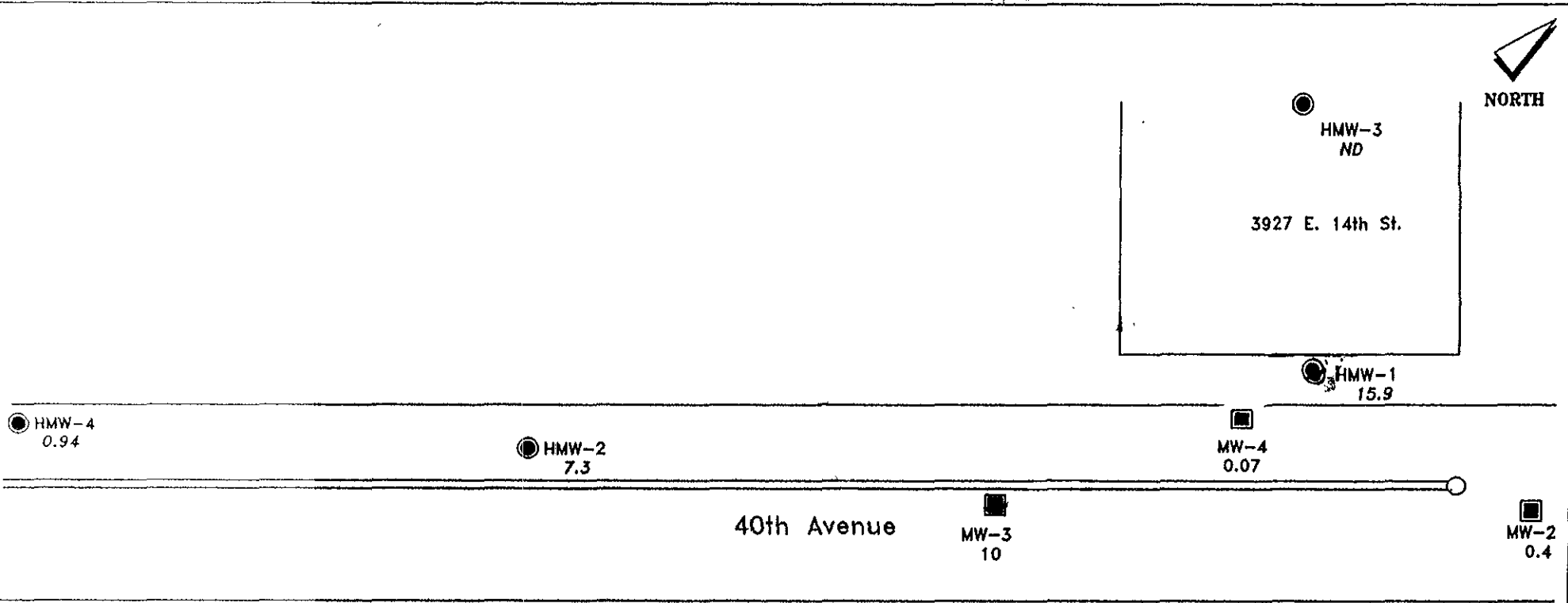
1234 40th Ave.

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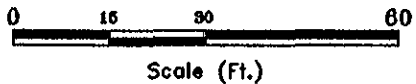
SITE MAP
3927 E. 14th Street
Oakland, California

Project No. 61137.0005 Figure 2

397th Ave



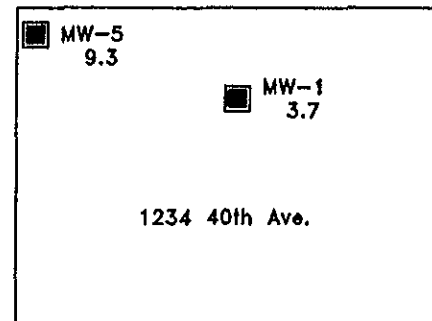
EXPLANATION



- HMW-3 Groundwater Monitoring Well (3927 E. 14th St.)
 ND Concentration of TPHd & THPg & TPHmo in samples collected on 6/28/98
- MW-1 Groundwater Monitoring Well (1234 40th Ave.)
 3.7 Concentration of TPHd & THPg in samples collected on 6/30/98
- Designation of sanitary sewer.
- Designation of storm sewer.

Notes:

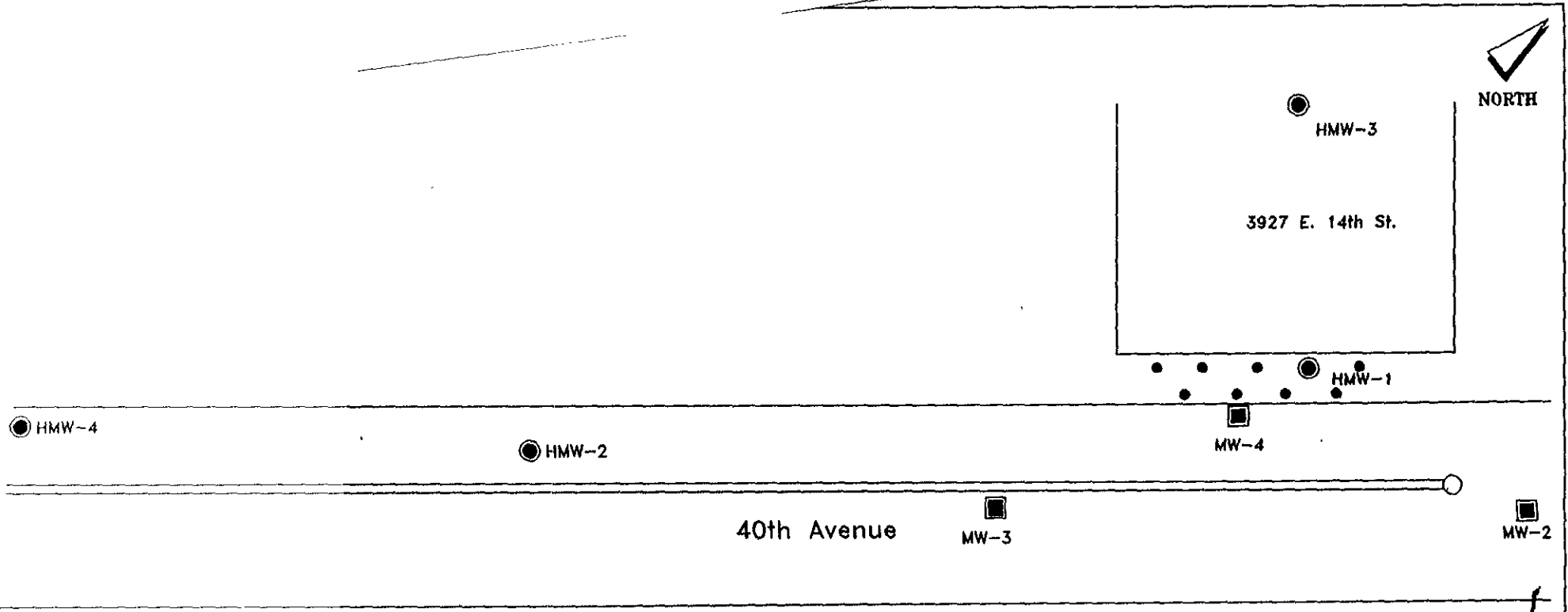
1. Base Map developed from survey map provided by Kler & Wright
2. Location of HMW-4 obtained from Artesian Environmental Project No.: 197-002-01 Date: 1/8/98
3. Location of MW-5 obtained from Aquatic & Environmental Applications, Project No.: 1004 Date: 3/27/98
4. ND indicates not-detected



VATC ASSOCIATES INC. <small>ENVIRONMENTAL, GEOTECHNICAL AND MATERIALS PROFESSIONALS</small>	
CONTOUR MAP OF TPH CONCENTRATIONS (mg/L) ON 6/98 3927 E. 14th Street Oakland, California	
Project No. 61137.0005	Figure 3



NORTH



3927 E. 14th St.

40th Avenue

HMW-3

HMW-1

HMW-4

HMW-2

MW-4

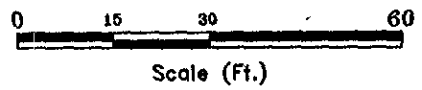
MW-3

MW-2

MW-5

MW-1

1234 40th Ave.



EXPLANATION

- HMW-3 Groundwater Monitoring Well (3927 E. 14th St.)
- MW-1 Groundwater Monitoring Well (1234 40th Ave.)
- Sanitary sewer.
- Storm sewer.
- ORC Injection point

Notes:

1. Base Map developed from survey map provided by Kler & Wright
2. Location of HMW-2 obtained from Artesian Environmental Project No.: 197-002-01 Date: 1/8/98
3. Location of MW-5 obtained from Aquatic & Environmental Applications, Project No.: 1004 Date: 3/27/98

VATC ASSOCIATES INC. <small>ENVIRONMENTAL, GEOTECHNICAL AND MATERIALS PROFESSIONALS</small>	
SITE MAP GENICO 3927 E. 14th Street Oakland, California	
Project No. 61137.0005	Figure 1

APPENDIX A

ORC SOURCE TREATMENT CALCULATIONS & ORC INFORMATION

ABOUT OXYGEN RELEASE COMPOUND, ORC®

Oxygen Release Compound (ORC) is a patented formulation of magnesium peroxide, MgO_2 , which slowly releases oxygen when moist. The hydrated product is magnesium hydroxide, $Mg(OH)_2$. The oxygen release rate is dependent upon the level of the contaminant flux. Generally, the product will continue to release oxygen for about 6 months.

We have found, and the literature supports, that oxygen is the limiting factor in aerobic bioremediation. The microorganisms, nutrients and moisture are typically present, but most sites are oxygen deficient with bioremediation proceeding anaerobically. The addition of oxygen significantly increases the rate of remediation, by one or two orders of magnitude. Throughout this software, a conservative 3:1 ratio of oxygen usage to carbon contamination has been used.

ORC will not harm an aquifer. It is virtually insoluble. Biofouling is inhibited by an elevated, but localized pH. Iron fouling is avoided, particularly when compared to air sparging, by the long, gentle release of dissolved oxygen which is dispersed widely. The hydrated product is a solid form of ordinary Milk of Magnesia.

ORC is useful as a slow release source of oxygen in the remediation of any compound that is aerobically degradable. It has been used in the successful remediation of dissolved phase compounds such as BTEX, MTBE, PAH's and certain chlorinated compounds such as vinyl chloride and PCP. *(Handwritten: Pentachlorobenzene)* ORC is most frequently used to address dissolved phase contamination plus sorbed material in the saturated, capillary fringe, and smear zones. It should not be used when more than a sheen of free product is evident.

ORC can be applied to meet several objectives. The product may be used in the bottom of a tank excavation to eliminate one of the toughest and most persistent sources of contamination at, or near, the soil/groundwater interface. ORC can create a highly oxygenated zone near the original source of the contamination, reducing the contaminant mass, and thereby collapsing the plume so that compliance may be achieved at a point closer to the source. ORC can also, be applied as an "oxygen barrier" which prevents contaminant migration off site. This ORC Application Software will assist in the proper design and application of ORC to meet any of these objectives.

More specific information about ORC may be found in the Appendix of this disk and in Technical Bulletins available from the company. Also, the Regenesiis web site has expanded technical and product performance information. The web site may be accessed at <http://www.regenesiis.com>, and is best viewed through MS Explorer v 3.0, Netscape v. 3.0, or AOL v. 3.0

ORC SOURCE TREATMENT APPLICATIONS

General

ORC may be used in the source area of the groundwater contamination. This application has two objectives. The first is fast site closure. Since aerobic bioremediation is about 10 to 100 times faster than anaerobic bioremediation, an ORC application results in much faster site closure than natural attenuation which generally operates under oxygen deficient conditions. ORC treatment can also be faster than highly engineered mechanical treatment methods. The second objective is risk reduction. Even if the source is not completely remediated, the application of ORC will collapse the plume and permit compliance at a point closer to the source.

In this application, ORC can be applied in completed monitoring wells using retrievable filter socks or into direct push holes using an ORC slurry mixture. The ORC slurry can be back filled or injected into direct-push bore holes, or back filled into augered holes. Using any one of these methods, a saturated zone source treatment with an ORC slurry targets dissolved phase contamination plus sorbed material within the saturated, capillary fringe, and smear zones. It is important that the entire vertical distance of these contaminant zones be covered by the ORC.

Specific installation instructions for mixing the slurry, for back-filling and for ORC injection are contained in the Installation Instruction section of this software.

Source Treatment Slurry Back-Fill Application

For the ORC Back-Fill Application, the software calculates the amount of ORC necessary to remediate the known dissolved phase hydrocarbon contamination plus an additional oxygen demand factor of your choice to handle unquantified sorbed hydrocarbons and additional COD and BOD oxygen requirements. In sites with groundwater flow, some oxygen provided by ORC placed at the edge of the source area may move out of the target contaminated zone and begin to treat the downgradient contamination. You need to consider all of these elements when selecting the demand factor. Based on detailed studies, field experience, and customer data that has been made available, Regensis normally recommends a treatment factor of about 8 since permanent wells are not being drilled which would permit replacement of spent ORC.

Given the demand and the ORC required, the software asks you for the size of the direct-push or augered bore holes you will be drilling. The software calculates the number of bore holes and spacing that is required. If there are too many boreholes for your site or the holes can not be placed properly due to obstructions, etc., then you have some alternatives:

- 1 Use a larger diameter direct-push bore hole
- 2 Consider a second application of ORC in the hottest zones can be considered
- 3 Select the ORC Slurry Injection Application which will require less bore holes

ORC Source Treatment Slurry Injection Application

In this application the ORC slurry is applied under pressure into the contaminated groundwater.

About Source

capillary fringe and smear zones. After calculating the hydrocarbon load and the ORC required, the software will ask you for the bore hole spacing that you desire on the site and the number of ORC bore holes will be calculated. If too many are required, the solids content may be decreased which permits wider ORC dispersion and, hence, wider bore hole spacing. The dispersion of the oxygen from the ORC must be considered. A thorough discussion of this subject is found in Regenes Technical Bulletins 4-1.0 through 4-1.3. In general, to get overlapping oxygen coverage the bore holes need not be placed less than six feet on center. Twenty feet on center is about the maximum spacing which will provide overlapping zones of oxygen.

Solute Transport Model

The ORC Application Software, version 2.0, contains a Dominico-Schwartz Attenuation model, published by Tim Buschek of Chevron. This model is useful in estimating the amount of dissolved phase contamination at a downgradient monitoring, or compliance, point. After the required mass of ORC has been calculated and the groundwater velocity and distance to the compliance point have been entered, you are asked to input the ratio of ORC provided to ORC required (which will be less than 100%). You may vary this ratio and obtain the estimated contaminant levels at the compliance point. If above the contaminant level you may decrease the ratio (or, if below increase the ratio). This permits the user to tailor the amount of ORC applied to the specific requirements at a downgradient compliance point.

ORC Source Treatment in Replacement Wells

ORC can be used in completed monitoring wells installed in the proper area and which are screened through the vertical portion of the saturated zone, the capillary fringe and the smear zone. In this application, a mixture of ORC and inert silica sand is contained in filter socks. After 6 months, when the oxygen is depleted, the socks should be removed from the wells. Additional factors to account for unknown oxygen demands are not as important in these applications since the socks may be replaced. However, a safety factor of about 2 is recommended for unknown oxygen sinks. Since monitoring wells are expensive to drill and permit, cost can be minimized when the treatment objective is risk reduction with compliance at a point downgradient. The ORC filter socks can be replenished until downgradient compliance is achieved and compliance is achieved and maintained.

Once the basic site characteristics are entered, the software will ask for your desired well diameter, desired number of wells, distance to the downgradient compliance point and the number of change-outs desired. From this data, a calculation of percent oxygen available to oxygen required is generated. If this number is greater than 1.0, there is theoretically enough oxygen provided by the system to remediate the hydrocarbon load after all of the planned ORC changeouts have been completed. It should be noted that actual treatment efficiencies may vary downgradient due to discrete variability in the hydraulic conductivity, groundwater velocity, hydrocarbon mass present, and the spreading of dissolved oxygen from the source. If the ratio of oxygen required to oxygen available is less than 1.0 then the program calculates the projected hydrocarbon concentration at the downgradient compliance point using a variation of the Dominico-Schwartz attenuation model, published by Tim Buschek of Chevron. The effect of more ORC changeouts is to reach a lower contamination level at the downgradient compliance point.

If hydrocarbon load is too high or the required spacing of the wells be too close or inappropriate for the site then there are some alternatives

- 1 Increase the number of ORC changeouts

About Source

2. Increase the well diameter.
3. Add more wells or multiple lines of wells.
4. The wells may be spaced further apart; if contaminant break-through is measured, install additional wells just at those points. This iterative approach may be most economical, allowing a "mid-course" correction based upon actual field experience.
5. Augment the treatment with ORC slurry injections.

Slurry Injection

REGENESIS Bioremediation Products

ORC® Slurry Installation Instructions Geoprobe® Injection into the Soil Matrix

SAFETY:

Pure ORC is shipped to you as a fine powder rated at -325 mesh (passes through a 44 micron screen). It is considered to be a mild oxidizer and as such should be handled with care while in the field. Field personnel should take precautions while applying the pure ORC. Typically, the operator should work upwind of the product as well as use appropriate safety equipment. These would include eye and respiratory protection, and gloves as deemed appropriate by exposure duration and field conditions.

Personnel operating the field equipment utilized during the installation process should have appropriate training, supervision and experience.

GENERAL GUIDELINES:

ORC may be installed in the contaminated saturated zone in the ground utilizing hand augered holes, Geoprobe® type hydraulic punch equipment, or hollow stem augers. This set of instructions is specific for Geoprobe equipment. Alternate instructions may be obtained from the Regenesys Technical Support Department.

For optimum results the ORC slurry installation should span the entire vertical contaminated saturated thickness, including the capillary fringe and "smear zone".

Two general installation approaches are available. The first is to backfill only the probe hole with slurry. This is a simple approach, in that it is easy, straightforward, and the location of the ORC slurry is precisely known after installation. However, this method requires significantly more probe holes than the alternative, and may take more time for the completion of the remediation process. A separate set of instructions for this method utilizing Geoprobe equipment is available from Regenesys.

The second method is to inject the slurry through the probe holes into the contaminated saturated zone. This method requires fewer probe holes, is less disruptive to the site, and aids the spread of oxygen by spreading the ORC source material. However, it may be difficult to know the exact, final disposition of the ORC installed with this method. This is the method described in these instructions

Note It is important that the installation method and specific ORC slurry point locations be established prior to field installation. It is also important that the ORC slurry volume and solids content for each drive point be predetermined. The Regenesys Technical Service Department is available to discuss these issues, and Helpful Hints at the end of these instructions offers relevant information. Regenesys also has available Technical Bulletins covering source treatments with

Slurry Injection

ORC.

SPECIFIC INSTALLATION PROCEDURES:

- 1) Identify the location of all underground structures, including utilities, tanks, distribution piping, sewers, drains, and landscape irrigation systems.
- 2) Identify surface and aerial impediments.
- 3) Adjust planned installation locations for all impediments and obstacles.
- 4) Pre-mark the installation grid point locations, noting any that have special depth requirements.
- 5) Set up the Geoprobe unit over each specific point, following the manufacturer recommended procedures. Care should be taken to assure approximate vertical probe holes.
- 6) Penetrate surface pavement, if necessary, following standard Geoprobe procedures.
- 7) Drive the 1 1/2" (one-and-one-half inch) pre-probe (part #AT-148B) with the expendable tip (part #AT142B) to the desired maximum depth. Standard 1" (one inch) drive rods (part #AT104B) should be used, after the pre-probe. (Hint: Pre-counted drive rods should be positioned prior to the installation driving procedure to assure the desired depth is reached.)
- 8) Disconnect the drive rods from the expendable tip, following standard Geoprobe procedures.
- 9) Mix the appropriate quantity of ORC slurry for the current drive point. (See separate Directions for ORC® Slurry Mixing and Helpful Hints). **Note: Do not mix more slurry than will be used within a 30 minute period. See Helpful Hint "A.1 Slurry" for mixing suggestions.**
- 10) Set up and operate an appropriate slurry pump according to manufacturer's directions. Based on our experience, a Geoprobe model GS-1000 pump is recommended. Connect the pump to the probe grout pull cap (GS-1054) via a 1 inch diameter delivery hose. The hose is then attached to the 1" drive rod with its quick connector fitting. Upon confirmation of all connections add the ORC slurry to the pump hopper/tank.
- 11) While slowly withdrawing the pre-probe and drive stem 4'(four feet), pump the predetermined amount of ORC slurry into the aquifer (step 13). (Also note Helpful Hints - Operations at end of instructions.)
- 12) Optional pretreatment step (See Helpful Hints - Operations at end of instructions) Pump one to two gallons of tap water into the aquifer to enhance dispersion pathways from the probe hole, if necessary
- 13) Pump the predetermined quantity of ORC slurry for the depth interval being injected. Observe pump pressure levels for indications of slurry dispersion or refusal into the

Slurry Injection

- aquifer. (Increasing pressure indicates reduced acceptance of material by the aquifer).
- 14) Remove one 4' section of the 1" drive rod. The drive rod will contain slurry. This slurry should be returned to the ORC bucket for reuse.
 - 15) Repeat steps 11, 12, 13, and 14 until treatment of the entire affected thickness has been achieved. It is generally recommended that the procedure extend to the top of the capillary fringe/smear zone.
 - 16) Install an appropriate seal, such as bentonite, above the ORC slurry through the entire vadose zone. This helps assure that the slurry stays in place and prevents contaminant migration from the surface. Depending on soil conditions and local regulations, a bentonite seal can be pumped through the slurry pump or added via chips or pellets after probe removal.
 - 17) Remove and decontaminate the drive rods and pre-probe.
 - 18) Finish the probe hole at surface as appropriate (concrete or asphalt cap, if necessary).
 - 19) Move to the next probe point, repeating steps 5 through 18.

HELPFUL HINTS:

- A. Physical characteristics
 - A1. Slurry

The ORC slurry is made using the dry ORC powder (rated at -325 mesh). It makes a smooth slurry, with a consistency that depends on the amount of water used.

A thick, but pumpable, slurry that approaches a paste can be made by using 65-67% solids. This material would normally be used for back-filling a bore or probe hole. It is especially useful where maximum density is desired such as where ground water is present in the hole or there are heaving sands.

Thinner slurries can be made by using more water. Typical solids for the thinner slurries content will range from 35% to 62%. Such slurries are useful for injecting through a probe or bore hole into the saturated aquifer. When tighter soils are encountered, or a larger radius of influence around each injection point is desired, an even thinner slurry can be tested in the field. Solids contents as low as 10% (wt:wt) can be used.

As a rule, it is best to mix the first batch of slurry at the maximum solids content one would expect to use. It can then be thinned by adding additional water in small increments. By monitoring this process, the appropriate quantities of water for subsequent batches can be determined.

The slurry should be mixed at about the time it is expected to be used. It is best to not hold it for more than 30 minutes. Thinner slurries, especially, can experience a separation upon standing. All ORC slurries have a tendency to form cements when left standing. If a slurry begins to thicken too much, it should be mixed again and additional water added if necessary.

Slurry Injection

Care should be taken with slurry that may be left standing in a grout pump or hose. Problems can generally be avoided by periodically recirculating the slurry through the pump and hose back into the pump's mixing or holding tank.

A2. Equipment

Most geotechnical grout pumping equipment has a holding tank with a capacity sufficient for injection.

When applying measured volumes of ORC slurry to probe holes, it is sometimes useful to know the volumes and content of the delivery system lines. The following information may be useful in this regard:

Geoprobe pump: At the end of a pump stroke virtually no deliverable slurry remains in the pump.

5/8" O.D. connecting hose (10 feet long):	.2 gallons (26 fluid ounces).
Four foot (4') length of 1" drive rod:	.04 gallons (5 fluid ounces).
Three foot (3') length of 1 1/2" pre-probe:	.03 gallons (4 fluid ounces).

Cleaning and maintenance:

Pumping equipment and drive rods can be lightly cleaned by circulating clear water through them. Further cleaning and decontamination (if necessary due to subsurface conditions) should be performed according to the equipment supplier's standard procedures and local regulatory requirements.

B. Operating characteristics

B1. Operations - General

Judgment will be needed in the field when injecting ORC slurries. In general, it is relatively easy to inject ORC slurries into sandy soils, and this can usually be accomplished at very moderate pressures. Silts and clays require more pressure, and may accept less slurry.

Careful observation of pressure during slurry pumping is the best indication of the effectiveness of the slurry injection. To test the soil's ability to accept the slurry and to "precondition" the injection point for the slurry, it is sometimes useful to inject a small volume of plain water prior to the slurry. Normally, one-half (0.5) gallons to two (2) gallons would be appropriate.

During injection, increasing pressure and decreasing flow rate are signs of refusal by the soil matrix to accept the slurry. The optional tap water injection (step 12) may be attempted in this situation. The site geologist should determine whether to increase pressure, and possibly fracture ("frac") the soil matrix to achieve ORC slurry installation in a tight site that has refused the slurry at lower pressures.

B2 Fill Volumes Probe hole back-filling

Slurry Injection

Probe hole capacities:

Per 10' (Ten Foot) length

	<u>Theoretical Volume</u>	<u>Operating Volume</u>	
	<u>(Gallons/Fluid Ounces/Cubic Inches)</u>	<u>(Gallons/Fluid Ounces)</u>	
	<u>Sand, Silts & Clay</u>	<u>Sand</u>	<u>Silts & Cl</u>
1" Diameter	.41 gal/52 fl. oz./94.2 cu. in.	.61 gal/78 fl. oz.	.51 gal/65 fl.
1 1/2" Diameter	.92 gal/117 fl. oz./212.0 cu. in.	1.38 gal/176 fl. oz.	1.15 gal/14
2" Diameter	1.63 gal/209 fl. oz./376.8 cu. in.	2.44 gal/313 fl. oz.	2.04 gal/261
2 1/4" Diameter	2.06 gal/264 fl. oz./476.9 cu. in.	3.09 gal/396 fl. oz.	2.57 gal/330

Note that the operating volumes include a 50% excess above the theoretical volume in sands and 25% clays and silts. This is important to successful treatment. The additional material allows for a small degree of infiltration of the slurry into the surrounding soil and fractures, as well as hole diameter variability. It is important to assure that the entire contaminated saturated zone is treated (including the capillary fringe), since this is often the area of highest pollution concentration. Failure to treat this area due to improper installation can undermine an otherwise successful remediation effort.

ORC SLURRY INJECTION

Dissolved Hydrocarbon Level (ppm)
(For gasoline sites use BTEX measurements)

16

Treatment Zone Width (ft)

10

Treatment Zone Length (ft)

50

Thickness of Saturated Treatment Zone (ft)

10

Porosity

0.35

(sand = 0.3, silt = 0.35, clay = 0.4)

Total Treatment Zone Volume (cu. ft)

5,000

Dissolved Phase Hydrocarbon Mass (lbs)

1.7

Additional Demand Factor (assumed)

8

(REGENESIS recommends a factor of about 8)

Loaded Hydrocarbon Mass (lbs)

13.6

Oxygen Required (lbs)

40.8

ORC Required (lbs) *1/2 O₂ by wt.*

408.0

ORC Unit Cost

\$ 10.00

Total Cost of ORC

\$ 4,080.00

Solids Content (%)

40%

Hole Spacing (ft)

8

Number of Holes in Grid

8

ORC per Hole (lbs)

51.0

Water needed per Hole for Slurry (gal)

9.2

APPLICATION COMMENTS

* ORC per hole is above lower limit of 1 pound per linear foot.

$5000 \text{ ft}^3 (0.35)$

$\text{Vol} \times \text{porosity} \times 16 \text{ ppm}$

$1750 \text{ ft}^3 \times 28.3 = 49,525 \text{ lb} \times 16 \text{ mg/l} \times 10^{-3} \text{ g/l} \times \frac{1}{1000} \text{ mg}^{-1}$
 $= 1.745 \text{ lb} \times 8 \times 3 \times 10 = 419$

*Denitrification Model: Jack Rainey (ORC)
 (125) 444-1106*

Placerville H. Co.

FOR SOLUTE TRANSPORT MODEL ENTER VALUES BELOW

GW Velocity (ft / day)

0.1

Compliance Pt (ft)

100

Ratio of O₂ provided O₂ required (percent)

75%

HC Level at compliance point

after selected ratio of oxygen in ppm

0.040