★ Stellar Environmental Solutions

2110 Sixth Street, Berkeley, CA 94710
Tel: (510) 644-3123 • Fax: (510) 644-3859

Geoscience & Engineering Consulting

December 4, 1998

Mr. Scott Seery
Alameda County Health Care Services Agency
Department of Environmental Health, Hazardous Materials Division
1131 Harbor Bay Parkway, Suite 250
Alameda, California 94502

Subject: Site Closure Assessment for Redwood Regional Park Service Yard Site, Oakland, California

Dear Mr. Seery:

Enclosed is the Stellar Environmental Solutions (SES) Site Closure Assessment Report for the underground fuel storage tank (UFST) site located at the Redwood Regional Park Service Yard Site, 7867 Redwood Road in Oakland, California. This project is being conducted for the East Bay Regional Park District (District). The key regulatory agencies for this investigation are Alameda County Health Care Services Agency (ACHCSA) and the California Department of Fish and Game (DFG).

This report provides a critical evaluation of site contamination data associated with former UFSTs at the site, including the September 1998 groundwater and creek surface water monitoring event completed by SES. The District has discussed the findings of this and previous investigations with ACHCSA and DFG, and has elected to implement the following actions to address the regulatory concerns. **Two macroinvertebrate bioassessment events (winter 1998 and spring 1999) will be conducted to evaluate if current conditions are impacting Redwood Creek, and continued quarterly groundwater and surface water sampling will be conducted in accordance with the historically agreed-upon sampling program.** The results of field activities will be initially summarized in letter-format data summaries, and a summary report will be prepared at the conclusion of this phase. The summary report will include an asssessment of the necessity for interim remedial action (which may include the use of oxygen-enhancing compounds to stimulate aerobic degradation), and what continued site monitoring may be required. **The proposed actions represent a revision to the October 9, 1998 SES workplan for the continued site investigation.**

If you have any questions regarding this report, please contact Mr. Ken Berger of the District or contact us directly at (510) 644-3123.

Sincerely,

Bruce M. Rucker

Bruce M. Rucker, R.G., R.E.A
Project Manager

REGISTERED GEOLOGIST
BRUCE M. RUCKER
No. 6814
Exp. 9/00
STATE OF CALIFORNIA

Richard S. Makdisi, R.G., R.E.A
Principal

cc: Michael Rugg, California Department of Fish and Game
Warren Gee and Ken Berger, East Bay Regional Park District

SITE INVESTIGATION AND SITE CLOSURE ASSESSMENT REPORT

REDWOOD REGIONAL PARK SERVICE YARD
OAKLAND, CALIFORNIA

Prepared For:

EAST BAY REGIONAL PARK DISTRICT
OAKLAND, CALIFORNIA

Prepared By:

STELLAR ENVIRONMENTAL SOLUTIONS
2110 SIXTH STREET
BERKELEY, CALIFORNIA 94710

December 4, 1998

Project No. 98031

TABLE OF CONTENTS

TABLES

Table		Page
Table 1	Groundwater Monitoring Well Construction Data	12
Table 2	Groundwater and Creek Surface Water Sample Analytical Results - September 18, 1998 Redwood Regional Park Corporation Yard Oakland, California	16
Table 3	Surface and Ground Water Quality Criteria for Detected Contaminants	22
Table 4	Contaminant Concentration (in µg/L) Reductions	31
Table A.1	Summary of Soil Sample Analytical Results Redwood Regional Park Corporation Yard - Oakland, California	
Table A.2	Summary of Groundwater Sample Analytical Results Redwood Regional Park Corporation Yard - Oakland, California	
Table A.3	Summary of Surface Water Sample Analytical Results Redwood Regional Park Corporation Yard - Oakland, California	

EXECUTIVE SUMMARY

Stellar Environmental Solutions (SES) was retained by East Bay Regional Park District (Park District) in September 1998 to evaluate the site historical data, complete one groundwater monitoring event, identify site regulatory considerations, and develop a site closure strategy that will be compliant with applicable regulations. This work included the completion of one creek surface water and groundwater sampling event at three monitoring wells. The site is the Redwood Regional Park Service Yard at 7867 Redwood Road, Oakland, Alameda County, California.

The site has undergone site investigations and remediation since 1993 to address the subsurface contamination caused by leakage from one or more of the two former underground fuel storage tanks (UFSTs) that contained gasoline and diesel fuel.

The September 18, 1998 surface water and groundwater sampling event showed a decrease in the TPHd, TPHg and BTEX contaminants analyzed in the downgradient well MW-4, which has the highest and most persistent residual contamination. The decrease compared to the previous analytical event of February 1998 is attributed to lower groundwater level conditions in September 1998.

Evaluation of the hydrochemical trends show a slight decrease over time since groundwater monitoring of the hydrocarbons in the wells began in 1994; the BTEX components have shown a more pronounced decrease than the TPHg or TPHd, reflecting some volatilization as well as biodegradation. Dissolved oxygen has not yet been measured in the monitoring wells, but the groundwater is suspected to be relatively oxygen depleted. There is also indicated to be a "slug" of higher concentration TPH-contaminated groundwater that will eventually arrive at the location of well MW-4 or pass it by to the south and daylight at the base of Redwood Creek. The concentration profile and length of time until the slug arrives at the creek is not known.

The volume of residual hydrocarbon contamination in the soil is estimated to be approximately 550 cubic yards and is located mainly in the " smear" zone along the pathway of the plume as it migrates toward Redwood Creek. The soil contamination at concentrations above 1,000 mg/Kg is estimated to be located in a zone 5-foot thick by 20-foot wide by 150-foot long, averaging about 12 feet below ground surface. The residual contaminated soil is still acting as a source of input to the groundwater plume.

Site groundwater has been impacted by several fuel-related hydrocarbons in excess of drinking water standards. While site groundwater is not considered to be a drinking water source, drinking water standards could be applied by the regulators as cleanup standards. Benzene has been sporadically detected in Redwood Creek at concentrations in excess of its surface water quality objective, in the immediate vicinity of where the groundwater plume intersects the creek. Benzene has never been detected immediately downstream of that location and therefore it is very unlikely that the site poses any impacts to Upper San Leandro Reservoir, the nearest drinking water source. The Department has a zero-discharge policy regarding pollution in surface waters, and they have requested an instream bioassessment study to determine the potential impact of the detected contaminants at the stream interface on invertebrate life in the stream. The DFG has a specific field and laboratory procedure to execute such a study.

The extent to which current conditions at the site reflect the maximum amounts of dissolved plume concentrations expected is a critical issue in the evaluation of the potential long-term impacts from the plume, and will determine whether or not the site should achieve regulatory closure based on the merits of expected natural attenuation. This, in turn, is affected by the volume and concentration of the residual contaminated soil that may continue to act as a source of input to the plume.

Initial examination of the data suggests that Monitored Natural Attenuation (MNA) could be a viable corrective action remedy if there are no current or projected impacts to the creek biology. Interim remediation measures that can be considered if the creek impacts are determined to be unacceptable are: 1) a passive or reactive cut-off wall, 2) a vapor extraction system, and/or 3) the use of oxygen releasing compounds to accelerate natural attenuation.

Following the District's review of the draft of this report, the District discussed the current site conditions with ACHCSA and DFG and has elected to implement the following program to address regulatory concerns:

- Conduct an additional (in December 1998) groundwater monitoring and analysis event in which natural attenuation parameters such as dissolved oxygen, redox potential and iron concentrations are measured, in addition to historically conducted laboratory analyses. We recommend that hydrochemical analyses be discontinued in transgradient well MW-5 based on the historical absence of signficant detectable contamination at that location.
- Conduct an additional (in December 1998) creek surface water sampling and analysis event.
- Per the recommendations of DFG, complete an initial instream bioassessment of macroinvertebrates, in conformance with the DFG procedures, to evaluate if there are any immediate impacts of concern. This will consist of two events (winter 1998 and spring

1999). The need for subsequent bioassessment events will be evaluated based on the findings of the proposed investigation.

- Complete and submit to ACHCSA and DFG letter-format data summaries following each field event, and a comprehensive report summarizing the entire phase, including conclusions regarding the findings and proposed actions to address remaining regulatory issues.

1.0 INTRODUCTION

PROJECT BACKGROUND

The subject property is the Redwood Regional Park Service Yard located at 7867 Redwood Road in Oakland, Alameda County, California. The site has undergone site investigations and remediation since 1993 to address the subsurface contamination caused by leakage from one or more of two former underground fuel storage tanks (UFSTs) containing gasoline and diesel fuel. The Alameda County Health Care Services Agency, Department of Environmental Health, Hazardous Materials Division (ACHCSA) has provided regulatory oversight of the investigation since its inception.

KEY OBJECTIVES AND SCOPE OF WORK

The key objectives of this site investigation are to:

- Critically evaluate site hydrochemical and contaminant migration data.
- Identify site-specific Applicable, Relevant and Appropriate Regulations (ARARs) and regulatory agency site closure criteria.
- Evaluate current and future impacts associated with site contamination.
- Assess the need for additional remediation and/or investigation.
- Evaluate remedial strategies to meet site closure or cleanup objectives.

The tasks that were conducted to meet these objectives include:

- Conduct an additional groundwater and surface monitoring, sampling and analysis event.
- Evaluate site hydrochemical trends.
- Estimate the mass of residual contamination in soil and groundwater.
- Identify potential receptors and other impacts associated with site contamination.
- Discuss the relevant site analytical and geologic data with respect to ARARs.
- Evaluate if additional site remediation and/or investigation is necessary in light of ARARs, potential impacts and regulator site closure criteria. If remediation is deemed necessary,

evaluate viable remedial strategies, including Monitored Natural Attenuation (MNA) and active mass removal/reduction techniques.

SITE DESCRIPTION

The project site is located at 7867 Redwood Road in Oakland, Alameda County, California. Figure 1 shows the location of the project site. The site slopes to the west, from an elevation of approximately 564 feet above mean sea level (MSL) at the eastern edge of the service yard to approximately 545 feet above MSL at Redwood Creek, which approximately defines the western edge of the project site. Figure 2 is a site plan of the project site.

The project site is a service yard for Redwood Regional Park, and utilized two UFSTs (one 2,000-gallon diesel fuel and one 5,000-gallon unleaded gasoline) from the mid-1960s to 1993. Figure 2 shows the location of the former UFSTs. Both UFSTs were reportedly installed between 1965 and 1968 (Parsons, 1993a). The 5,000-gallon steel UFST contained unleaded gasoline, and was reportedly a converted channel buoy purchased from the Navy (Parsons, 1993a). The tanks and piping underwent integrity testing in 1984, 1986, 1988 and 1989. The unleaded gasoline UFST system failed the 1988 and 1989 tests (Parsons, 1993a).

SITE INVESTIGATION AND REMEDIATION HISTORY

The following summarizes historical site remediation and characterization activities that have been conducted since 1993, beginning with removal of the UFSTs. Appendix A contains tabular summaries of historical soil and groundwater analytical results. A complete listing of previous site investigation and remediation reports is included in the References section.

UFST Removals and Soil Remediation Activities

The two project site UFSTs were excavated and transported offsite for disposal in April 1993, at which time discolored soil was observed in the excavation pit below the gasoline UFST location. Initial confirmation soil samples collected from beneath each UFST indicated soil impacts by total petroleum hydrocarbons-gasoline range (TPHg) and aromatic hydrocarbons [benzene, toluene, ethylbenzene and total xylenes (BTEX)] (Parsons, 1993a). No elevated levels of lead were detected in those soil samples.

Approximately 600 cubic yards of contaminated soil in the vicinity of the UFSTs were excavated and stockpiled for onsite aeration in June 1993. The excavation covered a surface area of approximately 5,000 square feet, and had a maximum depth of approximately 25 feet (below grade relative to the eastern edge of the excavation). Soil excavation activities were halted due to the potential for slope instability, the presence of significant facility constraints (roads and buildings) and the infiltration of spring water into the excavation. Figures 2 and 3 show the approximate limits of the final UFST excavation.

Five confirmation excavation soil samples were collected by Parsons in June 1993 prior to excavation backfilling. Discolored soil was noted only in the eastern wall of the excavation. However, confirmation soil samples from other areas contained up to 1,700 parts per million by volume (ppmv) total ionizable vapors as measured with a photoionization detector (PID) and a total hydrocarbon vapor analyzer (THVA). Maximum concentrations detected in excavation confirmation soil samples include 12,000 milligrams per kilogram (mg/Kg) TPHg, 1,300 total petroleum hydrocarbons-diesel range (TPHd), 80 mg/Kg benzene, 390 mg/Kg toluene, 230 mg/Kg ethylbenzene, and 1,100 mg/Kg total xylenes (Parsons, 1993c).

The excavation was backfilled between June and August 1993 with previously excavated clean overburden (estimated 270 cubic yards) and imported fill (estimated 330 cubic yards), and the surface was repaved with asphalt.

The approximately 600 cubic yards of contaminated soil were stockpiled on plastic sheeting at an open area behind the Redwood Park Fire Station #2 located on Redwood Road approximately 500 feet east of the project site. Confirmation soil samples were collected from the stockpiled soil in July 1993, and aeration of the stockpiled, contaminated soil began in August 1993 (Parsons, 1993a). Following ACHCSA approval, the soil was relocated to Sibley Regional Preserve in Contra Costa County, California for further aeration and final disposition at that site (EBRPD, 1995).

Initial Site Characterization

At the request of ACHCSA, a technical workplan was submitted (Parsons, 1993b) and an initial site characterization was conducted in September and October 1993 in the vicinity of the former UFST excavation. The objective of the program was to evaluate the nature, magnitude and extent of soil and groundwater contamination associated with the residual UFST-sourced soil contamination. Seventeen exploratory borings were drilled, five of which were converted to temporary well points. A total of 27 soil and 5 "grab" groundwater samples were collected for laboratory analysis (Parsons, 1993c). No significant soil contamination was detected in soil borings immediately north, south or east of the former UFST remedial excavation. Fuels in soil were detected in soil borings up to 90 feet southwest of the former UFST excavation; maximum soil concentrations detected included 1,900 mg/Kg TPHg, 1,300 mg/Kg total petroleum hydrocarbons-kerosene range (TPHk), and 198 mg/Kg BTEX constituents. Maximum fuel concentrations detected in groundwater collected from temporary well points included 810,000 μg/L TPHg, 2,300,000 μg/L TPHk, 570 μg/L TPHd and 125,000 μg/L BTEX (including 12,000 μg/L benzene) (Parsons, 1993c).

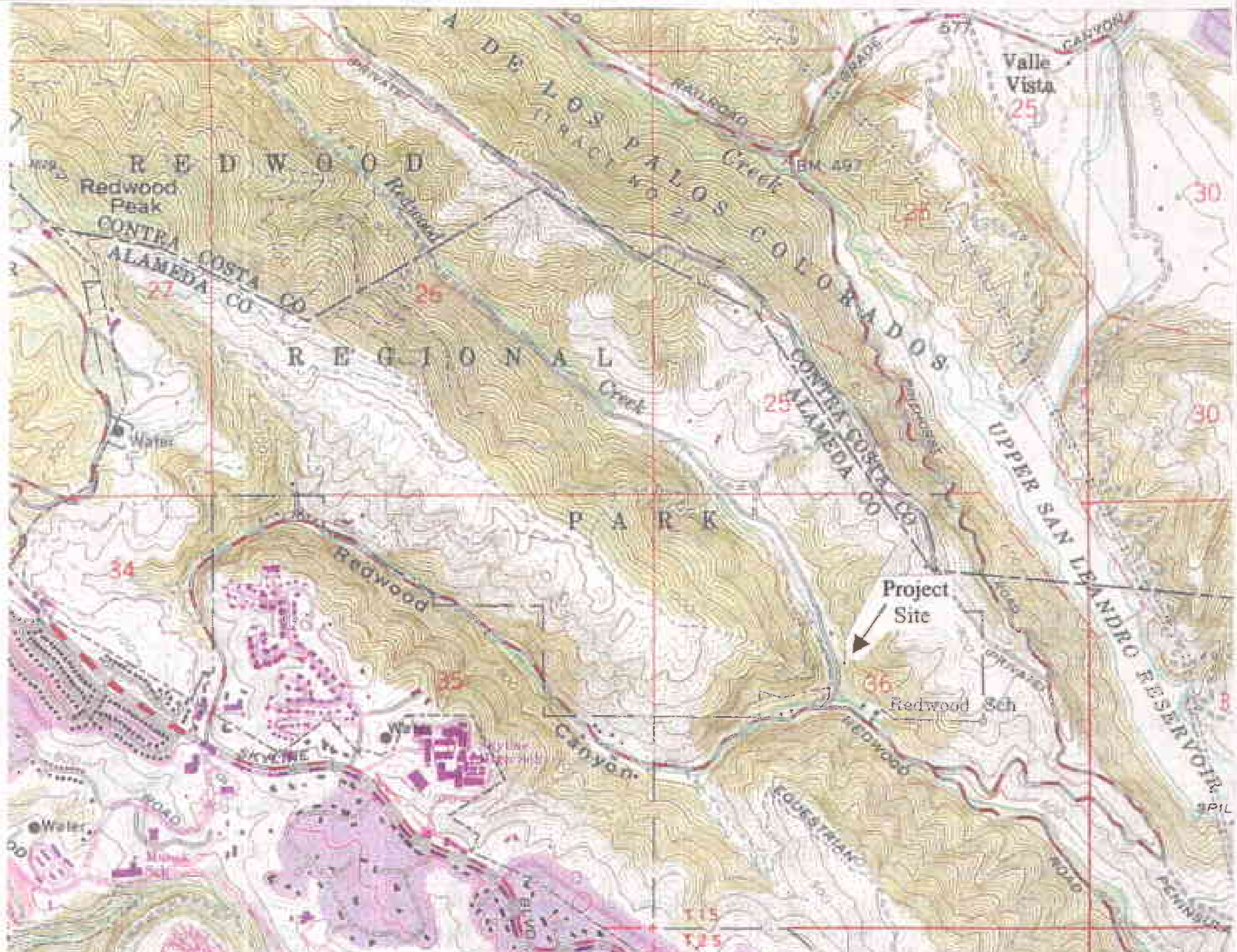
Creek Soil and Surface Water Sampling

In early 1994, discolored soil was observed in the eastern bed of Redwood Creek immediately downstream of the fish ladder, approximately 150 feet southwest of the former UFSTs. Soil and surface water samples were collected for laboratory analysis in February and March 1994 (Parsons, 1994a and 1994b). One soil sample was collected in February 1994 for laboratory analysis from the discolored soil. That sample contained 3 mg/Kg of TPHd; neither TPHg nor BTEX constituents were detected. Field observations have indicated the presence of both a petroleum sheen and an orange algae on the creek water surface in the area of the discolored soil suggesting that the fuel is acting as a carbon source for the algae. Surface water samples have been collected from Redwood Creek at locations upstream, downstream, and in the immediate vicinity of the area of discolored soil, when surface water is available, since February 1994. Figure 2 shows these sampling locations and Section 4 provides a detailed discussion of analytical results.

Groundwater Monitoring and Sampling

Prior to the recent (September 1998) sampling event, 12 groundwater monitoring, sampling and analysis events have been conducted on an approximately quarterly frequency since November 1994. The lateral extent of groundwater contamination by TPHg, TPHd and BTEX constituents is well-defined by existing site groundwater monitoring wells, and currently the maximum detected concentrations are in downgradient well MW-4 adjacent to Redwood Creek, approximately 130 feet southwest of the former UFSTs. Groundwater contaminant concentrations have shown an overall decreasing trend, with the exception of an unusually wet winter that resulted in a rebound of groundwater contamination levels to near historical maxima. A detailed analysis of site hydrochemical trends is presented in Section 4.0.

Historical ACHCSA-approved revisions to the groundwater sampling program have included: 1) discontinuing hydrochemical sampling and analysis in wells MW-1, MW-3 and MW-6; and 2) reducing the frequency of creek surface water sampling from quarterly to semi-annually (ACHCSA, 1996). In addition, the previous most recent report (March 1998) submitted by the previous consultant recommended further revisions to the site characterization program, including: 1) discontinuing hydrochemical sampling and analysis in well MW-5; 2) reducing the frequency of groundwater monitoring and sampling in the remaining two wells from quarterly to annually; 3) discontinuing creek surface water sampling and analysis at upstream location SW-1; and 4) reducing the frequency of creek surface water sampling from semi-annually to annually in the other two creek locations. The Conclusions and Recommendations section of this report evaluates and revises these recommendations based on the results of this phase of the investigation.



N

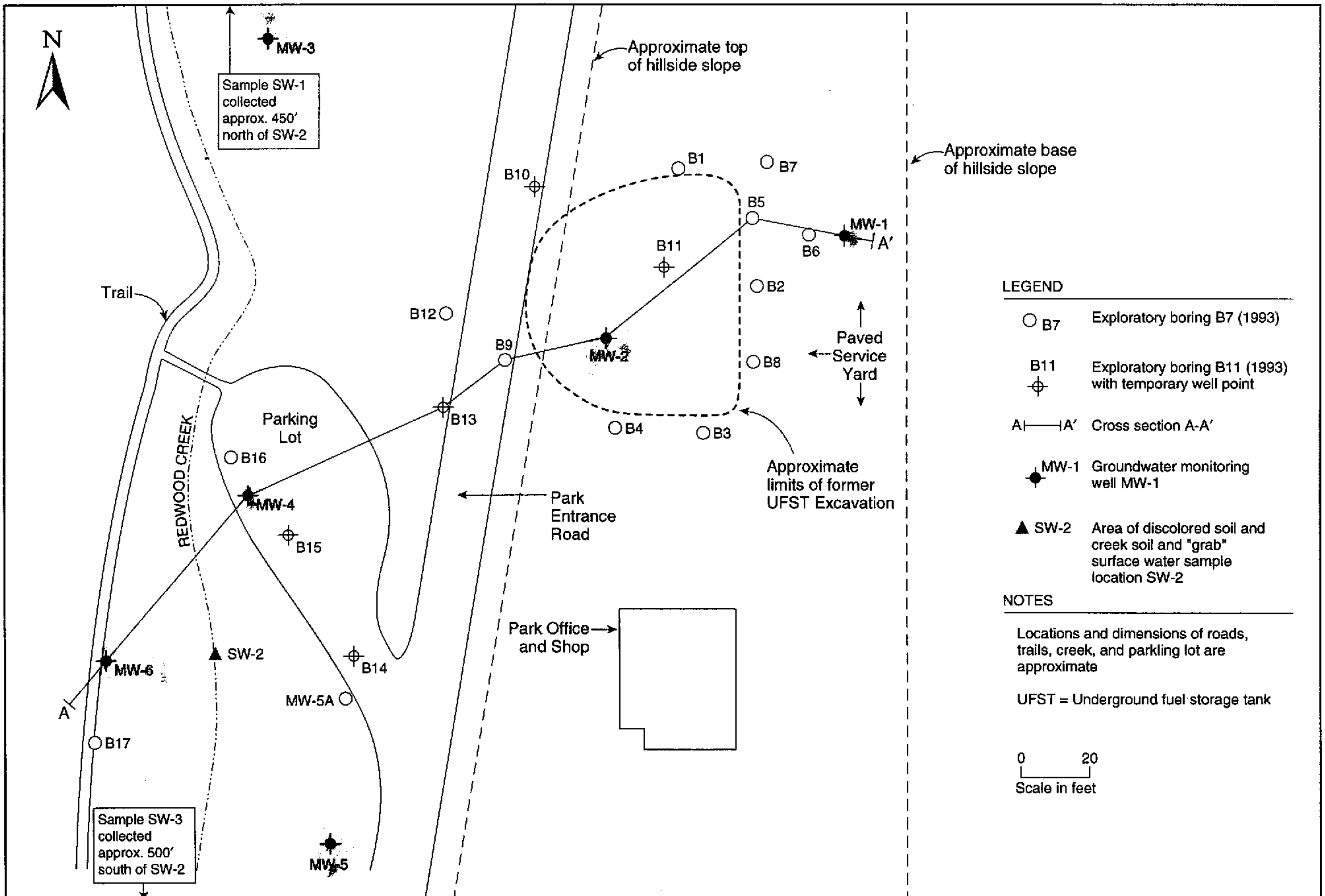
U.S.G.S. TOPOGRAPHIC MAP SHOWING SITE LOCATION

Redwood Regional Park Service Yard
Oakland, Alameda County, California

By: MJC | NOVEMBER 1997

Figure 1

★ Stellar Environmental Solutions
Geoscience & Engineering Consulting



Stellar Environmental Solutions
Geoscience & Engineering Consulting

Site Plan and Cross Section A-A' Location
Redwood Regional Park Service Yard, Oakland, CA

Figure 2

by: MJC | OCTOBER 1998

98031-2-b

2.0 PHYSICAL SETTING

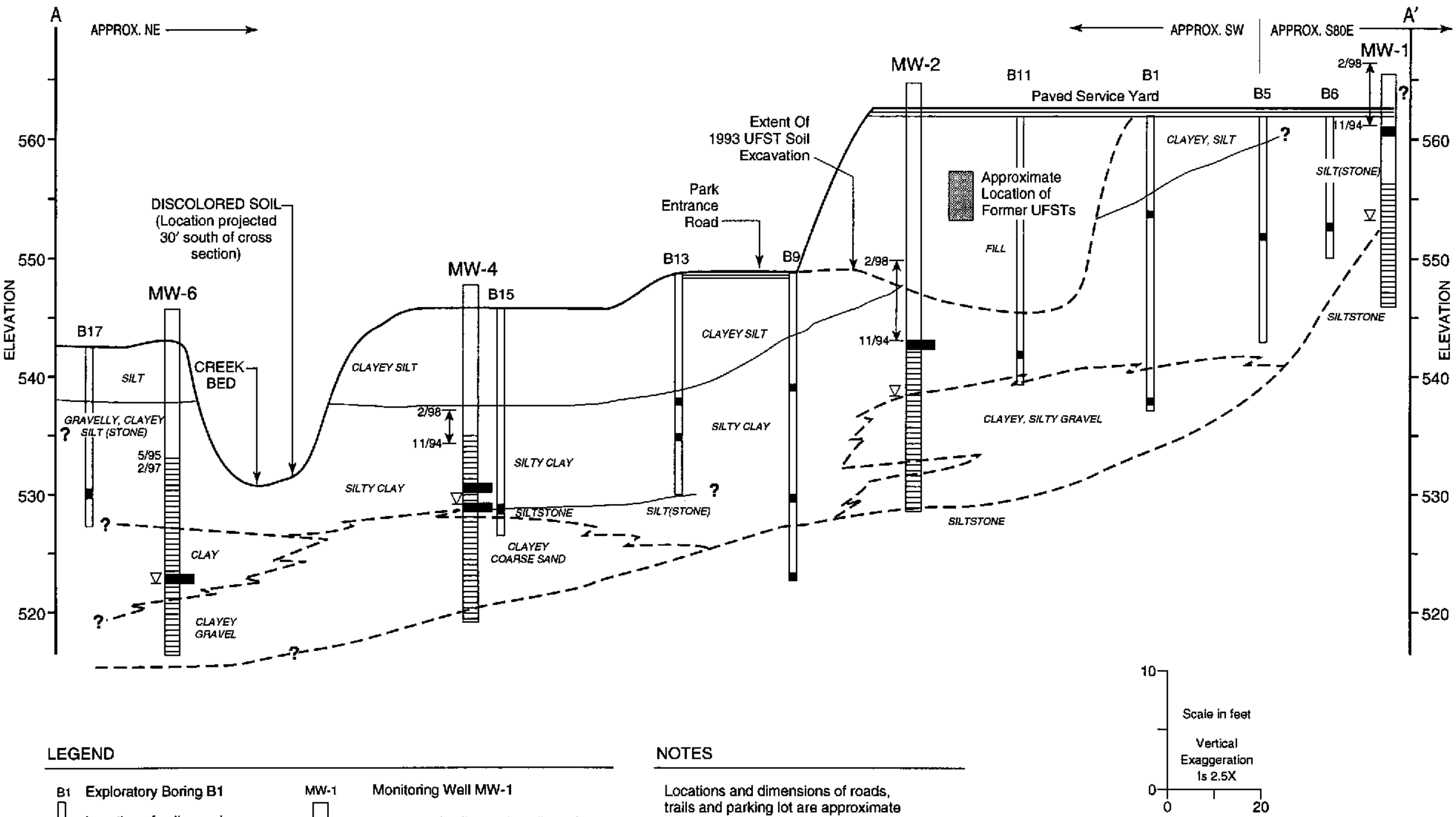
The following evaluation of the hydrogeologic conditions at the project site is based on geologic logging and water level measurements collected at the site since September 1993. This section summarizes site geology and groundwater and surface water hydrology.

GEOLOGY

The site is located approximately 7 miles east of the southeastern shoreline of San Francisco Bay, within the Coast Ranges physiographic province of California. The San Francisco Bay Area is an elongated structural depression bounded by the Santa Cruz Mountains on the west and the Diablo Range on the east. The Oakland-Berkeley Hills, in which the site is located, are encompassed by the Diablo Range.

The San Francisco Bay Area is a seismically active region. The area's main geologic structures are associated with two major faults: the San Andreas Fault in the Santa Cruz Mountains and the Hayward Fault which forms the western boundary of the Diablo Range. The Diablo Range has been uplifted and the bay has gradually subsided over the last three million years. The site is located approximately 2.5 miles east of the Hayward Fault (Norris and Webb 1990, Nilsen et al., 1979).

The bedrock in these mountain ranges is composed of sedimentary, metamorphic and volcanic rocks of Jurassic through Tertiary age (Borcherdt et al., 1975). Overlying the bedrock in Redwood Creek canyon is Quaternary alluvium consisting of silt, sand and gravel. Subsurface stratigraphy, along with other pertinent information at the site, is illustrated in cross section A-A' (Figures 3). These data are based on soil boring data acquired during the 1993 initial site characterization and the November 1994 well installation program. Shallow soil stratigraphy consists of a surficial 3- to 10-foot thick clayey silt unit underlain by a 5- to 15-foot thick silty clay unit. In all monitoring well borings, a 5- to 10-foot thick clayey coarse-grained sand and clayey gravel unit was encountered that laterally grades to a clay or silty clay. This unit overlies a weathered siltstone at the base of the observed soil profile. Soils in the vicinity of MW-1 are inferred to be landslide debris.



LEGEND

B1 Exploratory Boring B1

Location of soil sample collected for laboratory analysis

MW-1 Monitoring Well MW-1

Location of soil sample collected for laboratory analysis

Well screen interval

▽ First encountered groundwater during drilling (10/94)

2/98 – 11/94 Range of static water levels measured between November 1994 and September 1998 showing dates of measured maxima and minima

NOTES

Locations and dimensions of roads, trails and parking lot are approximate

UFST = Underground fuel storage tank

UFSTs not drawn to scale

All elevations surveyed by EBRPD relative to United States Geological Survey (USGS) Survey Benchmark No. JHF-49 and are expressed as feet above mean sea level (MSL)

Well casing and boring widths not to scale

Some borings projected into cross section (see Figure 2)

Stellar Environmental Solutions Geoscience & Engineering Consulting	Cross Section A-A′ Redwood Regional Park Service Yard, Oakland, CA	Figure 3	
		by: MJC	OCTOBER 1998

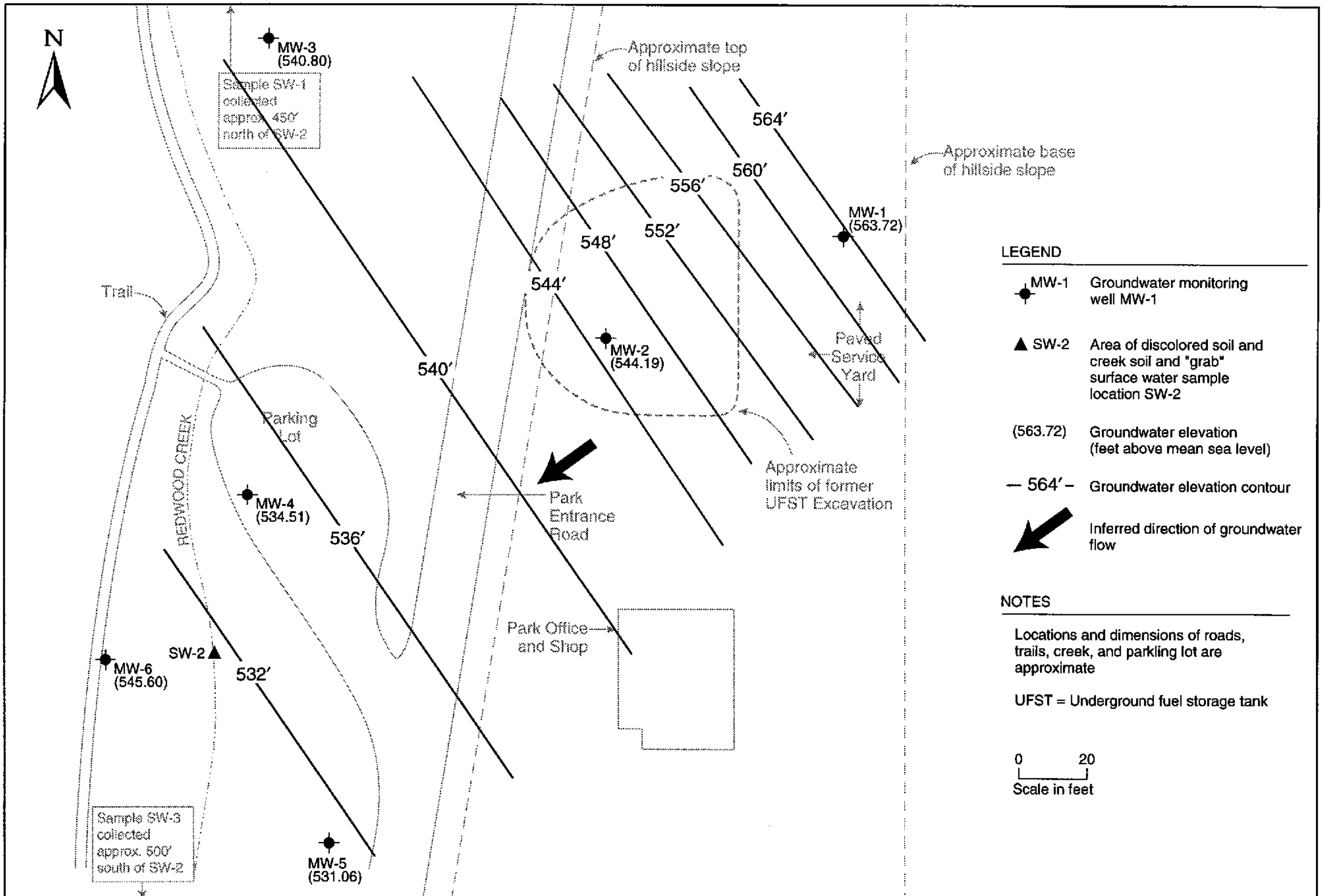
98031-1-d

GROUNDWATER HYDROLOGY

Groundwater at the site occurs under predominantly unconfined conditions, as evidenced by the equilibrated static water levels relative to the water level in Redwood Creek and the level of water seepage out of the north face of the former excavation. Groundwater was first observed at the top of the clayey, silty sand-gravel zone in all monitoring well borings except MW-1. First occurrence of groundwater during drilling was encountered from approximately 3 to 25 feet bgs, and equilibrated water levels ranged from 2 to 18 feet bgs (Parsons, 1993c). The difference between first occurrence of groundwater and equilibrated water level ranged from 0 to 13 feet. These differences were the greatest in areas east of the road and were much less west of the road. Figure 3 shows the range of static water levels measured in site wells between November 1994 and September 1998.

Figure 4 shows a groundwater elevation map constructed from the September 1998 monitoring well static water levels. The direction of local groundwater flow in the portion of the study area east of Redwood Creek is from northeast to southwest. This groundwater flow direction is consistent with previously recorded measurements made in site wells and boreholes since September 1993. It is inferred that local groundwater flow direction west of Redwood Creek is toward the east (toward the creek). The groundwater gradient is relatively steep, at approximately 0.1 feet per feet between wells MW-2 and Redwood Creek, and is approximately 2 feet per feet between well MW-1 and the former UFST source area. The increased groundwater gradient in that area is inferred to result from the topography and the highly disturbed nature of sediments in the landslide debris. A static groundwater level above the ground surface was noted in well MW-1 in the February 1998 event. The actual elevations of the groundwater table are likely to be between the first encountered groundwater at a depth of 18 feet bgs or more, and the equilibrated groundwater elevations in the monitoring wells, showing a depth of about 10 feet bgs.

As discussed above, the materials encountered at the water table in borings in the vicinity of the former UFSTs are predominantly clayey silt and silty clay. A hydraulic conductivity value of approximately 0.003 ft/day and an effective porosity value of 30 percent are representative values of these parameters for this soil type (Fetter, 1988). Given a groundwater gradient of 0.1 feet per feet as estimated from static water level measurements west of the UFST source area, the average linear groundwater velocity would be approximately 0.4 feet per year. Materials encountered a few feet below the water table in five of the six monitoring wells include a 5- to 10-foot thick clayey coarse-grained sand/clayey gravel unit. This is probably the major water-transmitting unit in the observed soil profile. A hydraulic conductivity value of approximately 0.05 ft/day and an effective porosity of 35 percent are representative of these parameters for this soil type (Fetter, 1988), yielding an average linear groundwater velocity of approximately 5 feet per year (approximately ten times



Stellar Environmental Solutions Geoscience & Engineering Consulting	Groundwater Elevation Map, September 18, 1998 Redwood Regional Park Service Yard, Oakland, CA	Figure 4 by: MJC — OCTOBER 1998

98031-3

the value for the upper silty clay, clayey silt unit). These values are approximations only, and actual groundwater velocities could vary substantially. There are no comprehensive data on groundwater hydrology in the area of the project site (ACFCWCD, 1988).

SURFACE WATER HYDROLOGY

Redwood Creek borders the site to the west, and is a seasonal creek known for the occurrence of rainbow trout. Creek flow in the vicinity of the site shows significant season variation. During the summer and fall dry season, the creek has no flow and standing water is limited to discontinuous pools. During the winter and spring wet season, the creek flows vigorously with water depths over a foot in places. Redwood Creek flows from northwest to southeast and discharges into Upper San Leandro Reservoir, located approximately 1 mile southeast of the site. Redwood Creek is a gaining stream (i.e., it is recharged by groundwater) in the vicinity of the site, as evidenced by historical observations of fuel-contaminated capillary fringe soils in the eastern bank of Redwood Creek.

3.0 SEPTEMBER 1998 MONITORING AND SAMPLING

This section summarizes recent (September 1998) field activities conducted at the project site related to the current investigation. Monitoring and sampling protocols were in accordance with the SES technical workplan. Activities conducted included:

- Measuring static water levels data and collecting groundwater analytical samples from site wells
- Collecting creek surface water samples

Groundwater level monitoring and creek sampling were conducted by SES. Groundwater monitoring well purging and sampling were conducted by BlaineTech Services under direct supervision of SES personnel. The locations of all site monitoring wells and creek water sampling locations are shown on Figure 2. Well construction information is summarized in Table 1. Appendix B contains the groundwater monitoring field record.

Table 1
Groundwater Monitoring Well Construction Data

Well	Well Depth	Screened Interval	Depth to TOC	Ground Surface Elevation	TOC Elevation
MW-1	18	7-17	-2.3	563.6	565.9
MW-2	36	20-35	-2.4	564.1	566.5
MW-3	42	7-41	-2.8	558.1	560.9
MW-4	26	10-25	-2.1	546.0	548.1
MW-5	26	10-25	-2.3	545.2	547.5
MW-6	26	10-25	-2.3	543.3	545.6

Remarks: 1) TOC = Top of Casing
2) All depths are feet below ground surface unless otherwise specified. Negative values for "Depth to TOC" indicate that the TOC is above ground surface.
3) All elevations are feet above USGS mean sea level (MSL). Elevations were surveyed by EBRPD relative to USGS Benchmark No. JHF-49.
4) All wells are 4-inch inside diameter

GROUNDWATER LEVEL MONITORING AND SAMPLING

Static water levels were measured (Appendix B) in all six site wells on September 18, 1998. All water level measurements were made using an electric water level indicator.

In accordance with an ACHCSA recommendation (ACHCSA, 1997), "non-purge" groundwater samples were collected prior to well purging. The non-purge approach has been accepted by several local implementing agencies, as well as by the Regional Water Quality Control Board – San Francisco Bay Region. The site conditions meet all the criteria required by the RWQCB for implementing the non-purge approach (RWQCB, 1997). "Post-purge" samples were also collected for laboratory analysis to allow for comparison between the two sample sets. Non-purge samples were collected from wells MW-2, MW-4 and MW-5 with a pre-cleaned stainless steel bailer.

Groundwater sampling of MW-2, MW-4, and MW-5 was conducted in accordance with state of California guidelines for sampling dissolved analytes in groundwater associated with leaking UFSTs (State Water Resources Control Board 1989). Prior to collecting groundwater samples, a pre-cleaned submersible pump was used to purge a minimum of three casing volumes from each well. Electrical conductivity (EC), hydrogen ion index (pH), and temperature (T) of purge water were measured during well purging, to document the stabilization of formation-water in the wells. Glass sample containers were filled with sample water from a pre-cleaned Teflon ™ bailer. The water samples collected from wells MW-2 and MW-4 had a petroleum odor. There was no visual or odiferous evidence of contamination during purging and sampling of the groundwater wells. Appendix B includes water level data and groundwater monitoring field notes from the groundwater monitoring event.

To prevent cross-contamination, groundwater sampling equipment was decontaminated prior to use and between each monitoring well with an Alconox™ wash followed by three deionized water rinses. Following sample collection, sample containers were labeled, placed in a cooler packed with "blue ice," and transported under chain-of-custody the same day to a laboratory accredited by the California Environmental Protection Agency (Cal EPA) Department of Health Services (DHS) Environmental Laboratory Accreditation Program (ELAP). Chain-of-custody records for the groundwater samples are included in Appendix C.

A total of approximately 97 gallons of purge water and decontamination rinsate from the current groundwater sampling event was containerized in the onsite plastic tank. As discussed in the Conclusions and Recommendations section, SES is recommending that well purging continue based on the significantly higher concentrations detected in post-purge samples. Therefore, the purge water will continue to be accumulated in the onsite tank until it is full, at which time it will be transported offsite.

CREEK SURFACE WATER SAMPLING

Surface water samples were collected on September 18, 1998 from locations SW-1, SW-2, and SW-3 in Redwood Creek (for locations see Figure 2). Surface water samples were collected in a new glass sampling container by immersing the container just under the water surface, transferring the sample to the appropriate container, and immediately capping the containers, which were then labeled, chilled and transported under chain-of-custody the same day to the analytical laboratory. **Petroleum sheen was noted in the immediate vicinity of sampling location SW-2.** At the time of sampling, there was no creek flow, the majority of the creek upstream of SW-2 was dry, and maximum depth of standing water was approximately 6 inches.

ANALYTICAL RESULTS

All creek surface water and groundwater samples were analyzed for historical constituents of concern, including TPHg, TPHd and BTEX. **Samples were also analyzed for the first time for methyl tertiary butyl ether (MTBE),** a fuel oxygenating additive that has recently been identified as a constituent of concern at fuel release sites. Table 2 summarizes the analytical results of the September 1998 creek surface water and groundwater samples.

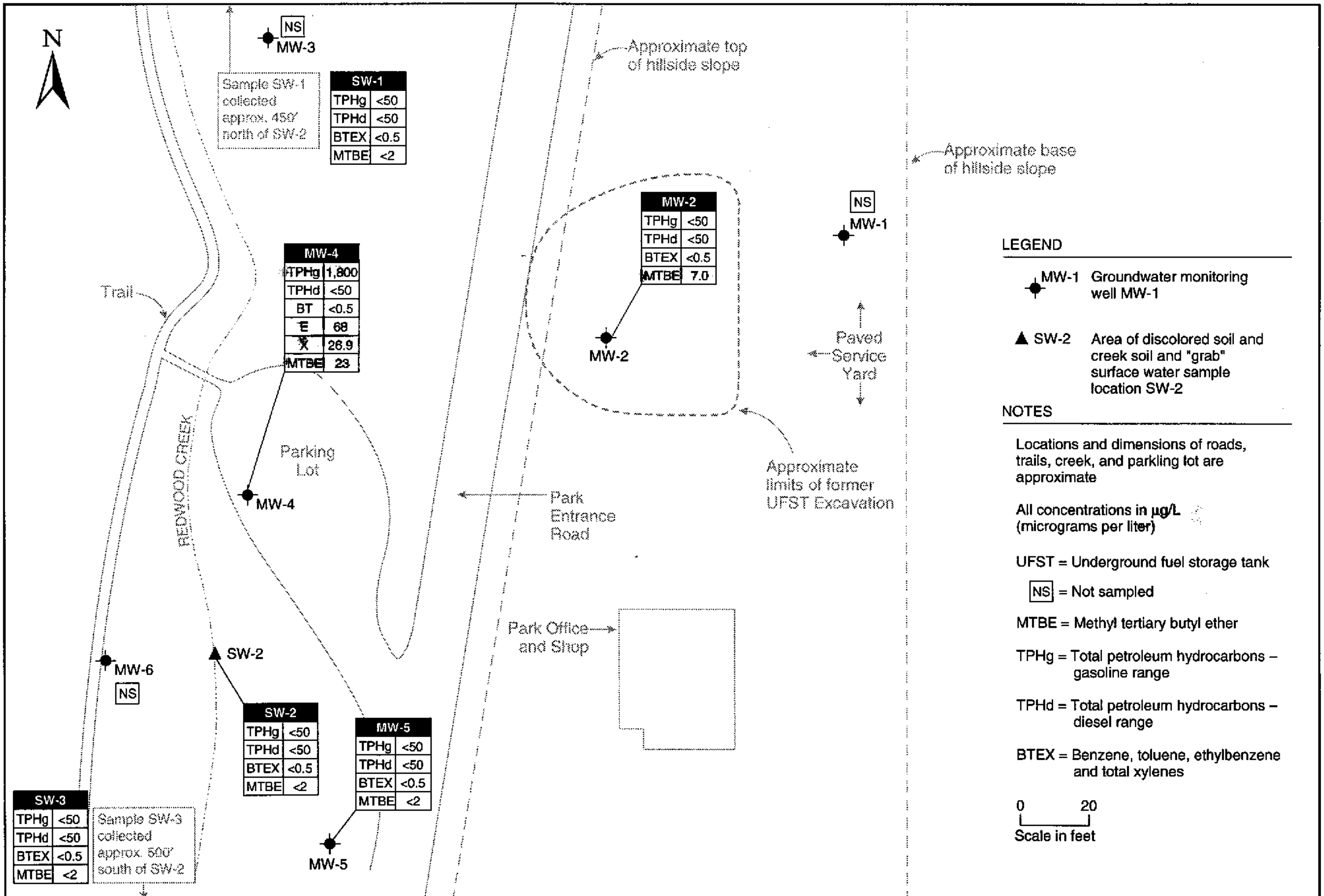
Creek Surface Water Samples

No compounds were detected above their respective method reporting limits.

Groundwater Sample Results

Figure 5 shows the results from the September 1998 sampling event. TPHg, ethylbenzene and total xylenes were detected only in well MW-4. **MTBE was detected in both MW-2 and MW-4 samples.** No constituents of concern were detected in cross-gradient well MW-5. The only contaminant detected in the source area well MW-2 was MTBE (7 μg/L). Neither TPHd, benzene nor toluene were detected above the method reporting limit in any of the samples. Section 4.0 discusses the significance of these results as regards historical and projected hydrochemical trends.

For detected compounds, significant variations were observed between the non-purge and post-purge samples (between 124% and 192%) relative percent difference (RPD). **In all cases, post-purge concentrations were greater than the respective non-purge concentration.**



Stellar Environmental Solutions

Geoscience & Engineering Consulting

Groundwater and Surface Water Analytical Results, September 18, 1998

Redwood Regional Park Service Yard, Oakland, CA

Figure 5

by: MJC

OCTOBER 1998

98031-4-a

Table 2
Groundwater and Creek Surface Water
Sample Analytical Results - September 18, 1998
Redwood Regional Park Corporation Yard
Oakland, California

Compound	Concentrations in µg/L						
	TPHg	TPHd	Benzene	Toluene	Ethyl-benzene	Total Xylenes	MTBE
Groundwater Samples							
MW2							
Non-purge	< 50	< 50	< 0.5	< 0.5	< 0.5	< 0.5	**6.7**
Post-purge	< 50	< 50	< 0.5	< 0.5	< 0.5	< 0.5	**7.0**
RPD							4.4%
MW4							
Non-purge	**330**	< 50	< 0.5	< 0.5	**5**	**0.54**	**5.4**
Post-purge	**1,800**	< 50	< 0.5	< 0.5	**68**	**26.9**	**23**
RPD	138%				173%	192%	124%
MW5							
Non-purge	< 50	< 50	< 0.5	< 0.5	< 0.5	< 0.5	< 2
Post-purge	< 50	< 50	< 0.5	< 0.5	< 0.5	< 0.5	< 2
Creek Surface Water Samples							
SW-1	< 50	< 50	< 0.5	< 0.5	< 0.5	< 0.5	< 2
SW-2	< 50	< 50	< 0.5	< 0.5	< 0.5	< 0.5	< 2
SW-3	< 50	< 50	< 0.5	< 0.5	< 0.5	< 0.5	< 2

Notes:
MTBE = Methyl tertiary butyl ether
RPD = Relative Percent Difference between non-purge sample and post-purge sample.
TPHg = Total petroleum hydrocarbons - gasoline range (equivalent to total volatile hydrocarbons - gasoline range)
TPHd = Total petroleum hydrocarbons - diesel ranges (equivalent to total extractable hydrocarbons - diesel range)
NA = Not Analyzed
µg/L = Micrograms per liter, equivalent to parts per billion (ppb)

Quality Control Sample Analytical Results

One post-purge field duplicate sample (MW-0A) was collected from well MW-4 and analyzed for TPHg and BTEX to assess whether field procedures produced reproducible results. For detected compounds, relative percent differences (RPDs) (aka variance from the mean) in concentration between the field and duplicate samples included: 11.8% (TPHg); 9.6% (benzene); 10.2% (total xylenes); and 49.2 % (MTBE). Neither toluene nor ethylbenzene were detected in either sample. With the exception of the MTBE results, these data suggest very good reproducibility of laboratory analyses. Field duplicate samples will continue to be analyzed and evaluated to determine if the recent MTBE results are an anomaly.

Laboratory QC samples (e.g., method blanks, matrix spikes, surrogate spikes, etc.) were analyzed by the laboratory in accordance with requirements of each analytical method. All laboratory QC sample results and sample holding times were within the acceptance limits of the methods (Appendix C).

4.0 RESIDUAL CONTAMINATION AND BENEFICAL USES

SITE REGULATORY HISTORY

Alameda County Health Care Services Agency (ACHCSA) has been the lead regulatory agency for the case since its inception, with regulatory correspondence with the Park District going back to the January 1994 review of the December 1993 ES report documenting the UFST's removal. The ACHCSA is a Local Oversight Program (LOP) to the RWQCB, and provides its own oversight until some resolution such as site closure is agreed upon, at which time it sends its recommendation to the RWQCB for approval of the closure. Other interested regulatory agencies, such as the California Department of Fish and Game (DFG), communicate their concerns directly to ACHCSA.

While ACHCSA is usually in concurrence with the RWQCB's position on the need to remediate and on site closure criteria, they can also differ from it based on the case-by-case findings. The ACHCSA has no published guidance regarding TPH or the TPH components BTEX. They generally adhere to the basic non-degradational policy, but recognize that some degradation is unlikely to be irreversible and will accept case closures where there is the demonstration that no public health or ecological risks will occur as a result of the residual contamination.

Mr. Thomas Peacock of ACHCSA wrote the Park District in September 1997 suggesting that recommendations needed to be formulated to address the contamination. He further suggested that some form of in-situ remediation such as an oxygen releasing compound (ORC) might be considered. In early 1998 the DFG communicated their concern about the potential ecological impact to the creek from the release into the creek recorded in two of the dry weather sampling events. In July 1998 the Park District met with ACHCSA and DFG, concluding that a determination of whether remediation was needed should be complete, and if remediation was indicated to be necessary, what method would be effective to move the site towards closure resolution. This report addresses that objective with this section evaluating the applicable or relevant and appropriate regulations (ARARs).

SOIL, GROUNDWATER AND SURFACE WATER CLEANUP AND FURTHER ASSESSMENT CRITERIA

The Applicable Relevant and Appropriate Regulations (ARARs) for this site should be considered in the light of the following areas of concerns:

- There is an indeterminant amount of residual TPHg, TPHd and BTEX in the soil and groundwater following the UFST removals that is migrating towards Redwood Creek. Impacts to fish and invertebrates should be evaluated as well as acute and chronic toxicity.
- Groundwater daylights at the base of the slope within the creek during the low flow period in summer with detectable levels of TPHg and benzene which could have ecological impacts on the riparian zone, aquatic life, and local wildlife in the creek.
- The extent to which natural biodegradation of the subsurface TPHg, TPHd and BTEX in the soil and groundwater can be expecteed to naturally remediate the contamination.

Soil Contamination Cleanup and Further Assessment Criteria

As part of the evaluation of site closure, site analytical data must be reviewed in the context of media-specific regulatory requirements and considerations, including its classification as hazardous waste or as designated waste. There are no specific hazardous waste definitions for petroleum products in soil, except in the unlikely event that there is enough product in the soil for it to be considered ignitable. The regulatory environment evaluation of the amount of residual TPH considered acceptable is related to its potential impact on groundwater.

A contaminant that is neither hazardous nor potentially hazardous by the criteria explained above may be classified as a designated waste due to the substances' potential impact to groundwater on a case-by-case basis. The California Regional Water Quality Control Board (RWQCB) uses a Designated Level Methodology (DLM) as a guide in determining if a waste at a given site should be classified as a designated waste and, if so, what cleanup level is needed. The DLM calculations are site-specific and consider the depth to groundwater, type of soil, total pollutant load, amount of rainfall, and attenuation factors. Relevant criteria for soil contamination by the regulatory environment for TPH contamination are generally evaluated on a case-by-case basis, most often using some form of the RWQCB's DLM discussed above. In the past, the RWQCB used 100 mg/Kg in soil as a general criteria for assessing impacts to groundwater in their Leaking Underground Fuel Storage Tank (LUFT) Manual investigation guidance. The LUFT manual uses the DLM which utilizes a screening-level methodology that accounts for site-specific factors related to the ability of soil contamination to migrate to groundwater (i.e., a leaching potential analysis) to estimate the allowable concentrations of residual soil contamination. If allowable concentrations are exceeded, the guidance recommends that a more detailed general risk appraisal be conducted to determine potential impacts to groundwater. In addition, the feasibility and cost benefit of remediation of residual soil contamination is a factor to be considered.

The leaching potential analysis in the LUFT Manual guidance stipulates the allowable concentrations of fuel contamination in soil that can be left in place without impacting groundwater are as follows:

- TPHg: 10 mg/kg to 1,000 mg/kg
- TPHd: 100 mg/kg to 10,000 mg/kg
- BTEX (individual or cmbined consituents): to be considered ARAR of 1 mg/kg

Using the preliminary screening methodology in that guidance, the site is considered to be "most sensitive" and the allowable concentration of TPHg and TPHd would be 10 mg/Kg and 100 mg/Kg, respectively. For this type of site, the guidance does not provide BTEX allowable levels and states that a general risk appraisal should be conducted. The site residual soil TPHg and TPHd concentrations exceed the LUFT Manual allowable concentrations, and therefore could be considered by regulatory agencies to have the potential to impact groundwater. This finding is validated by the detected TPHg and TPHd in groundwater (see following discussion).

As discussed in Section 1.0, the 1993 UFST excavation removed 600 cubic yards of contaminated soil. Confirmation samples collected at the base of the UFST excavation showed the maximum residual soil contamination of 12,000 mg/kg TPHg and 1,800 mg/Kg BTEX. Though these residual hydrocarbon levels in the soil are above the often cited RWQCB LUFT manual guidance levels that are construed as adversely impacting groundwater, the LUFT guidance has been largely superceded by the findings of the Lawrence Livermore National Laboratory (LLNL) report in October 1995 (LLNL, 1995). The LLNL report completed a statistical analyses of hydrocarbon plume characteristics of length and persistence in hundreds of RWQCB cases throughout the state, concluding that hydrocarbons will slowly degrade over time and are more significantly limited in size than previously thought. These findings prompted the RWQCB to adopt an evaluation of residual TPH contamination in the context of an assessment of risk on a case-by-case basis, encouraging the use of risk-based corrective action (RBCA) assessments.

Groundwater Contamination Cleanup and Further Assessment Criteria

Table 3 shows the water quality standards for the site contaminants.

There are several potential "action" standards for groundwater contamination. The standard which can be applied by the local agency with jurisdiction is the strictest of any applicable state or federal standards, including federal and California Maximum Contaminant Levels (MCLs) and state action levels (SALs). For purposes of this investigation, groundwater analytical data can be evaluated in the context of federal or State of California enforceable "action" levels for groundwater (MCLs) only for BTEX, as there are no MCLs or SALS for TPHg or TPHd, although concentrations of less than 5 mg/L in the absence of TPHg and BTEX concentrations of significance will not often require cleanup action unless sensitive receptors, such as proximity to sensitive aquatic life, are apparent. MTBE, a fuel TPH additive with potential impacts, has a recently proposed primary MCL of 14 µg/L and secondary MCL of 5 µg/L. The September 1998 sampling event was the first in which MTBE was analyzed for.

As discussed above, the ACHCSA, similar to the RWQCB, will evaluate groundwater contamination impacts by TPH and BTEX on a case-by-case basis. The RWQCB uses the DLM methodology, considering such criteria as designated land use, sensitive biological receptors, depth to groundwater and beneficial use of groundwater.

Criteria that are favorable for receiving case closure by the ACHCSA and RWQCB include:

- The source area (i.e., contaminated soil) has been remediated to the extent that is cost-effective;
- Groundwater contamination is immobile;
- Contaminant concentrations are stable or reducing sufficiently such that biodegradation is at work on the residual soluble fraction; and
- Contaminant toxicity is low (e.g., extractable-range hydrocarbons only and little or no TPHg and BTEX) and there are no sensitive receptors.

For cases in which groundwater concentrations are stable or reducing sufficiently, and where the requisite environmental conditions favor biodegradation, a case can be made for natural attenuation to remediate the contamination over time. In such cases where there is a residual soluble fraction of TPHg and BTEX, and the absence of future source material or sensitive receptors, the plume should further reduce over time. Such cases have been granted site closure status by the ACDEH and RWQCB. A site may be granted closure when the groundwater concentrations are at higher levels than ARARs, if a risk assessment can demonstrate acceptable risk.

Cleanup action level criteria can also be modified by natural geochemical conditions at a site. For example, where an existing aquifer has a yield of less than 200 gallons per day or TDS of > 3,000 µg/L, the water is considered unusable. Measured electrical conductivity values of groundwater at the site are historically below 900 µmhos/cm (Appendix B) and don't exceed the maximum value of 5,000 µmhos/cm (equivalent to µS/cm) established by the SWRCB for potential public water supplies. Additionally, sustained yield of site wells is likely to be greater than the 200 gallons per day [gpd] criterion for potentially suitable drinking water (State Water Resources Control Board

Table 3
Surface and Ground Water Quality Criteria for Detected Contaminants

Analyte	Regulatory Limit (µg/L)	Regulatory Source
TPH-gasoline	NE	RWQCB LUFT Manual
TPH-diesel	NE	RWQCB LUFT Manual
Benzene	0.34 1 1.2 21 71	Water Quality Objective California Primary MCL Water Quality Objective EPA IRIS value for consumption of water & organisms EPA IRIS value for consumption of organisms only
Toluene	40 1,000 6,800 200,000	Proposed Federal Secondary MCL Proposed Federal Primary MCL EPA IRIS value for consumption of water & organisms EPA IRIS value for consumption of organisms only
Ethylbenzene	30 680 3,100 29,000	Proposed Federal Secondary MCL California Primary MCL EPA IRIS value for consumption of water & organisms EPA IRIS value for consumption of organisms only
Total Xylenes	20 1,750	Proposed Federal Secondary MCL California Primary MCL
MTBE	5 14	Proposed California Secondary MCL Proposed California Primary MCL

Notes: EPA Water Quality Objectives (WQO) for inland surface waters that are potential drinking water sources. EPA IRIS = Environmental Protection Agency Integrated Risk Information System criteria giving concentration at which there is a carcinogenicity risk of 10E-6 or less. NE=Not Established

1991). Based on these data, groundwater at the site may be considered as a potential drinking water source, and therefore drinking water standards (i.e., Maximum Contaminant Levels [MCLs]) may be applicable to contaminated groundwater at the site.

There are no drinking water MCLs for total petroleum hydrocarbons in groundwater. This contaminant would therefore be regulated under the RWQCB general "nondegradation of beneficial use" policy (RWQCB, 1992).

BENEFICIAL USES AND WATER QUALITY OBJECTIVES

The surface water ARARs are drawn from inland water quality criteria (WQOs) published by the RWQCB (RWQCB, 1994) and from EPA Integrated Risk Information System (IRIS) criteria that evaluate contaminant concentrations relative to the 1 in 1 million human cancer risk. Beneficial uses of surface water quality in California are used to establish water quality standards and discharge prohibitions (RWQCB, 1992). There are no listed direct beneficial uses for Redwood Creek beyond being an aquatic creek, but the existing fish ladder within 30 feet of the area where the plume intermittently daylights indicates the creek to be a sensitive receptor. There are listed beneficial uses for Upper San Leandro Reservoir (located approximately 4,000 feet south [downstream] of the project site), into which Redwood Creek flows. Existing beneficial uses for Upper San Leandro Reservoir include: water contact recreation; municipal and domestic supply; warm and cold fresh water habitats; wildlife habitat; and fish spawning. Potential beneficial uses include non-contact water recreation. While there are no identified ARARs exceeded, the fundamental question that needs to be answered is whether there are measurable adverse impacts to the Redwood Creek aquatic environment.

Groundwater seepage occurs along the eastern boundary of Redwood Creek approximately 150 feet west (downgradient) of the UFST source area. The smear zone of soil contamination, as can be seen in Figure 6, is estimated to be located mainly below the elevation of the creek, with only the uppermost portion in potential contact with the base of the creek and the plume daylighting at this location. The creek itself appears to act as a hydraulic barrier against migration of the groundwater plume beyond the creek, as evidenced by the absence of historical detectable groundwater contamination in well MW-6 located on the other side of the creek from the site. During periods of sufficient creek flow, surface water originating at the seeps would be expected to flow into Upper San Leandro Reservoir approximately 4,000 feet south (downstream).

GROUNDWATER AND SURFACE WATER REGULATORY EVALUATION

Groundwater

Maximum fuel concentrations detected in site groundwater samples during the previous year of groundwater monitoring (all at sample location SW-2 immediately downgradient of the former UFST) that are in excess of published regulatory agency ARARs for groundwater include:

- Benzene (110 µg/L; exceeds the California WQOs)
- Toluene (92 µg/L, exceeds the proposed Federal Secondary MCL)
- Ethylbenzene (320 µg/L; exceeds the proposed Federal Secondary MCL)
- Total xylenes (600 µg/L; exceeds the proposed Federal Secondary MCL)

- MTBE (23 µg/L; exceeds the proposed Federal Primary and Secondary MCLs)

Surface Water

No site-sourced contaminants have been detected in excess of regulatory ARARs in site creek water samples during the previous year of creek water monitoring. The only contaminant that has been detected in creek water samples in excess of published regulatory agency ARARs for surface water is benzene, detected in 3 out of the 11 surface watering monitoring events since February 1995. The detected benzene concentrations ranged from 1.9 to 13 µg/L, which exceed the 0.34 µg/L and 1.2 µg/L WQOs for inland surface waters that are potential drinking water sources. However, the samples analyzed do not represent an average concentration over a 30-day period, upon which the WQO is based, and therefore are not directly comparable to the WQO. Neither TPH nor BTEX have ever been detected at the downstream SW-3 location.

5.0 RESIDUAL CONTAMINATION EVALUATION AND SIGNIFICANCE

This section addresses the following objectives: 1) an evaluation of the site data collected to date to determine the extent of residual soil contamination and the groundwater quality trends in the groundwater and surface water; 2) an assessment of the plume stability; and 3) a discussion of the impacts on the known beneficial uses of the groundwater and surface water given the known or suspected residual contamination.

VOLUME AND EXTENT OF CONTAMINATED SOIL REMEDIATED

The 1993 site excavation of residual TPH-contaminated soil resulted in the removal of approximately 600 cubic yards (CY). The extent of the residual contaminated soil left in the area of the excavation was primarily a function of the concern over unstable ground immediately upslope (east) of the excavation.

RESIDUAL CONTAMINATED SOIL

An estimated 20-100 CY of TPH-contaminated soil remains at the source area. The maximum concentrations of residual soil contamination detected in excavation base and sidewall samples included 12,000 milligrams per kilogram (mg/Kg) TPHg, 1,300 TPHd, 80 mg/Kg benzene, 390 mg/Kg toluene, 230 mg/Kg ethylbenzene and 1,100 mg/Kg total xylenes.

The estimated volume of the TPH residual contaminated soil above 1,000 mg/Kg TPH, based on the available historical data points of excavation confirmation samples, exploratory borings and monitoring well installation soil samples (see Table A.1, Appendix A) is estimated to range from between about 400 to 550 CY, depending on the extent of the "smear" zone.

The smear zone is the area of soil contamination that was contaminated through the process of sorbing the hydrocarbon contamination in the aqueous phase as the plume migrates through the soil and water levels fluctuate. The maximum estimate of 550 CY is based on the assumption of a 5-foot thick by 20-foot wide "smear" zone extending the length of 150 feet to the creek from the former UFST source area. Figures 6 and 7 illustrate in cross section and plan view the area of residual soil contamination. While the highest concentration of residual contamination is associated with the 16-

foot samples collected at the base of the excavation at the time of the UFST removal, the majority of the residual contamination (80%) is estimated to be associated with the relatively thin layer along the migrational pathway of the plume.

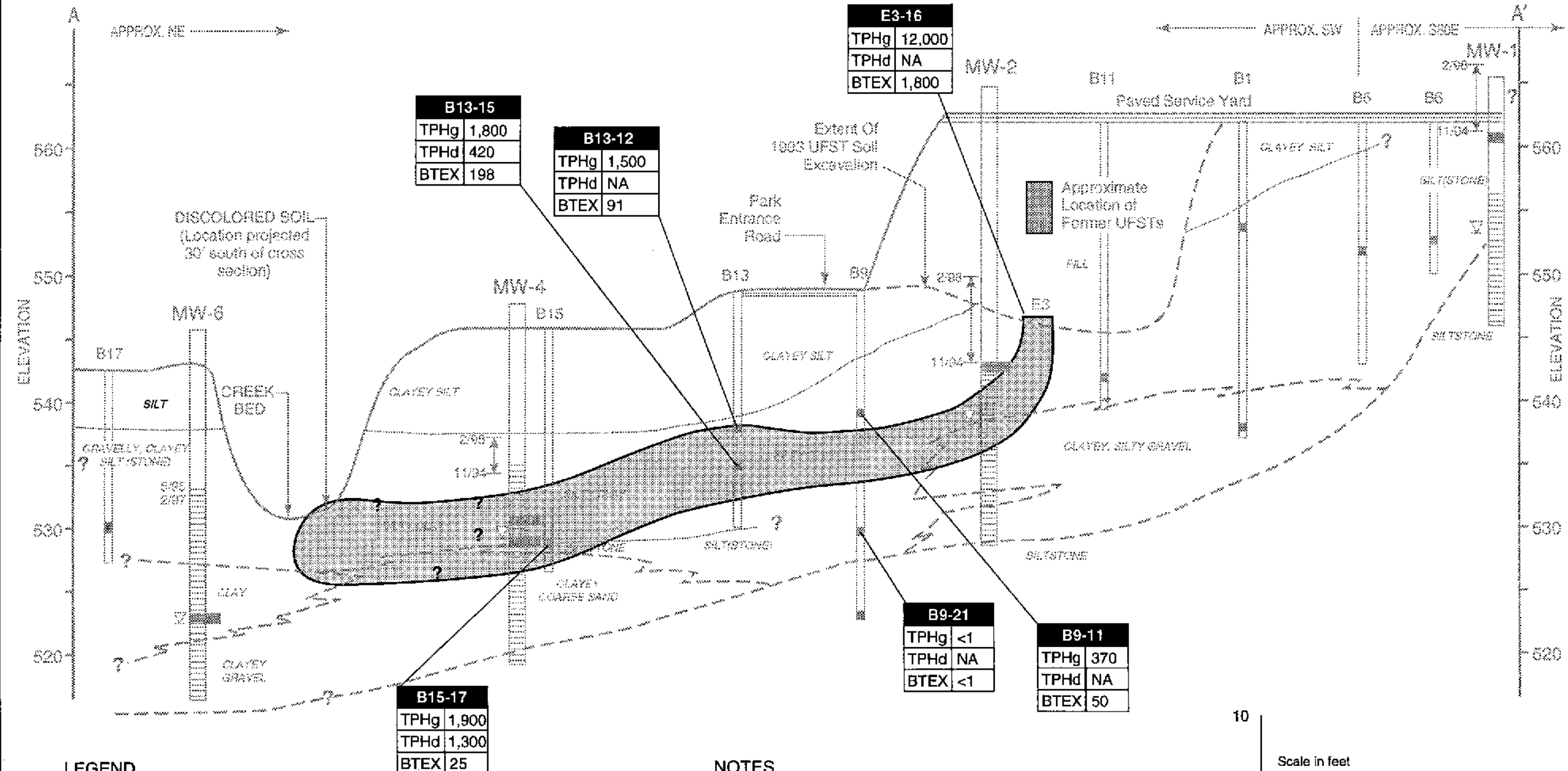
Actual elevations of the groundwater table are likely to be between the first encountered groundwater at a depth of 18 feet bgs or more, and the equilibrated groundwater elevations in the monitoring wells, showing a depth of about 10 feet bgs.

Examination of the TPHg to BTEX ratio in Figure 6 indicates both volatilization and degradational mechanisms at work. The TPHg to BTEX ratio increases significantly as it moves downgradient in the soil. At the residual source area, represented by sample E3-16', the ratio is 6.6, showing significant BTEX, while at the intermediate location of B13 the ratio is 16 while the most downgradient soil sample, at MW-4 shows a ratio of 75. This demonstrates that the BTEX components in the soil have volatilized or been biodegraded more quickly than the TPHg.

SOIL REMEDIATION METHOD EFFECTIVENESS & IMPACT OF RESIDUAL CONTAMINATED SOIL

The soil remediation program objective of identifying and excavating the residual contaminated soil with TPHg, TPHd and BTEX above about 100 mg/kg in order to remove a potential long-term source of groundwater contamination was successfully completed in 1993, within the limitations of the slope stability constraints. Due to the location of the excavation being near the top of a landslide area, the excavation could not remove small pockets of relatively high concentration TPH-contaminated soil.

The distribution of the residual TPH soil at depth along the length of the 150-foot long plume makes it economically burdensome to remove. It is well documented in the literature that petroleum hydrocarbons in soil and groundwater will diffuse and slowly degrade by microbial utilization of the hydrocarbons as a carbon food source to break it down into benign byproducts of carbon dioxide, water and biomass. The soil in this area should be rich in TPH degrading microbes based on the general soil profiles suggesting adequate nutrients and moisture. The oxygen, however, may be somewhat depleted in the area of the highest concentrations of TPH. Typical in-situ biodegradation rates calculated from respiration tests at bioventing pilot tests in soils in the literature are between 500 and 1,000 mg/kg TPHd per year (Makdisi and others, 1992; Miller and others, 1993). In this environment, where there is no supplied oxygen as there is in the case of a bioventing system, the degradation rates will be slower.



LEGEND

B1 Exploratory Boring B1

Location of soil sample collected for laboratory analysis

First encountered groundwater during drilling (10/94)

Approximate boundaries of residual contaminated soil >1000 mg/kg

MW-1 Monitoring Well MW-1

Location of soil sample collected for laboratory analysis

Well screen interval

2/98 – 11/94 Range of static water levels measured between November 1994 and September 1998 showing dates of measured maxima and minima

NOTES

Locations and dimensions of roads, trails and parking lot are approximate

UFST = Underground fuel storage tank

NA = Not analyzed

UFSTs not drawn to scale

All elevations surveyed by EBRPD relative to United States Geological Survey (USGS) Survey Benchmark No. JHF-49 and are expressed as feet above mean sea level (MSL)

Well casing and boring widths not to scale

Some borings projected into cross section (see Figure 2)

Stellar Environmental Solutions

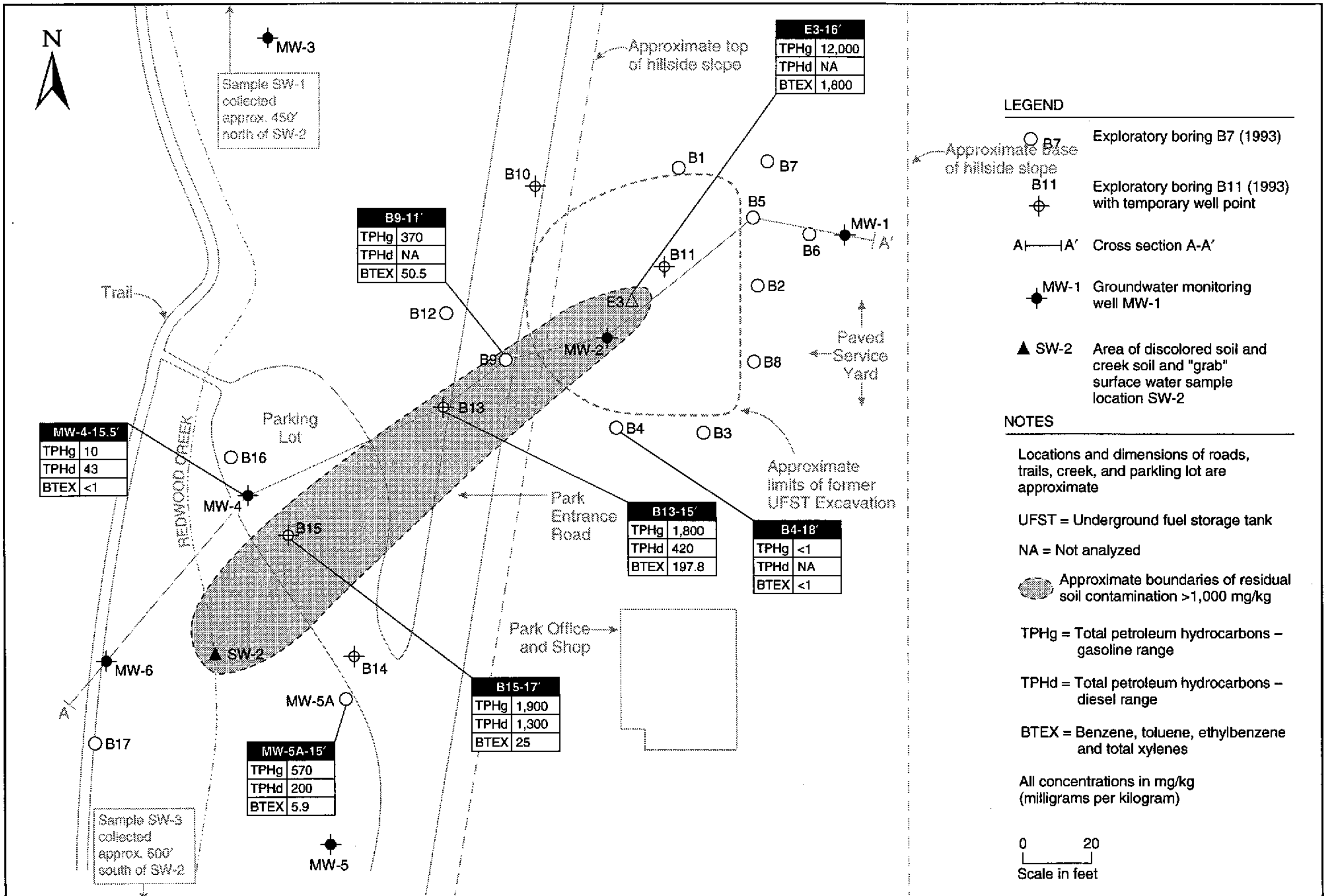
Geoscience & Engineering Consulting

Cross Section Showing Residual Soil Contamination Redwood Regional Park Service Yard, Oakland, CA

Figure 6

by: MJC | **OCTOBER 1998**

98031-6-a



98031-5-a

Stellar Environmental Solutions

Geoscience & Engineering Consulting

Plan View Showing Residual Soil Contamination
Redwood Regional Park Service Yard, Oakland, CA

Figure 7

by: MJC | OCTOBER 1998

Remediation by excavation at the site provided the residual TPH in the soil with more available oxygen through the layer of permeable backfill material overlying the original excavation. This should provide more oxygen transfer critical to aerobic degradation. Indigenous microbes common to the type of soils found, in combination with the low concentrations of residual contamination at the site, should result in reduction of the TPH to non-detectable levels over time, even with relatively low biodegradation rates (Howard and others, 1992).

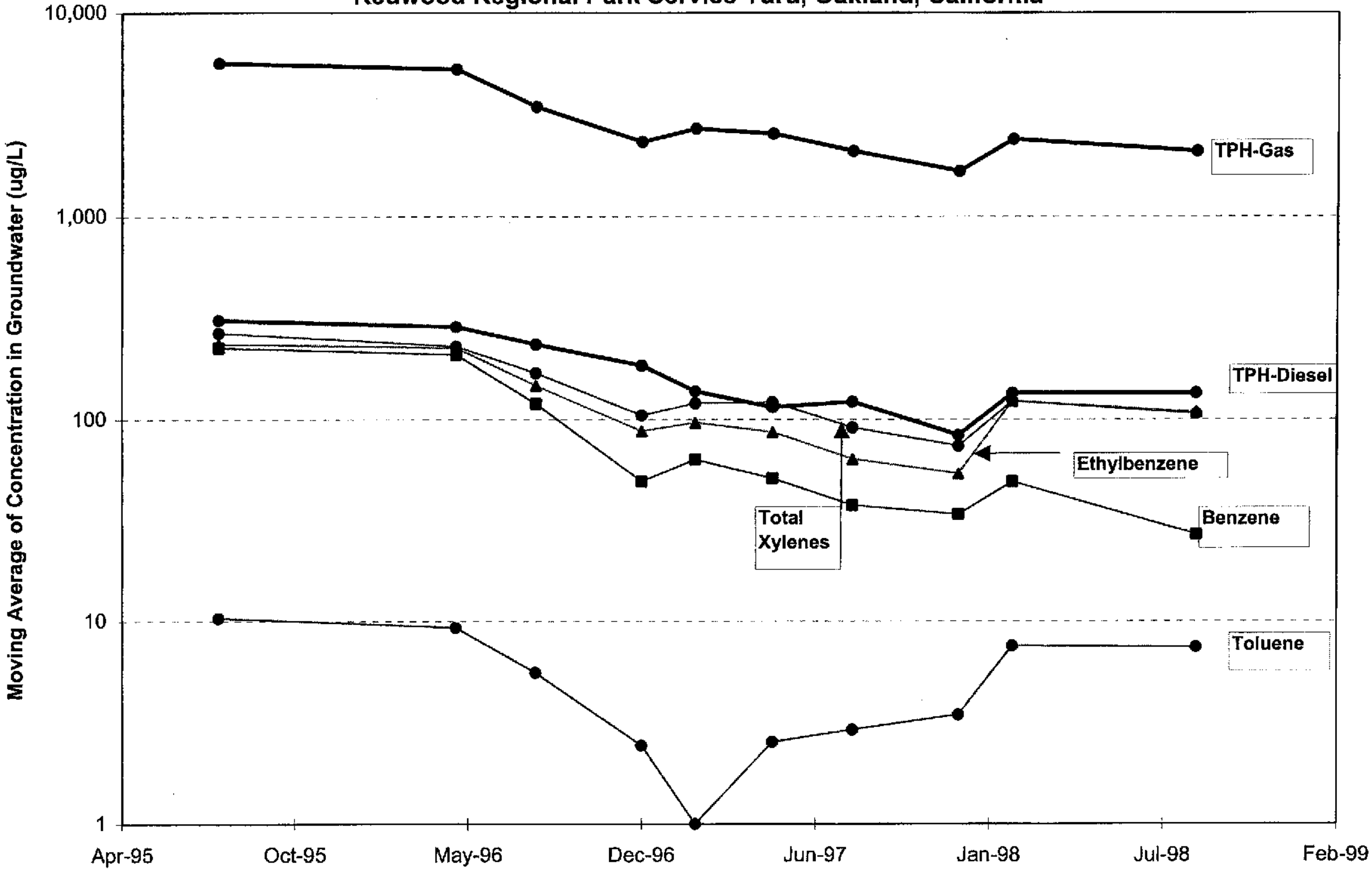
The key to evaluating the impacts of leaving the residual soil contamination in place is the extent to which it will continue to degrade groundwater quality and ultimately what the maximum "worst-case" concentrations will be at the groundwater-creek interface. Based on the initial data evaluation, Monitored Natural Attenuation (MNA) is a viable remedial remedy to address the residual contamination, particularly if the current conditions are representative of the "worst-case" scenario. The determination of the extent to which a slug of higher concentration contamination is expected will be assessed in the next phase of the investigation using an attenuation model, as discussed in more detail in a subsequent section of this report. If it is determined that there will be greater concentrations of significance, or if the current conditions pose unacceptable impacts to the creek biological community, then other interim remediation systems should be considered. The most promising of these are: 1) a cut-off or reactive wall across the transverse section of the plume just upgradient of the creek; 2) a vapor extraction system, or 3) the use of oxygen releasing compounds to catalyze the degradation of hydrocarbons.

GROUNDWATER HYDROCHEMISTRY AND GROUNDWATER PLUME STABILITY ANALYSES

There have been 13 groundwater monitoring events completed at site wells since November 1994. Data from these events form the basis of the hydrochemical trend analyses completed in this report. Hydrochemical trend analyses were performed for the analytes TPHg, TPHd and BTEX. A tabular summary of historical chemical analyses is provided in Table A.2 (Appendix A) and hydrochemical trend plots for individual constituents are also included in Appendix A.

Figure 8 illustrates the hydrochemical trends for all of the hydrocarbon compounds analyzed for in the downgradient well MW-4. This well has historically shown the highest and most persistent concentrations. The figure presents these data as a four quarter moving average on a logarithmic scale to enhance trend lines and allow for the comparison of the TPHd, TPHg and BTEX constituents on one plot. The PHg and benzene concentrations show a generally downward trend line. The TPHd, ethylbenzene and xylene concentrations show a reducing trend and the start of stabilization from about 1997. Toluene, with the lowest concentrations, shows a reduction until mid-1996, and then an increase through the latest September 1998 sampling. The sharper TPHg and

Figure 8
Historical Ground Water Analytical Results: Well MW-4
Four Quarter Moving Average
Redwood Regional Park Service Yard, Oakland, California



Lab-sum

benzene reductions are likely to be the result of volatilization. Appendix D contains the full set of hydrochemical plots for each of the constituents and without the smoothing effect inherent in the four-quarter moving average. The concentrations show a wide range of fluctuations within the general downward trend, reflecting the seasonal groundwater elevation effects on the residual contaminated soil acting as continuing input source.

The stability of the plume and the general effects of natural attenuation with volatilization can be evaluated by comparing site groundwater contamination concentrations reductions from historical maxima to current conditions. Because of the significant seasonal variations in groundwater contaminant concentrations, contaminant reduction calculations in Table 4 are based on November 1994 and September 1998 analytical results, as these events are representative of the same seasonal conditions.

As discussed previously, only site wells MW-2 and MW-4 have persistent contaminant concentrations. Maximum TPH and BTEX concentrations have historically been detected in downgradient well MW-4, the well closest to Redwood Creek, indicating that the center of the mass of the groundwater plume has moved from the source area and beyond MW-2. As shown in Table 4, some reductions in TPH and BTEX concentrations have occurred in both wells MW-2 and MW-4 since November 1994. However, as illustrated in Figure 8, the fluctuations in concentrations suggest continuous input from the residual contaminated soil at the source area and in the downgradient smear zone. Whether or not higher concentrations in well MW-4, and subsequently the creek, will occur in the future will be evaluated in the next phase of the investigation by additional site characterization and the output of the attenuation model.

GROUNDWATER IMPACTS AND BENEFICIAL USE

In general, impacts of contamination on the environment by TPH and BTEX are evaluated on a case-by-case basis with consideration given to MCLs and Als when designated (as for BTEX). As discussed in the previous section while the concentrations in the groundwater can be compared to MCLs or Als for the BTEX compounds, there are no such ARARs for TPHg and TPHd and there is no use of the groundwater in this area for drinking water or other water supply purposes. The beneficial use to the groundwater is entirely associated with its recharge of the surface water to Redwood Creek. This same recharge, as evidence by the area of daylighting of the plume at the creek base in times of low flow, is the area where the impact analyses of the beneficial uses lie. While the ARARs for surface water have not been exceeded in the recent analyses of the surface water at the point of entry into the creek, the Department of Fish and Game (DFG) requires that an evaluation be conducted to determine that the "placement" or release of contamination does not adversely affect the instream biota. The inland water quality criteria address the

Table 4
Contaminant Concentration (in μg/L) Reductions

Well ID	Contaminant	Maximum Concentration	Date of Max. Concentration	Nov. 1994 Concentrations	Sept. 1998 Concentrations	Contaminant % Reduction from Nov. 1994
MW-1	TPHd	<50	NR	NR	NR	NR
	TPHg	<50				
	BTEX	<0.5				
MW-2	TPHd	89	2/1995	<50	<50	NC
	TPHg	2,000	2/1998	66	<50	132%
	BTEX	1,112	2/1998	4.3	<0.50	860%
MW-3	TPHd	<50	NR	NR	NR	NR
	TPHg	<50				
	BTEX	<0.5				
MW-4	TPHd	440	5/1995	230	< 50	460%
	TPHg	11,200	2/1995	2,600	1,800	69%
	BTEX	1,033	2/1995	362.8	103.8	350%
MW-5	TPHd	<50	NR	<50	<50	NC
	TPHg	80	8/1996	50	<50	NC
	BTEX	0.60	2/1995	<0.5	<0.5	NC
MW-6	TPHd	<50	NR	NR	NR	NR
	TPHg	<50				
	BTEX	<0.5				

Notes: NC = Not Computable; NR = Not Relevant

acute and chronic toxicity, which the concentrations are below, but the DFG also requires that an instream bioassessment study be conducted to evaluate if any reproductive effects on fish and invertebrates be conducted. The preferred protocol for an instream biassessment has been provided to SES by DFG and are included as Appendix D.

A key issue in the completion of such an evaluation of the beneficial use and possible impacts of the contaminated groundwater is the extend to which the current observed concentrations are indicative of future concentrations.

6.0 CONCLUSIONS AND RECOMMENDATIONS

SUMMARY AND CONCLUSIONS

The summary and conclusions presented in this section are based on previous investigation and remediation reports, field investigation descriptions, analytical results, and interpretations delineated and developed in the body of this report. Interpretations are based on data collected by previous investigators between 1993 and February 1998, and on the results of the September 1998 sampling event conducted by SES.

- The site utilized two UFSTs (diesel and gasoline) that were excavated and removed from the site in 1993, along with 600 CYof contaminated soil. An estimated volume of 550 CY of petroleum-contaminated soil with concentrations above 1,000 mg/Kg is estimated to be left in place in the area of the original excavation and downgradient of it along the pathway of the plume. Most of the residual contaminated soil exists in the capillary fringe up to 150 feet downgradient of the former UFSTs, resulting from the sorption of fuel constituents from contaminated groundwater onto capillary fringe soils during periods of high groundwater elevation.

- Groundwater sampling conducted on an approximately quarterly frequency since November 1994 (13 events) has shown an overall decreasing concentration trend in groundwater contaminants, which include gasoline, diesel and BTEX. MTBE was detected in both the source area and the downgradient monitoring wells when it was analyzed for the first time in September 1998.

- Near-maximum historical groundwater contaminant concentrations were detected in February 1998, coinciding with unusually heavy rains and correspondingly high groundwater elevations, which likely desorbed capillary fringe soil contamination into groundwater.

- The September 1998 groundwater analytical data showed results consistent with previous analyses, with only wells MW-2 and MW-4 showing detectable contamination, and maximum concentrations detected in well MW-4. In addition, "post-purge" groundwater contaminant concentrations are significantly greater than "no-purge" concentrations, and are more representative of historical groundwater hydrochemistry.

- Maximum groundwater contaminant concentrations have historically been detected in downgradient well MW-4, suggesting that the center of mass of the contaminant groundwater plume may have moved from the UFST source area and beyond well MW-2. Based on historical, limited grab-groundwater sampling analytical results, it is likely that greater contaminant concentrations will occur in well MW-4, and subsequently Redwood Creek, as the plume migrates downgradient. Confirming this hypothesis will require additional site characterization to define the lateral extent and magnitude of the groundwater plume followed by use of a analytic attenuation model.

- The limits of the groundwater contaminant plume are well defined by site groundwater monitoring wells, and extends from the source area to Redwood Creek, a distance of approximately 150 feet. The maximum width of the plume, as defined by cross-gradient wells MW-3 and MW-5, is approximately 230 feet, and is likely substantially more narrow.

- Discharge of petroleum-contaminated groundwater into Redwood Creek is evidenced by: historical observation of petroleum-discolored soil in the bank of Redwood Creek downgradient of the former UFSTs; periodic detection of fuel constituents in creek surface water samples collected at that location; and the growth of an algae on the surface water surface at that location suggesting that the petroleum is serving as a carbon source. That algae has also been observed in the downgradient monitoring well MW-4.

- There are no established cleanup criteria for residual soil contamination by TPH. The RWQCB has a to-be-considered ARAR of 1 mg/kg total BTEX in soil. However, the need for remedial action in the soil media and the remedy selection for corrective action should be based on potential impacts to groundwater and surface water quality resulting from desorption of soil contamination.

- Site groundwater contaminants that have been historically and currently detected in excess of drinking water standards at well MW-4 include benzene, ethylbenzene, total xylenes and MTBE; there are no drinking water standards for TPH compounds. While it is unlikely that site groundwater would be used as a drinking water source, drinking water standards could be applied by regulators as cleanup standards.

- Benzene is the only site-sourced contaminant that has been detected in creek surface water samples in excess of published water quality objectives (WQOs) for surface waters that are a potential drinking water source. Based on the absence of detected benzene immediately downstream of the site, it is unlikely that benzene would be considered a potential impact to the nearest drinking water source (Upper San Leandro Reservoir).

- The DFG code stipulates a zero-discharge policy, unless it can be demonstrated that complete removal of the petroleum is infeasible and that instream biota are not affected. The latter criterion can be demonstrated by conducting a stream bioassessment in accordance with established DFG protocols.

- The estimated maximum surface water contamination concentrations expected can be most cost-effectively determined by further site characterization of soil and groundwater contamination and the use of an analytical attenuation model. Potential impacts to human health receptors from surface water contamination can be determined by conducting a risk-based assessment.
- If current or projected conditions do not pose unacceptable impacts to Redwood Creek, Monitored Natural Attenuation (MNA) could be a viable remedial strategy to address residual site contamination. Otherwise, interim remedial measures may be required.

RECOMMENDATIONS

Based on the data collected, the following recommendations are made:

- Conduct a limited soil and hydropunch site investigation to provide the data gaps necessary to delineate the concentration gradient across and within the plume and to validate the assumed boundaries of the plume.
- Conduct an additional (in December 1998) groundwater monitoring and analysis event in which natural attenuation parameters such as dissolved oxygen, redox potential and iron concentrations are measured, in addition to historically conducted laboratory analyses. We recommend that hydrochemical analyses be discontinued in transgradient well MW-5 based on the historical absence of signficant detectable contamination at that location.
- Conduct an additional (in December 1998) creek surface water sampling and analysis event.
- Complete a two-dimensional analytical attenuation model using the data collected in the first two recommendations to evaluate the extent of biodegradation that is expected and what the likely concentration range at the Redwood Creek interface will be. Such a model, using site-specific data where feasible and literature-based values where applicable, will provide a determination of the probable degradational cycle of the plume and residual soil contamination.
- Complete a RBCA Tier 2 risk assessment based on the output data of the attenuation model. This will provide a conservative assessment of the pathways of exposure and impacts to human health receptors.

- Per the recommendations of DFG, complete an initial instream bioassessment of macroinvertebrates, in conformance with the DFG procedures, to evaluate if there are any immediate impacts of concern. This should preferably be completed in November 1998, at the beginning of the rainy season. The need for subsequent bioassessment events should be evaluated based on the findings of the proposed investigations

- Complete and submit to the District, ACHCSA and DFG a comprehensive report summarizing the investigation activities and findings, including recommendations for implementing the appropriate remedial strategy.

7.0 REFERENCES

Alameda County Health Care Services Agency (ACHCSA) 1996a. Letter to Mr. Ken Berger of EBRPD. January 9.

ACHCSA, 1997. Letter to Mr. Ken Berger of East Bay Regional Park District. September 16.

Alameda County Flood Control and Water Conservation District (ACFCWCD) 1988. Geohydrology and Groundwater Quality Overview of the East Bay Plain Area, Report 205 (j).

Borcherdt, R.D., J.F. Gibbs, and K.R. Lajoie, 1975. Maps Showing Maximum Earthquake Intensity Predicted in the Southern San Francisco Bay Region, California, For Large Earthquakes on the San Andreas and Hayward Faults, Sheet 3: Generalized Geologic Map.

California Code of Regulations, Title 26, Division 22, Sections 66194, 66206, 66699, 66700, 66720, and 66723.

East Bay Regional Park District (EBRPD), 1995. Letter from Mr. Warren Gee (EBRPD) to Mr. Paul Andrews (Contra Costa County Health Services Department). June 1.

Fetter, 1988. Applied Hydrogeology, MacMillan Publishing Company, New York.

Graves, Kevin, RWQCB, 1997. Personal communication regarding the RWQCB's plans to adopt and integrate the recommendations of the paper by Rice and others into the revision of the RWQCB's LUFT manual guidance. November 7.

Howard, P.H., R.S. Boethling, W.F. Jarvis, W.M. Meylan, and E.M. Michalenko, 1991. Handbook of Environmental Degradation Rates, Lewis Publishers, Inc.

Lawrence Livermore National Laboratory, 1995. Recommendations to Improve the Cleanup Process for California's Leaking Underground Fuel Tanks. October 16.

Makdisi, Richard S., D.C. Downey, and Dave A. Baskin, 1992. In-Situ Bioventing Technology at Federal Facilities, Hazardous Materials Control Research Institute Superfund Conference Proceedings, Washington D.C.

Nilsen, T.H., R.H. Wright, T.C. Vlasic, and W.E. Spangle, 1979. Relative Slope Stability and Land-Use Planning in the San Francisco Bay Region, California, USGS Professional Paper 944, 96 pp.

Norris and Webb, 1990. Geology of California, 2nd Edition, John Wiley and Sons, Inc., New York, 541 p.

Parsons, 1993a. Closure of Underground Fuel Storage Tanks and Initial Site Characterization at Redwood Regional Park Service Yard, Oakland, California. December 16.

Parsons, 1993b. Workplan for Site Characterization at East Bay Regional Park District, Redwood Regional Park Corporation Yard, Oakland, Alameda County, California. September 3.

Parsons, 1994a. Creek and Soil Sampling at Redwood Regional Park, Oakland, California. March 2.

Parsons, 1994b. Creek Surface Water at Redwood Regional Park, Oakland, California. May 13.

Parsons, 1994c. Workplan for Groundwater Characterization Program at East Bay Regional Park Service Yard, Oakland, California. August 17.

Parsons, 1994d. Quarterly Progress Report 1, Redwood Regional Park Service Yard, Oakland, California. December 28.

Parsons, 1995a. Quarterly Progress Report 2, Redwood Regional Park Service Yard, Oakland, California. March 8.

Parsons, 1995b. Quarterly Progress Report 3, Redwood Regional Park Service Yard, Oakland, California. June 23.

Parsons, 1995c. Quarterly Progress Report 4 and Annual Summary Assessment (November 1994 - August 1995), Redwood Regional Park Service Yard, Oakland, California. November 13.

Parsons, 1996a. Quarterly Progress Report 5, Redwood Regional Park Service Yard, Oakland, California. June 6.

Parsons, 1996b. Quarterly Progress Report 6, Redwood Regional Park Service Yard, Oakland, California. September 24.

Parsons, 1997a. Quarterly Progress Report 7, Redwood Regional Park Service Yard, Oakland, California. January 31.

Parsons, 1997b. Quarterly Progress Report 8 and Annual Summary Assessment, Redwood Regional Park Service Yard, Oakland, California. April 4.

Parsons, 1997c. Quarterly Progress Report 9, Redwood Regional Park Service Yard, Oakland, California. June 30.

Parsons, 1997d. Quarterly Progress Report 10, Redwood Regional Park Service Yard, Oakland, California. September 22.

Parsons, 1998. Quarterly Progress Report 11, Redwood Regional Park Service Yard, Oakland, California. January 28.

Regional Water Quality Control Board - San Francisco Bay Region (RWQCB), 1997. Utilization of Non-Purge Approach for Sampling of Monitoring Wells Impacted by Petroleum Hydrocarbons, BTEX, and MTBE. January 31.

RWQCB, 1992. Water Quality Control Plan for the San Francisco Basin. 17 January.

RWQCB, 1990. LUFT Manual Guidance

RWQCB, 1989. Designated Level Methodology for Waste Classification and Cleanup Level Determination.

Rice, D.W., B.P. Dooher, S.J. Cullen, L.G. Everett, W.E. Kastenberg, R.D. Grose, and M.A. Marino, 1995. Recommendations To Improve the Cleanup Process for California's Leaking Underground Fuel Tanks (LUFTS), Lawrence Livermore National Laboratory, University of California publication UCRI-AR-121762 (October 16).

State Water Resources Control Board, 1989. Leaking Underground Fuel Tank Field Manual: Guidelines for Site Assessment, Cleanup, and Underground Storage Tank Closure: State of California Leaking Underground Fuel Tank Task Force. October.

________, 1991. California Inland Surface Waters Plan, Water Quality Control Plan for Inland Surface Waters of California, Resolution No. 91-33 (including as an appendix Resolution No. 88-63). April.

8.0 LIMITATIONS

This report has been prepared for the exclusive use of East Bay Regional Park District and their authorized representatives or the Regulators. No reliance on this report shall be made by anyone other than the client and regulators for whom it was prepared.

The findings and conclusions presented in this report are based on the review of previous investigators' findings at the site and on the September 1998 groundwater sampling event conducted by SES. This report provides neither a certification nor guarantee that the property is free of hazardous substance contamination. This report has been prepared in accordance with generally accepted methodologies and standards of practice of the area. The SES personnel who performed this limited remedial investigation are qualified to perform such investigations and have accurately reported the information available but cannot attest to the validity of that information. No warranty, expressed or implied, is made as to the findings, conclusions and recommendations included in the report

The findings of this report are valid as of the present. Site conditions may change with the passage of time, natural processes or human intervention, which can invalidate the findings and conclusions presented in this report. As such, this report should be considered a reflection of the current site conditions as based on the investigation and remediation completed.

Historical Soil, Groundwater and Creek Surface Water Analytical Results

Table A.1
Summary of Soil Sample Analytical Results
Redwood Regional Park Corporation Yard
Oakland, California

Sample I.D.	Depth (ft bgs)	Concentrations in mg/kg					
		TPH-G	TPH D/K	Benzene	Toluene	Ethyl-benzene	Total Xylenes
*UFST Confirmation Samples – May and June 1993 (*indicates soil from that location was removed)*							
DT-1*	10	NA	**4**	< 0.005	< 0.005	< 0.005	< 0.005
DT-2*	10	NA	**3**	< 0.005	< 0.005	< 0.005	< 0.005
GT-1*	12	**800**	NA	**6.3**	**43**	**18**	**94**
GT-2	12	**2,200**	NA	**19**	**120**	**45**	**250**
E1-17	17	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
E2-16	16	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
E3-16	16	**12,000**	NA	**80**	**390**	**230**	**1,100**
E4-13	13	**6**	NA	**0.37**	**0.006**	**0.1**	**0.1**
E5-7.5	7.5	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
Exploratory Borehole Samples - September and October 1994							
B1-11	11	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
B1-27	27	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
B2-11	11	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
B2-15	15	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
B3-12	12	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
B3-18	18	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
B4-18	18	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
B4-23	23	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
B5-11	11	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
B7-12	12	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
B8-4	4	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
B8-10	10	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
B9-11	11	**370**	NA	**1.7**	**7.9**	**6.9**	**34**
B9-21	21	< 1	NA	**0.1**	**0.011**	**0.017**	**0.069**
B9-28	28	< 1	NA	< 0.005	**0.033**	**0.035**	**0.14**

Sample I.D.	Depth (ft bgs)	Concentrations in mg/kg					
		TPH-G	TPH D/K	Benzene	Toluene	Ethyl-benzene	Total Xylenes
B10-6	6	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
B10-21	21	< 1	7	< 0.005	< 0.005	< 0.005	< 0.005
B11-11.5	11.5	< 1	< 2	**0.021**	< 0.005	< 0.005	< 0.005
B12-14.5	14.5	**150**	NA	**0.24**	**0.44**	**1.7**	**4.6**
B12-15	15	**77**	NA	**0.15**	**0.24**	**0.9**	**2.7**
B12-21	21	**97**	NA	**0.46**	**1.2**	**2**	**5.4**
B13-12	12	**1,500**	NA	< 0.4	< 0.4	**13**	**78**
B13-15	15	**1,800**	**420**	**8.8**	**39**	**30**	**120**
B14-18	18	**210**	**50**	**0.017**	**0.1**	**0.34**	**0.63**
B15-17	17	**1,900**	**1,300**	**1.1**	**0.8**	**9.1**	**14**
B16-17.5	17.5	**50**	NA	< 0.1	< 0.1	**0.2**	**0.2**
B17-12.5	12.5	< 1	NA	< 0.005	< 0.005	< 0.005	< 0.005
Monitoring Well Installation Borehole Samples – October 1994							
MW1-5	5	< 1	**3**	< 0.005	< 0.005	< 0.005	< 0.005
MW-21	21	**130**	**48**	**0.31**	**0.18**	**1.3**	**4.4**
MW3-10	10	< 1	**3**	< 0.005	< 0.005	< 0.005	< 0.005
MW3-25	25	< 1	**5**	< 0.005	< 0.005	< 0.005	< 0.005
MW4-15.5	15.5	**22**	**4**	< 0.005	**0.038**	< 0.005	**0.49**
MW4-16.5	16.5	**10**	**43**	< 0.005	**0.009**	**0.11**	**0.21**
MW5A-15	15	**570**	**200**	< 0.005	**1.1**	**1.9**	**2.9**
MW5-15	15	< 1	**2**	< 0.005	< 0.005	< 0.005	< 0.005
MW6-19	19	< 1	**2**	< 0.005	< 0.005	< 0.005	< 0.005

Notes:

TPH-G – Total petroleum hydrocarbons – gasoline range
TPH-D/K – Total petroleum hydrocarbons – diesel/kerosene ranges
NA = Not Analyzed

Table A.2

GROUNDWATER ANALYTICAL SUMMARY
November 1994 - February 1998
Redwood Regional Park Service Yard, Oakland, California

Sample ID	Analyte	MRL (µg/L)	Nov. 1994	Feb. 1995	May 1995	August 1995	May 1996	August 1996	Dec. 1996	Feb. 1997	May 1997	August 1997	Dec. 1997	Feb. 1998
MW-1	TPH-G	50	ND	ND	ND	ND	*	*	*	*	*	*	*	*
	TPH-D/K	50	ND	ND	ND	ND	*	*	*	*	*	*	*	*
	BTEX	0.5	ND	ND	ND	ND	*	*	*	*	*	*	*	*
MW-2	TPH-G	50	66	89	ND	ND	ND	ND	ND	ND	67	ND	61	2,000
	TPH-D/K	50	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	200
	BTEX	0.5	4.3	29.6	8.0	5.7	ND	ND	7.9	1.2	14.0	5.6	31.4	1,112
MW-3	TPH-G	50	ND	ND	ND	ND	*	*	*	*	*	*	*	*
	TPH-D/K	50	ND	ND	ND	ND	*	*	*	*	*	*	*	*
	BTEX	0.5	ND	0.8	ND	ND	*	*	*	*	*	*	*	*
MW-4[(a)]	TPH-G	50	2,600	11,000	7,200	1,800	1,100	3,700	2,700	3,300	490	1,900	1,000	5,300
	TPH-D/K	50	230	330	440	240	140	120	240	ND	ND	150	84	340
	BTEX	0.5	362.8	1,337	1,033	227.3	98	409	242	372.5	13.4	142.7	122.5	908
MW-5	TPH-G	50	50	70	ND	ND	ND	80	ND	ND	ND	ND	ND	ND
	TPH-D/K	50	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	BTEX	0.5	ND	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-6	TPH-G	50	ND	ND	ND	ND	*	*	*	*	*	*	*	*
	TPH-D/K	50	ND	ND	ND	ND	*	*	*	*	*	*	*	*
	BTEX	0.5	ND	ND	ND	ND	*	*	*	*	*	*	*	*

Notes:

TPH-G = Total petroleum hydrocarbons, gasoline range (California Department of Toxic Substances Control [DTSC] Leaking Underground Fuel Tank [LUFT] Field Manual Method).
TPH-D/K = Total petroleum hydrocarbons, diesel and kerosene range (California Department of Toxic Substances Control [DTSC] Leaking Underground Fuel Tank [LUFT] Field Manual Method).
BTEX = Benzene, toluene, ethylbenzene and total xylenes (EPA Method 8020).
ND = Not detected above MRL.
MRL = Method reporting limit.
* = Well not sampled.
(a) = Concentration is for the field sample as opposed to the field duplicate sample.
µg/L = micrograms per liter (equivalent to parts per billion).

Table A.3

CREEK SURFACE WATER ANALYTICAL SUMMARY
February 1994 - February 1998
Redwood Regional Park Service Yard, Oakland, California

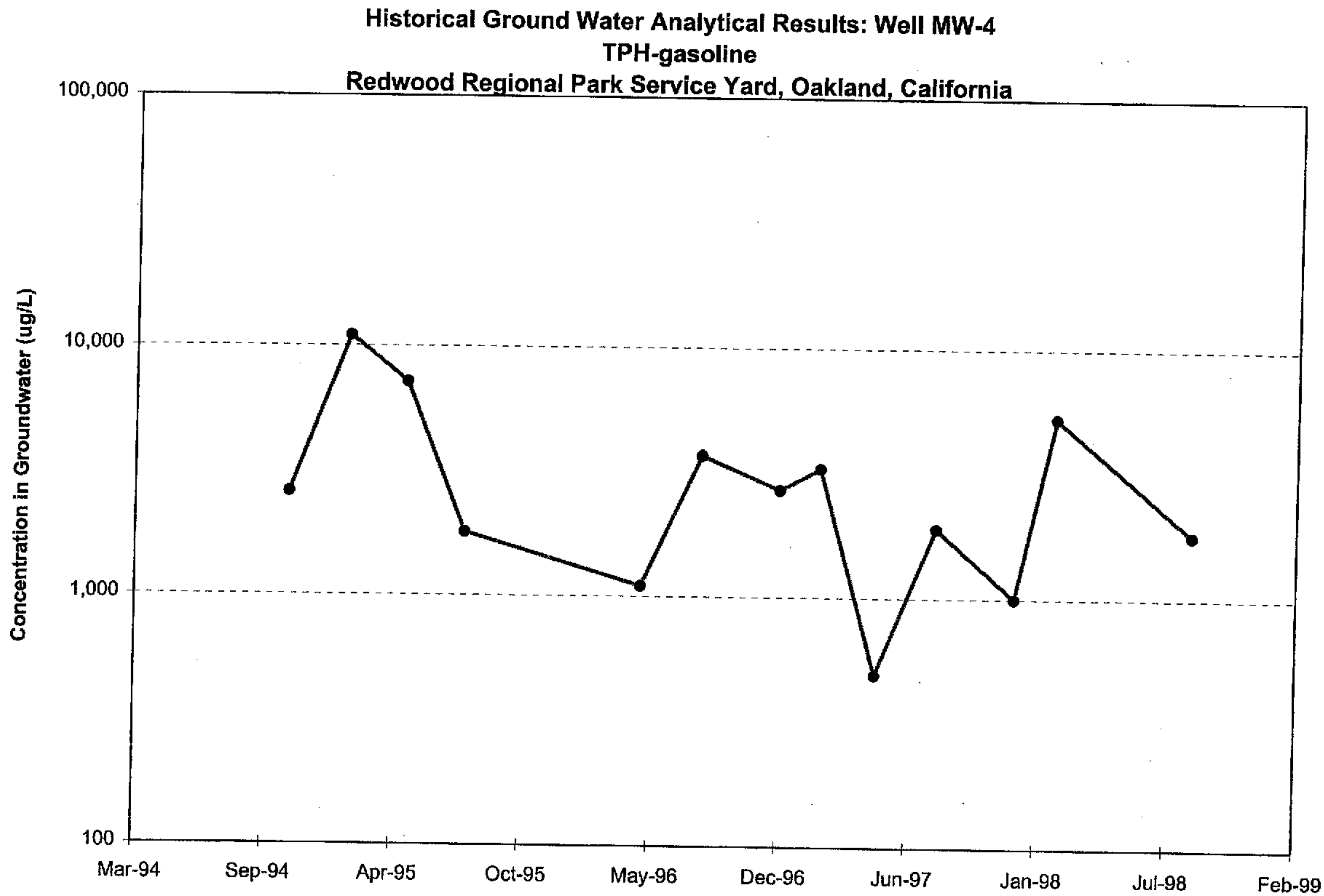
Sample ID	Analyte	MRL (µg/L)	February/March 1994	May 1995	August 1995	May 1996	August 1996	December 1996	February 1997	August 1997	December 1997	February 1998
SW-1[(a)]	TPH-G	50	50	ND	*	ND	ND	ND	ND	ND	ND	ND
	TPH-D/K	50	ND	ND	*	ND	ND	ND	ND	ND	ND	ND
	BTEX	0.5	ND	ND	*	ND	ND	ND	ND	ND	ND	ND
SW-2[(b)]	TPH-G	50	130/80	ND	ND	ND	200	ND	ND	350	ND	ND
	TPH-D/K	50	ND/ND	ND	ND	ND	ND	ND	ND	130	ND	ND
	BTEX	0.5	9.5/4.6	ND	ND	ND	12.9	ND	ND	43.6	ND	ND
SW-3	TPH-G	50	*	ND	ND	ND	69	ND	ND	ND	ND	ND
	TPH-D/K	50	*	ND	ND	74	ND	ND	ND	ND	ND	ND
	BTEX	0.5	*	ND	ND	ND	ND	ND	ND	ND	ND	ND

Notes:

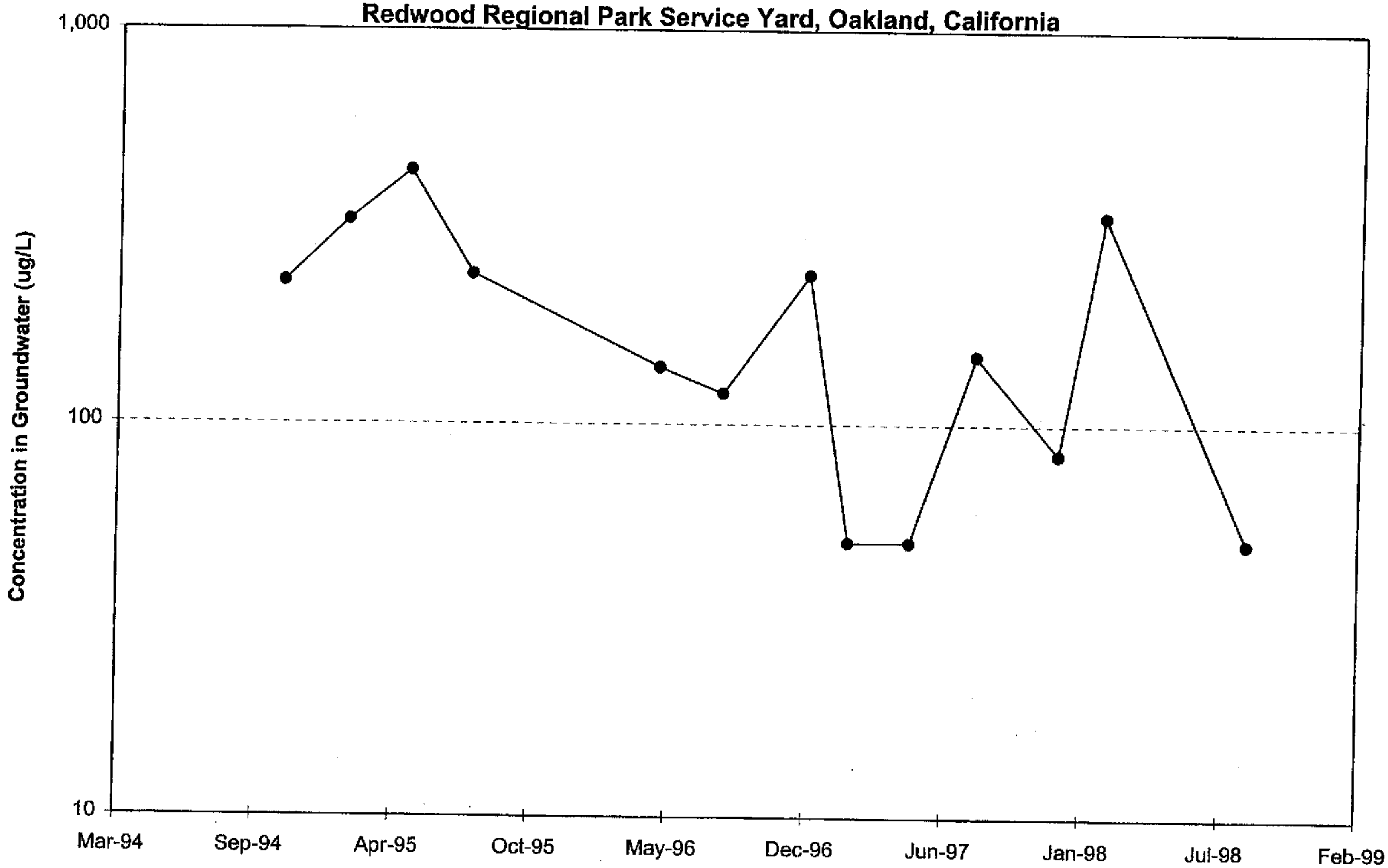
(a) Sample name is CW-2 for February 1994 sampling event.
(b) Sample name is CW-1 for February 1994 and CW-3 for March 1994 sampling event.

TPH-G = Total petroleum hydrocarbons, gasoline range (California Department of Toxic Substances Control [DTSC] Leaking Underground Fuel Tank [LUFT] Field Manual Method).
TPH-D/K = Total petroleum hydrocarbons, diesel and kerosene range (California Department of Toxic Substances Control [DTSC] Leaking Underground Fuel Tank [LUFT] Field Manual Method).
BTEX = Benzene, toluene, ethylbenzene and total xylenes (EPA Method 8020).
ND = Not detected above MRL.
* = Location not sampled.
MRL = Method reporting limit.
All concentrations are µg/L (equivalent to parts per billion).

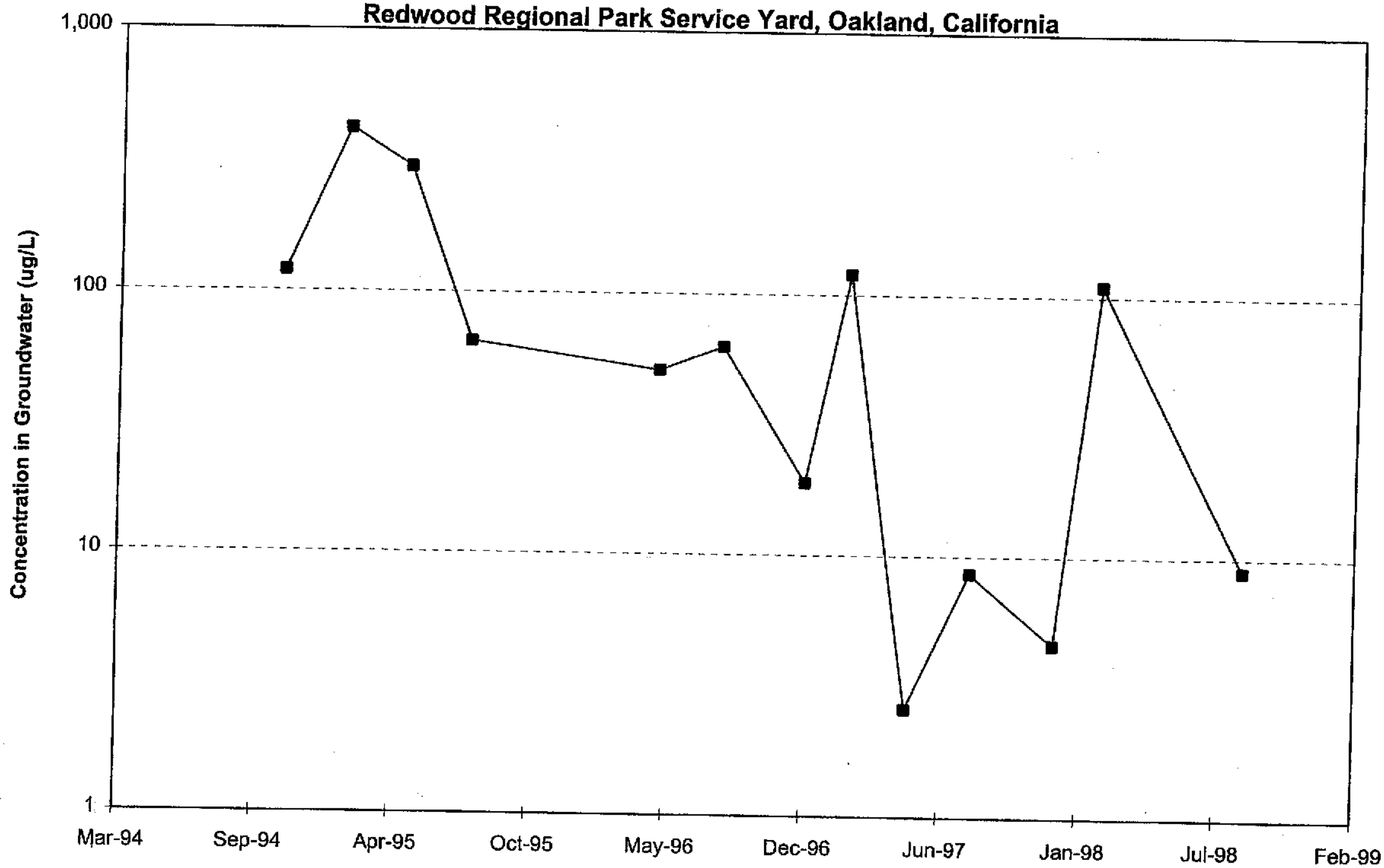
Hydrochemical Trend Plots


Historical Ground Water Analytical Results: Well MW-4
TPH-gasoline
Redwood Regional Park Service Yard, Oakland, California
100,000
10,000
1,000
100
Concentration in Groundwater (ug/L)
Mar-94
Sep-94
Apr-95
Oct-95
May-96
Dec-96
Jun-97
Jan-98
Jul-98
Feb-99

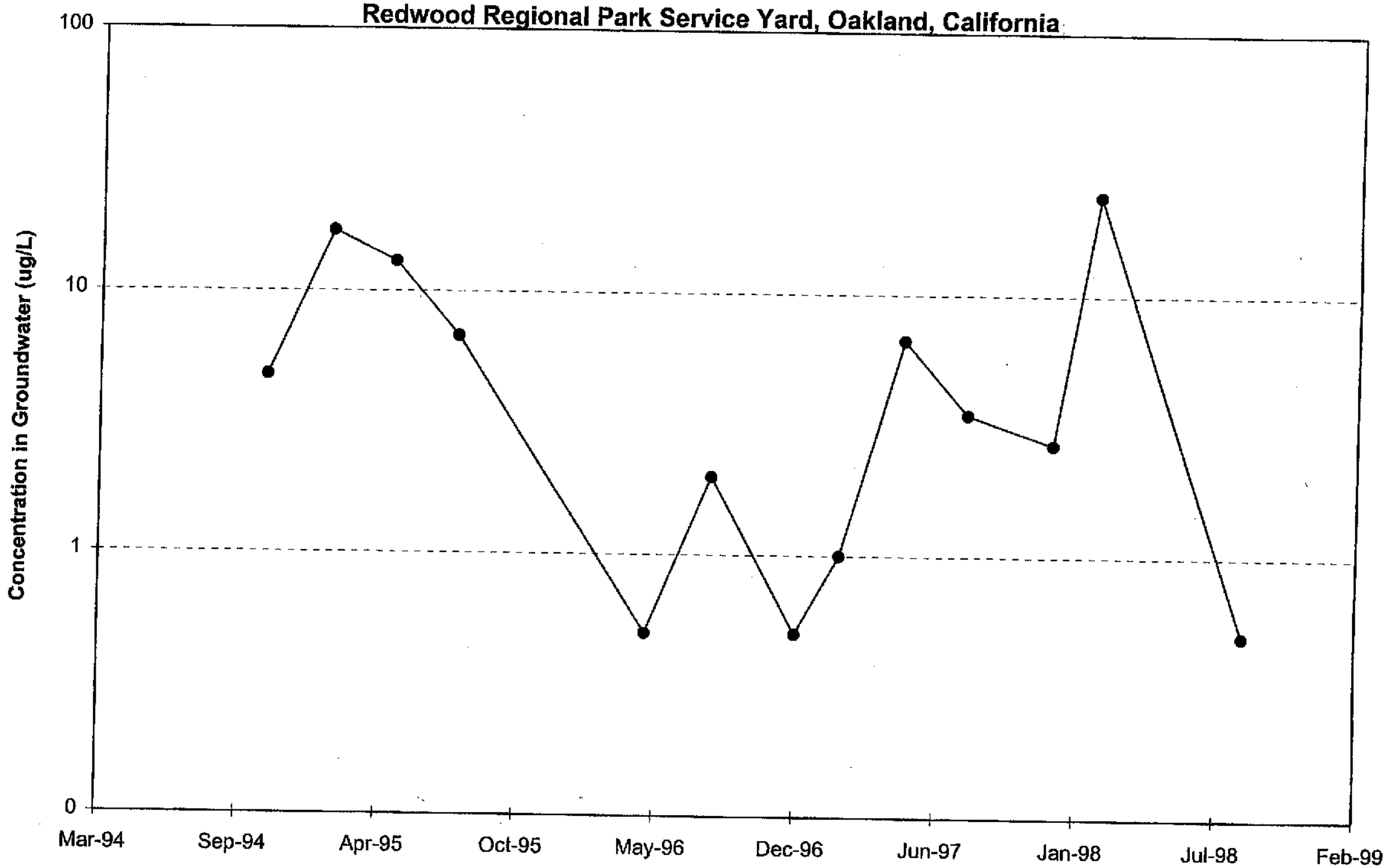
Historical Ground Water Analytical Results: Well MW-4
TPH-diesel
Redwood Regional Park Service Yard, Oakland, California

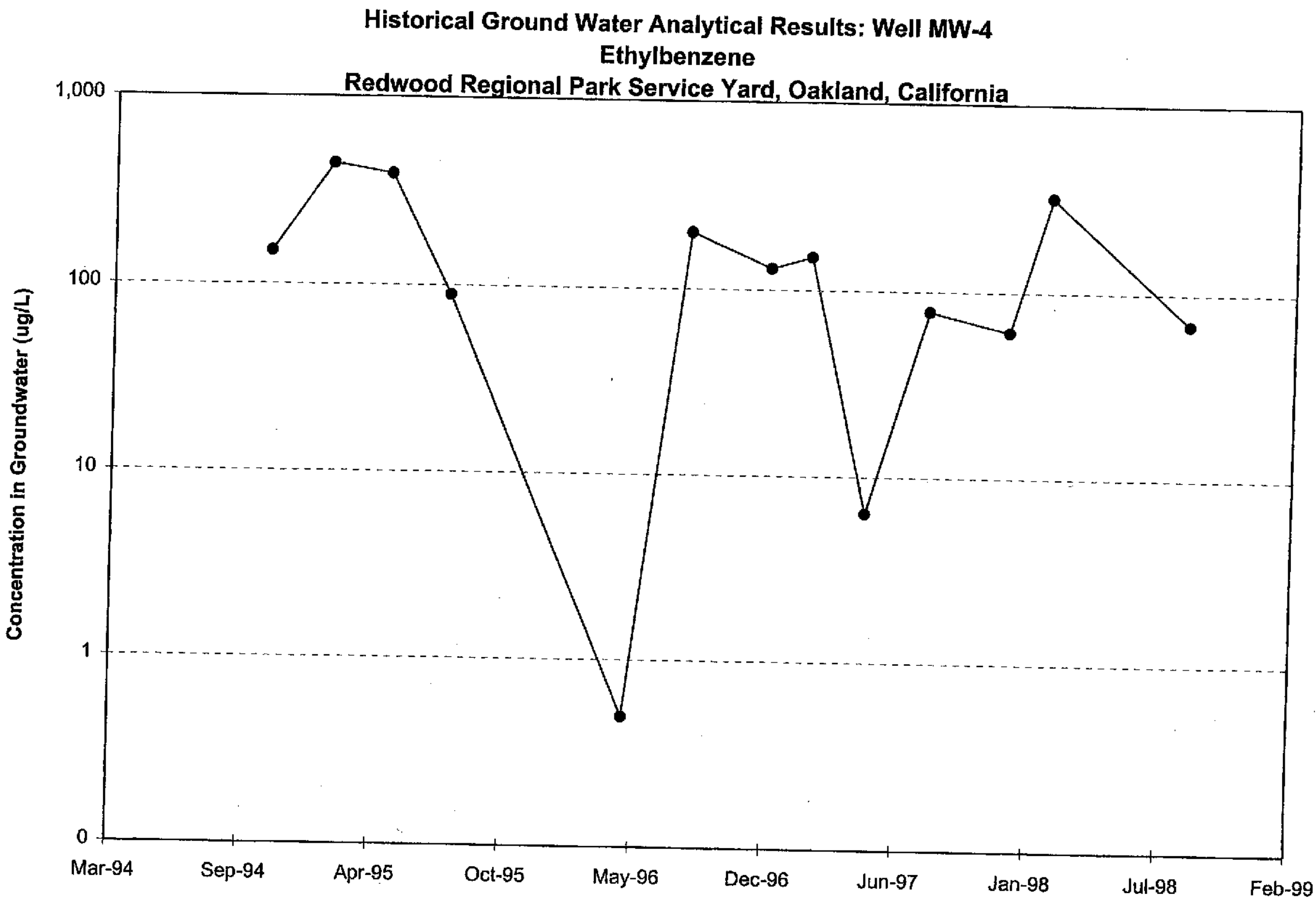


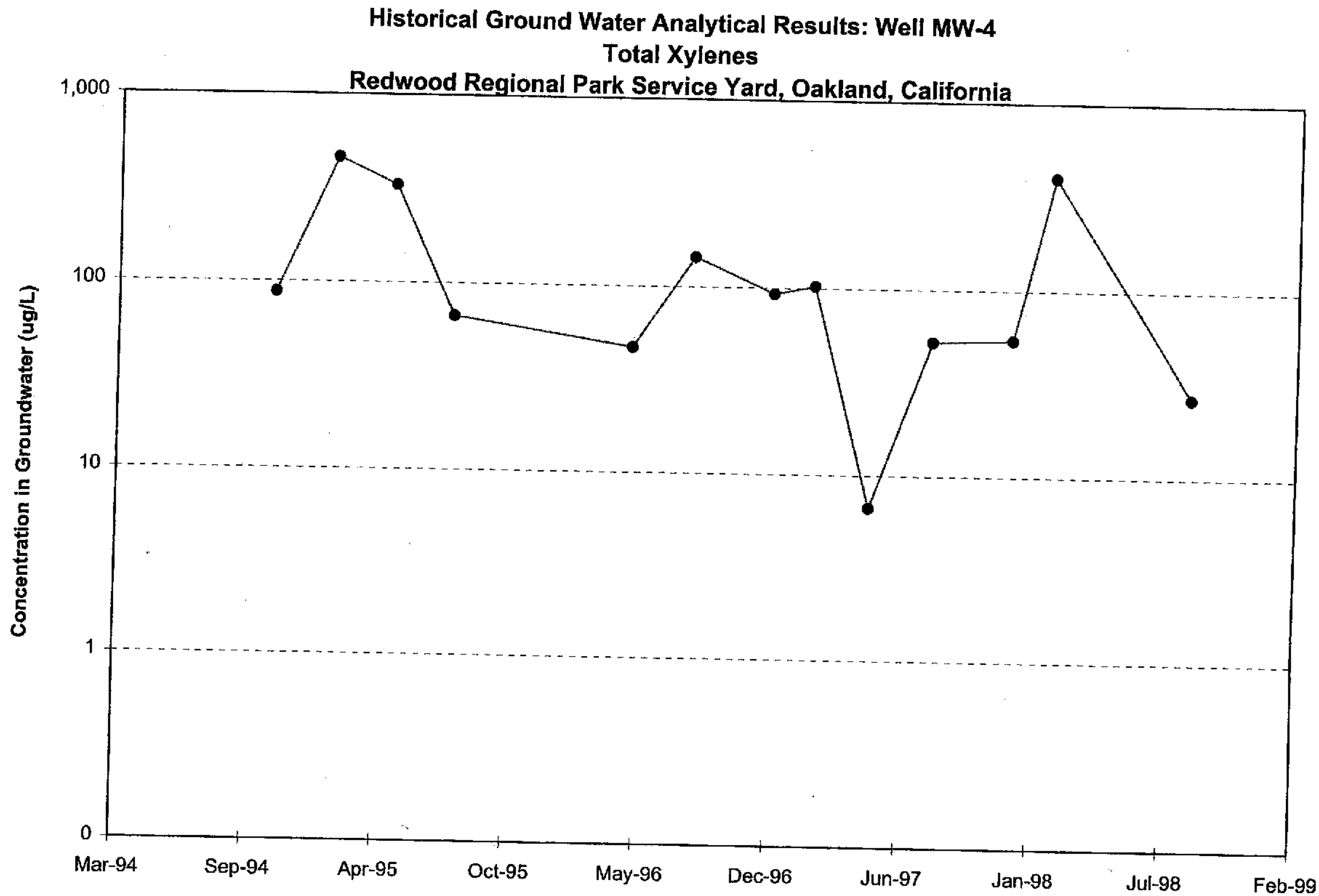
Historical Ground Water Analytical Results: Well MW-4
Benzene
Redwood Regional Park Service Yard, Oakland, California



Historical Ground Water Analytical Results: Well MW-4
Toluene
Redwood Regional Park Service Yard, Oakland, California




Historical Ground Water Analytical Results: Well MW-4
Ethylbenzene
Redwood Regional Park Service Yard, Oakland, California
1,000
100
10
1
0
Concentration in Groundwater (ug/L)
Mar-94
Sep-94
Apr-95
Oct-95
May-96
Dec-96
Jun-97
Jan-98
Jul-98
Feb-99


Historical Ground Water Analytical Results: Well MW-4
Total Xylenes
Redwood Regional Park Service Yard, Oakland, California
Concentration in Groundwater (ug/L)
1,000
100
10
1
0
Mar-94
Sep-94
Apr-95
Oct-95
May-96
Dec-96
Jun-97
Jan-98
Jul-98
Feb-99

WELL HEAD INSPECTION CHECKLIST AND REPAIR ORDER

Client ______ STELLAR ENV. SOLUTIONS ______

Site address _ Redwood Reg. Park Service Yard Oakland, CA ______

Inspection date: 9\18\98

Inspected by: Mark

BTS Event # 980918-K1

1. Lid on the box? Yes No	5. Water standing in the well box?	7. Can cap be pulled loose?
2. Lid whole?	5a. Standing above well top?	8. Can cap seal out water?
3. Lid secure?	5b. Standing below well top?	9. Padlock present?
4. Lid seal intact?	5c. Water even with top of well cap?	10. Padlock found locked?
	6. Well cap/plug present?	11. Padlock functional?

☐ Check box if *no deficiences* were found. Note below deficiencies you were able to correct.

Well I.D.	Deficiency	Corrective Action Taken

Note below all deficiences that could not be corrected and *still need to be corrected.*

Well I.D.	Persisting Deficiency	BTS Office assigns or defers Correction to:	Date assigned	Date corrected

Office review and assignments made by ______________________ date __________

WELL GAUGING DATA

Project # 980918-K1 Date 9/18/98 Client Stellar Env. Solution

Site Redwood Regional Park Service Yard Oakland, CA

Well ID	Well Size (in.)	Sheen / Odor	Depth to Immiscible Liquid (ft.)	Thickness of Immiscible Liquid (ft.)	Volume of Immiscibles Removed (ml)	Depth to water (ft.)	Depth to well bottom (ft.)	Survey Point: TOB or TOC	
* MW-2	4					22.31	36.0	TOC	
* MW-4	4					13.59	26.0	TOC	
* MW-5	4					16.44	26.0	TOC	
Gauge Only									
MW-1	4					2.18	18.0	TOC	
MW-3	4					20.10	42.0	TOC	
MW-6	4					12.43	26.0	TOC	
*	Sampled wells								

WELL MONITORING DATA SHEET

Project #: 980918-K1	Client: Stellar Env. Solutions
Sampler: Mark / Chris	Start Date: 9/18/98
Well I.D.: MW-2	Well Diameter: 2 3 (4) 6 8 ____
Total Well Depth: 36.0	Depth to Water: 22.31
Before: After:	Before: After:
Depth to Free Product:	Thickness of Free Product (feet):
Referenced to: (PVC) Grade	D.O. Meter (if req'd): YSI HACH

Purge Method: Bailer / Disposable Bailer / Middleburg / Electric Submersible X / Extraction Pump / Other: ______

Sampling Method: Bailer X / Disposable Bailer / Extraction Port / Other: ______

14.5 (Gals.) X 3 = 43.5 Gals.
1 Case Volume — Specified Volumes — Calculated Volume

Well Diameter	Multiplier	Well Diameter	Multiplier
2"	0.16	5"	1.02
3"	0.37	6"	1.47
X 4"	0.65	Other	radius² * 0.163

Time	Temp (°F)	pH	Cond.	Turbidity	Gals. Removed	Observations
915	Grab Sample				—	Pre Purge Sample
918	59.4	7.1	800.2		15.0	brown
920	59.3	7.1	854.1		30.0	sediment
922	59.6	7.2	851.3		44.0	

Did well dewater? Yes (No)	Gallons actually evacuated: 44.0
Sampling Time: MW-2Pre / MW-2Post	Sampling Date: 9/18/98
Sample I.D.: Pre 915 / Post 925	Laboratory: Curtis & Tompkins
Analyzed for: (TPH-G BTEX MTBE TPH-D)	Other:
Equipment Blank I.D.: @ Time	Duplicate I.D.:
Analyzed for: TPH-G BTEX MTBE TPH-D	Other:
D.O. (if req'd): Pre-purge: mg/L	Post-purge: mg/L
ORP (if req'd): Pre-purge: mV	Post-purge: mV

WELL MONITORING DATA SHEET

Project #: 980918-K1	Client: Steller Env. Solutions
Sampler: Mark \ Chris	Start Date: 9\18\98
Well I.D.: MW-4	Well Diameter: 2 3 (4) 6 8 ___
Total Well Depth: 24.0	Depth to Water: 13.59
Before: After:	Before: After:
Depth to Free Product:	Thickness of Free Product (feet):
Referenced to: (PVC) Grade	D.O. Meter (if req'd): YSI HACH

Purge Method: Bailer, Disposable Bailer, Middleburg, Electric Submersible X, Extraction Pump, Other: ______

Sampling Method: Bailer X, Disposable Bailer, Extraction Port, Other: ______

Well Diameter	Multiplier	Well Diameter	Multiplier
2"	0.16	5"	1.02
3"	0.37	6"	1.47
4"	0.65	Other	radius² * 0.163

9.5 (Gals.) X 3 = 28.5 Gals.
1 Case Volume — Specified Volumes — Calculated Volume

Time	Temp (°F)	pH	Cond.	Turbidity	Gals. Removed	Observations
849	Grab Sample				—	Pre Purge Sample
852	38.8	6.8	600.5		10	grey.
853	38.7	6.7	640.1		20	
854	38.7	6.6	661.6		29	

Did well dewater? Yes (No)	Gallons actually evacuated: 29
Sampling Time: MW-4 Pre / MW-4 Post	Sampling Date: 9\18\98
Sample I.D.: Pre 849 / Post 900	Laboratory: Curtis & Tompkins
Analyzed for: (TPH-G BTEX MTBE TPH-D)	Other:
Equipment Blank I.D.: @ Time	Duplicate I.D.: MW-DA @910
Analyzed for: (TPH-G BTEX MTBE) TPH-D	Other:
D.O. (if req'd): Pre-purge: mg/L	Post-purge: mg/L
ORP (if req'd): Pre-purge: mV	Post-purge: mV

WELL MONITORING DATA SHEET

Project #: 980918-K1	Client: Stellar Env. Solutions
Sampler: Mark / Chris	Start Date: 9/18/98
Well I.D.: MW-5	Well Diameter: (2) 3 (4) 6 8 ___
Total Well Depth: 26.0	Depth to Water: 16.44
Before: After:	Before: After:
Depth to Free Product:	Thickness of Free Product (feet):
Referenced to: (PVC) Grade	D.O. Meter (if req'd): YSI HACH

Purge Method: Bailer / Disposable Bailer / Middleburg / Electric Submersible X / Extraction Pump / Other: ______

Sampling Method: Bailer x / Disposable Bailer / Extraction Port / Other: ______

7.7 (Gals.) X 3 = 23.1 Gals.
1 Case Volume × Specified Volumes = Calculated Volume

Well Diameter	Multiplier	Well Diameter	Multiplier
2"	0.16	5"	1.02
3"	0.37	6"	1.47
x 4"	0.65	Other	radius^2 * 0.163

Time	Temp (°F)	pH	Cond.	Turbidity	Gals. Removed	Observations
830	Grab sample				—	Pre Purge Sample
833	59.6	7.6	777.0		8	cloudy gray
834	58.6	7.6	607.1		16	
835	58.7	7.6	594.2		24	

Did well dewater? Yes (No)	Gallons actually evacuated: 24
Sampling Time: MW-5 Pre / MW-5 Post	Sampling Date: 9/18/98
Sample I.D.: Pre 830 / Post 840	Laboratory: Curtis & Tompkins
Analyzed for: (TPH-G BTEX MTBE TPH-D)	Other:
Equipment Blank I.D.: @ Time	Duplicate I.D.:
Analyzed for: TPH-G BTEX MTBE TPH-D	Other:
D.O. (if req'd): Pre-purge: mg/L	Post-purge: mg/L
ORP (if req'd): Pre-purge: mV	Post-purge: mV

Curtis & Tompkins, Ltd., Analytical Laboratories, Since 1878
2323 Fifth Street, Berkeley, CA 94710, Phone (510) 486-0900, Fax (510) 486-0532

A N A L Y T I C A L   R E P O R T

Prepared for:

Stellar Environmental Solutions
2110 6th Street
Berkeley, CA 94710

Date: 13-OCT-98
Lab Job Number: 135658
Project ID: 98031
Location: Redwood Regional Park

Reviewed by: ____________

Reviewed by: ____________

Curtis & Tompkins, Ltd.

TVH-Total Volatile Hydrocarbons

Client: Stellar Environmental Solutions	Analysis Method: EPA 8015M
Project#: 98031	Prep Method: EPA 5030
Location: Redwood Regional Park	

Sample #	Client ID	Batch #	Sampled	Extracted	Analyzed	Moisture
135658-001	MW-2 PRE	43551	09/18/98	09/24/98	09/24/98	
135658-002	MW-2 POST	43551	09/18/98	09/24/98	09/24/98	
135658-003	MW-4 PRE	43551	09/18/98	09/24/98	09/24/98	
135658-004	MW-4 POST	43551	09/18/98	09/24/98	09/24/98	

Matrix: Water

Analyte	Units	135658-001	135658-002	135658-003	135658-004
Diln Fac:		1	1	1	1
Gasoline C7-C12	ug/L	<50	<50	330	1800
Surrogate					
Trifluorotoluene	%REC	112	111	117	135
Bromofluorobenzene	%REC	119	120	131	143

Curtis & Tompkins, Ltd

TVH-Total Volatile Hydrocarbons

Client: Stellar Environmental Solutions
Project#: 98031
Location: Redwood Regional Park

Analysis Method: EPA 8015M
Prep Method: EPA 5030

Sample #	Client ID	Batch #	Sampled	Extracted	Analyzed	Moisture
135658-005	MW-5 PRE	43551	09/18/98	09/24/98	09/24/98	
135658-006	MW-5 POST	43551	09/18/98	09/24/98	09/24/98	
135658-007	MW-OA	43551	09/18/98	09/24/98	09/24/98	

Matrix: Water

Analyte	Units	135658-005	135658-006	135658-007
Diln Fac:		1	1	1
Gasoline C7-C12	ug/L	<50	<50	1600
Surrogate				
Trifluorotoluene	%REC	110	113	135
Bromofluorobenzene	%REC	116	119	143

BTXE

Client:	Stellar Environmental Solutions	Analysis Method:	EPA 8020A
Project#:	98031	Prep Method:	EPA 5030
Location:	Redwood Regional Park		

Sample #	Client ID	Batch #	Sampled	Extracted	Analyzed	Moisture
135658-001	MW-2 PRE	43551	09/18/98	09/24/98	09/24/98	
135658-002	MW-2 POST	43551	09/18/98	09/24/98	09/24/98	
135658-003	MW-4 PRE	43551	09/18/98	09/24/98	09/24/98	
135658-004	MW-4 POST	43551	09/18/98	09/24/98	09/24/98	

Matrix: Water

Analyte Diln Fac:	Units	135658-001 1	135658-002 1	135658-003 1	135658-004 1
MTBE	ug/L	6.7	7	5.4	23
Benzene	ug/L	<0.5	<0.5	<0.5	8.9
Toluene	ug/L	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	ug/L	<0.5	<0.5	5	68
m,p-Xylenes	ug/L	<0.5	<0.5	0.54	25
o-Xylene	ug/L	<0.5	<0.5	<0.5	1.9
Surrogate					
Trifluorotoluene	%REC	108	109	118	115
Bromofluorobenzene	%REC	118	118	124	138

BTXE

Client:	Stellar Environmental Solutions	Analysis Method:	EPA 8020A
Project#:	98031	Prep Method:	EPA 5030
Location:	Redwood Regional Park		

Sample #	Client ID	Batch #	Sampled	Extracted	Analyzed	Moisture
135658-005	MW-5 PRE	43551	09/18/98	09/24/98	09/24/98	
135658-006	MW-5 POST	43551	09/18/98	09/24/98	09/24/98	
135658-007	MW-OA	43551	09/18/98	09/24/98	09/24/98	

Matrix: Water

Analyte	Units	135658-005	135658-006	135658-007
Diln Fac:		1	1	1
MTBE	ug/L	<2	<2	38
Benzene	ug/L	<0.5	<0.5	9.8
Toluene	ug/L	<0.5	<0.5	<0.5
Ethylbenzene	ug/L	<0.5	<0.5	64
m,p-Xylenes	ug/L	<0.5	<0.5	22
o-Xylene	ug/L	<0.5	<0.5	2.3
Surrogate				
Trifluorotoluene	%REC	111	112	124
Bromofluorobenzene	%REC	117	118	141

Lab #: 135658 BATCH QC REPORT Curtis & Tompkins, Ltd.

BTXE

Client: Stellar Environmental Solutions	Analysis Method: EPA 8020A
Project#: 98031	Prep Method: EPA 5030
Location: Redwood Regional Park	

LABORATORY CONTROL SAMPLE

Matrix: Water	Prep Date: 09/23/98
Batch#: 43551	Analysis Date: 09/23/98
Units: ug/L	
Diln Fac: 1	

LCS Lab ID: QC80595

Analyte	Result	Spike Added	%Rec #	Limits
MTBE	20.89	20	104	65-135
Benzene	16.31	20	82	69-109
Toluene	19.58	20	98	72-116
Ethylbenzene	20.85	20	104	67-120
m,p-Xylenes	42.07	40	105	69-117
o-Xylene	21.27	20	106	75-122

Surrogate	%Rec	Limits
Trifluorotoluene	110	53-124
Bromofluorobenzene	120	41-142

Column to be used to flag recovery and RPD values with an asterisk
* Values outside of QC limits
Spike Recovery: 0 out of 6 outside limits

BTXE

Client: Stellar Environmental Solutions	Analysis Method: EPA 8020A
Project#: 98031	Prep Method: EPA 5030
Location: Redwood Regional Park	

METHOD BLANK

Matrix: Water	Prep Date: 09/23/98
Batch#: 43551	Analysis Date: 09/23/98
Units: ug/L	
Diln Fac: 1	

MB Lab ID: QC80596

Analyte	Result	
MTBE	<2.0	
Benzene	<0.5	
Toluene	<0.5	
Ethylbenzene	<0.5	
m,p-Xylenes	<0.5	
o-Xylene	<0.5	
Surrogate	**%Rec**	**Recovery Limits**
Trifluorotoluene	111	53-124
Bromofluorobenzene	117	41-142

BTXE

Client:	Stellar Environmental Solutions	Analysis Method:	EPA 8020A
Project#:	98031	Prep Method:	EPA 5030
Location:	Redwood Regional Park		

MATRIX SPIKE/MATRIX SPIKE DUPLICATE

Field ID:	MW-OA	Sample Date:	09/18/98
Lab ID:	135658-007	Received Date:	09/18/98
Matrix:	Water	Prep Date:	09/24/98
Batch#:	43551	Analysis Date:	09/24/98
Units:	ug/L		
Diln Fac:	1		

MS Lab ID: QC80597

Analyte	Spike Added	Sample	MS	%Rec #	Limits
MTBE	20	37.51	54.07	83	65-135
Benzene	20	9.83	27.42	88	55-125
Toluene	20	<0.5	23.4	117	65-126
Ethylbenzene	20	64.34	81.38	85	60-129
m,p-Xylenes	40	21.55	62.94	103	68-116
o-Xylene	20	2.27	24.15	109	69-129

Surrogate	%Rec	Limits
Trifluorotoluene	125*	53-124
Bromofluorobenzene	143*	41-142

MSD Lab ID: QC80598

Analyte	Spike Added	MSD	%Rec #	Limits	RPD #	Limit
MTBE	20	54.81	87	65-135	1	20
Benzene	20	28.19	92	55-125	3	11
Toluene	20	24.26	121	65-126	4	11
Ethylbenzene	20	82.78	92	60-129	2	12
m,p-Xylenes	40	64.82	108	68-116	3	11
o-Xylene	20	24.99	114	69-129	3	12

Surrogate	%Rec	Limits
Trifluorotoluene	123	53-124
Bromofluorobenzene	143*	41-142

Column to be used to flag recovery and RPD values with an asterisk
* Values outside of QC limits
RPD: 0 out of 6 outside limits
Spike Recovery: 0 out of 12 outside limits

Curtis & Tompkins, Ltd.

TVH-Total Volatile Hydrocarbons

Client: Stellar Environmental Solutions	Analysis Method: EPA 8015M
Project#: 98031	Prep Method: EPA 5030
Location: Redwood Regional Park	

METHOD BLANK

Matrix: Water	Prep Date: 09/23/98
Batch#: 43551	Analysis Date: 09/23/98
Units: ug/L	
Diln Fac: 1	

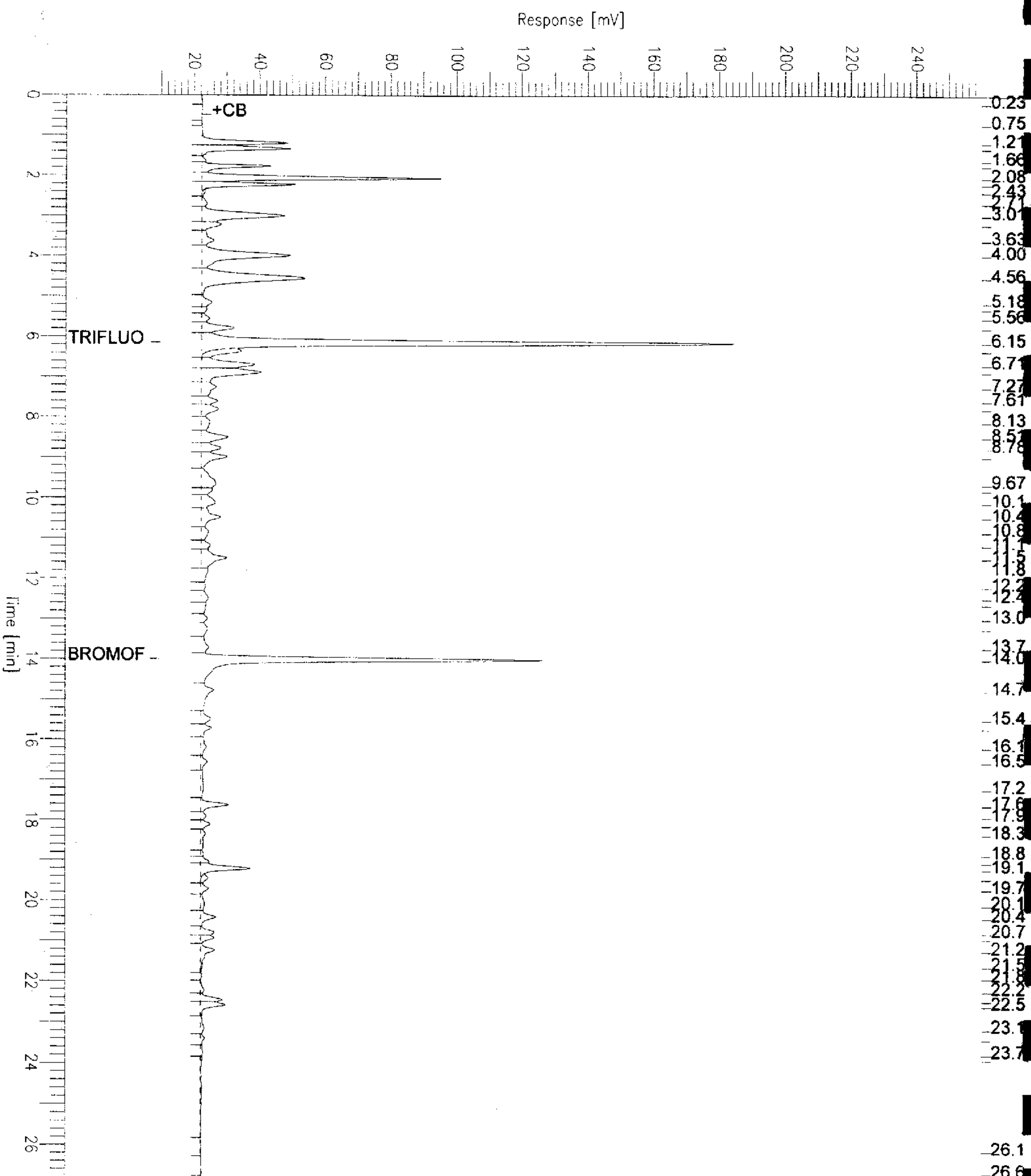
MB Lab ID: QC80596

Analyte	Result	
Gasoline C7-C12	<50	
Surrogate	**%Rec**	**Recovery Limits**
Trifluorotoluene	110	59-162
Bromofluorobenzene	115	59-162

GC05 'G' File TVH

Sample Name : S,135658-003,43551,
FileName : G:\GC05\DATA\266G024.raw
Method : TVHBTXE
Start Time : 0.00 min   End Time : 26.80 min
Scale Factor: -1.0   Plot Offset: 10 mV

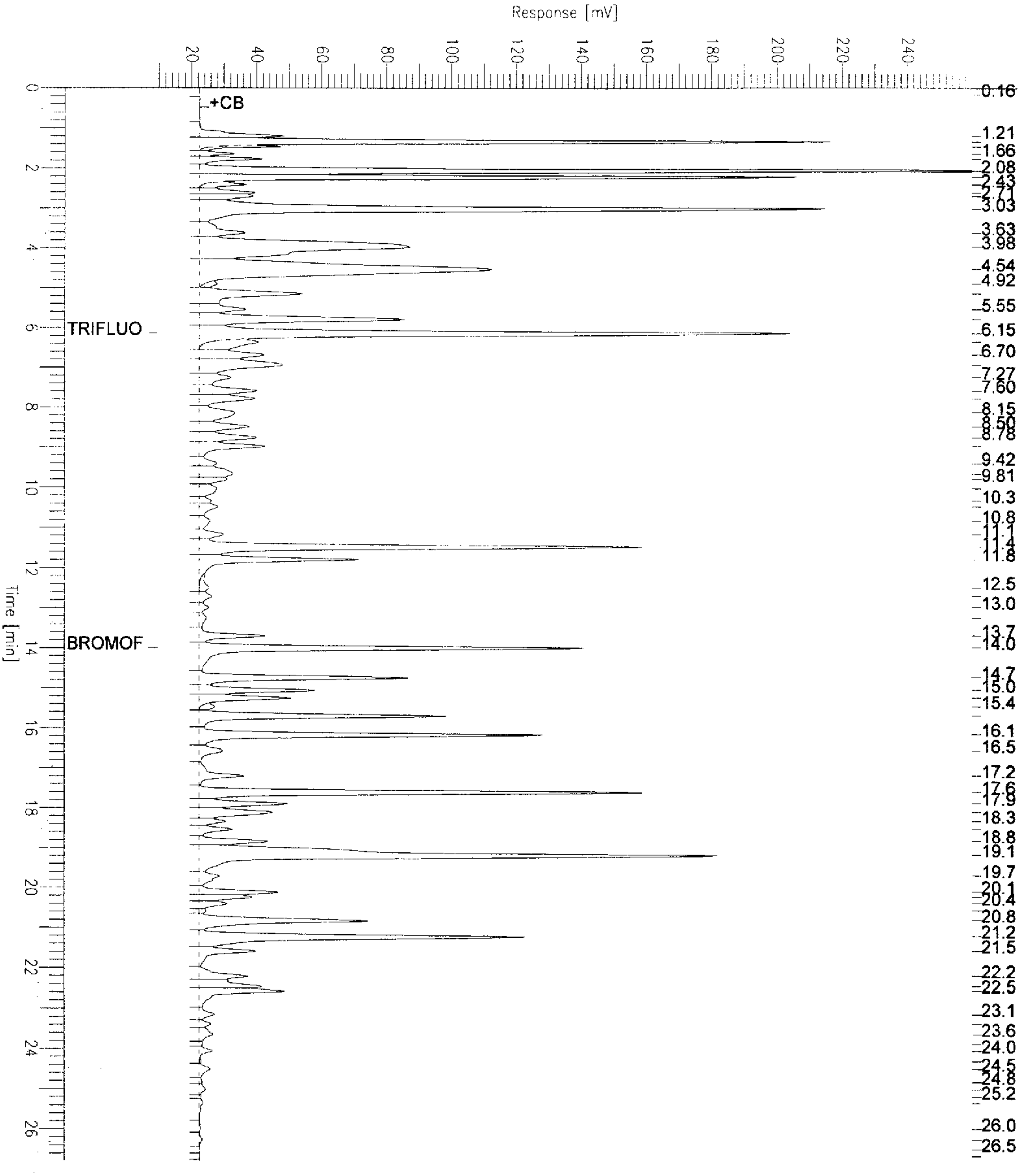
Sample #:
Date : 9/24/98 10:14 AM
Time of Injection: 9/24/98 01:38 AM
Low Point : 9.78 mV   High Point : 259.78 mV
Plot Scale: 250.0 mV



GC05 'G' File TVH

Sample Name : S,135658-004,43551,
FileName : G:\GC05\DATA\266G025.raw
Method : TVHBTXE
Start Time : 0.00 min
Scale Factor: -1.0
End Time : 26.80 min
Plot Offset: 10 mV

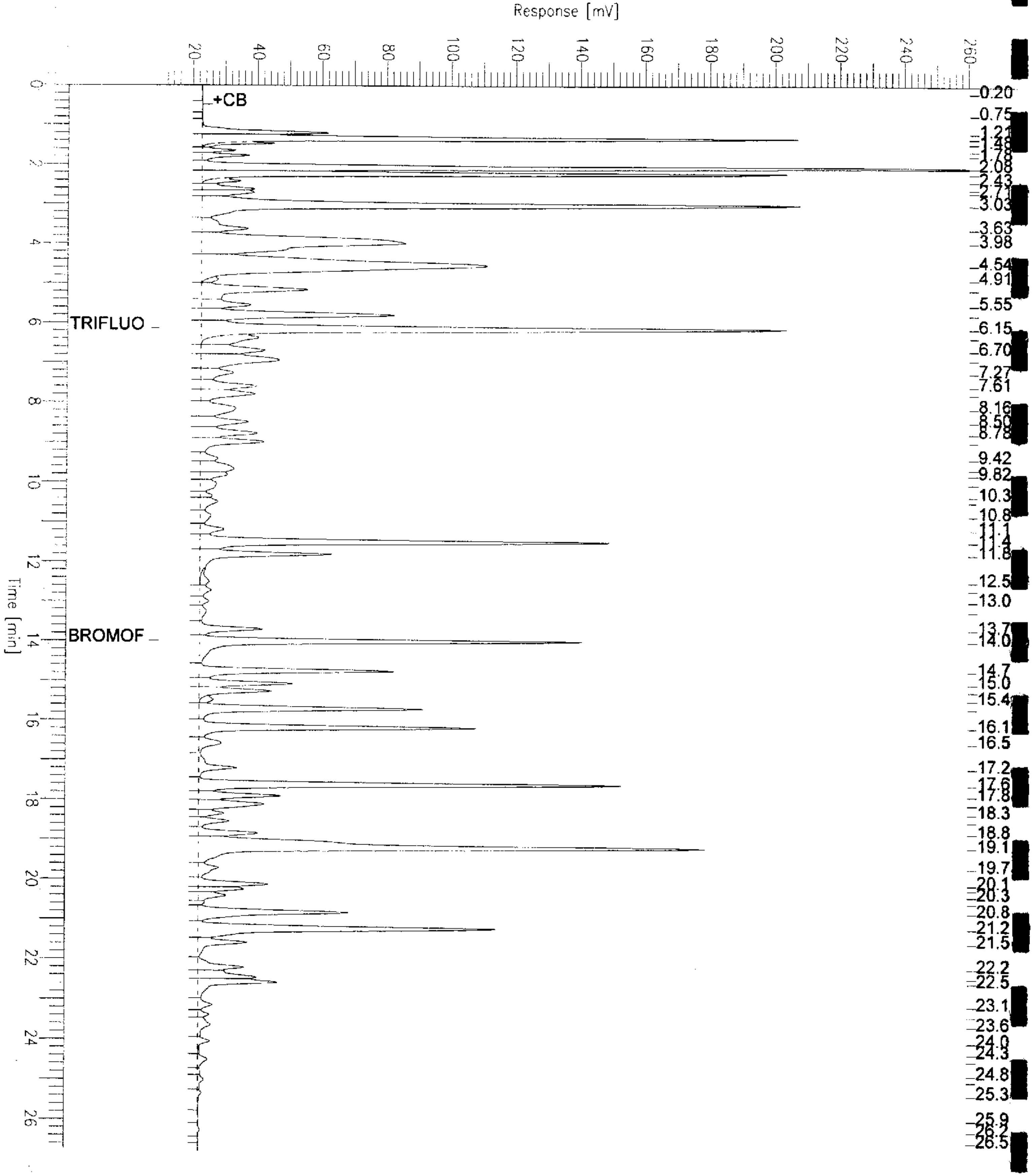
Sample #:
Date : 9/24/98 02:42 AM
Time of Injection: 9/24/98 02:15 AM
Low Point : 9.89 mV
Plot Scale: 250.0 mV
High Point : 259.89 mV



GC05 'G' File TVH

Sample Name : MSS,135658-007,43551,
FileName : G:\GC05\DATA\266G028.raw
Method : TVHBTXE
Start Time : 0.00 min
End Time : 26.80 min
Scale Factor: -1.0
Plot Offset: 10 mV

Sample #:
Date : 9/24/98 04:32 AM
Time of Injection: 9/24/98 04:04 AM
Low Point : 10.17 mV
High Point : 260.17 mV
Plot Scale: 250.0 mV

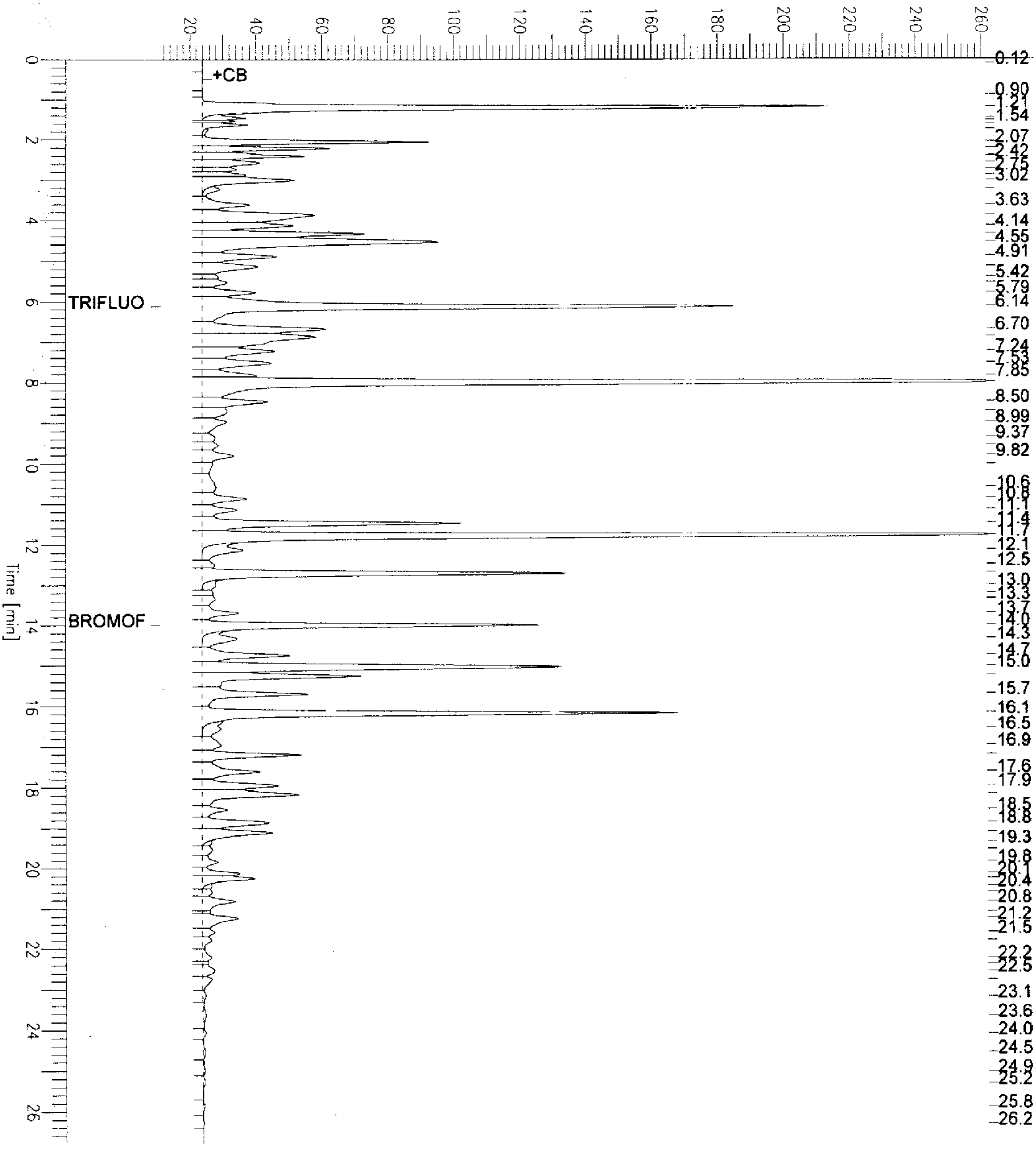


GC05 'G' File TVH

Sample Name : CCV/LCS,QC80594,98WS6389,43551,
FileName : G:\GC05\DATA\266G001.raw
Method : TVHBTXE
Start Time : 0.00 min **End Time** : 26.80 min
Scale Factor: -1.0 **Plot Offset**: 11 mV

Sample #: GAS **Page 1 of 1**
Date : 9/23/98 11:27 AM
Time of Injection: 9/23/98 10:59 AM
Low Point : 11.23 mV **High Point** : 261.23 mV
Plot Scale: 250.0 mV

Gasoline



TEH-Tot Ext Hydrocarbons

Client:	Stellar Environmental Solutions	Analysis Method:	EPA 8015M
Project#:	98031	Prep Method:	EPA 3520
Location:	Redwood Regional Park	Cleanup Method:	3630 some

Sample #	Client ID	Batch #	Sampled	Extracted	Analyzed	Moisture
135658-001	MW-2 PRE	43549	09/18/98	09/22/98	09/26/98	
135658-002	MW-2 POST	43549	09/18/98	09/22/98	09/26/98	
135658-003	MW-4 PRE	43549	09/18/98	09/22/98	09/26/98	
135658-004	MW-4 POST	43549	09/18/98	09/22/98	09/26/98	

Matrix: Water

Analyte	Units	135658-001	135658-002	135658-003	135658-004
Diln Fac:		1	1	1	1
Diesel C12-C22	ug/L	<50	<50	<50	<50
Surrogate					
Hexacosane	%REC	91	94	93	96

Curtis & Tompkins, Ltd.

TEH-Tot Ext Hydrocarbons	
Client: Stellar Environmental Solutions	Analysis Method: EPA 8015M
Project#: 98031	Prep Method: EPA 3520
Location: Redwood Regional Park	Cleanup Method: 3630 some

Sample #	Client ID	Batch #	Sampled	Extracted	Analyzed	Moisture
135658-005	MW-5 PRE	43549	09/18/98	09/22/98	09/26/98	
135658-006	MW-5 POST	43549	09/18/98	09/22/98	09/26/98	

Matrix: Water

Analyte	Units	135658-005	135658-006
Diln Fac:		1	1
Diesel C12-C22	ug/L	<50	<50
Surrogate			
Hexacosane	%REC	85	97

TEH-Tot Ext Hydrocarbons	
Client: Stellar Environmental Solutions	Analysis Method: EPA 8015M
Project#: 98031	Prep Method: EPA 3520
Location: Redwood Regional Park	Cleanup Method: EPA 3630 some

METHOD BLANK	
Matrix: Water	Prep Date: 09/22/98
Batch#: 43549	Analysis Date: 09/28/98
Units: ug/L	
Diln Fac: 1	

MB Lab ID: QC80588

Analyte	Result	
Diesel C12-C22	<50	
Surrogate	**%Rec**	**Recovery Limits**
Hexacosane	78	53-136

Curtis & Tompkins, Ltd.

Lab #: 135658

BATCH QC REPORT

TEH-Tot Ext Hydrocarbons

Client:	Stellar Environmental Solutions	Analysis Method:	EPA 8015M
Project#:	98031	Prep Method:	EPA 3520
Location:	Redwood Regional Park	Cleanup Method:	EPA 3630 some

BLANK SPIKE/BLANK SPIKE DUPLICATE

Matrix:	Water	Prep Date:	09/22/98
Batch#:	43549	Analysis Date:	10/05/98
Units:	ug/L		
Diln Fac:	1		

BS Lab ID: QC80589

Analyte	Spike Added	BS	%Rec	#	Limits
Diesel C12-C22	2475	2843	115	*	58-110

Surrogate	%Rec	Limits
Hexacosane	154*	53-136

BSD Lab ID: QC80590

Analyte	Spike Added	BSD	%Rec	#	Limits	RPD	#	Limit
Diesel C12-C22	2475	3120	126	*	58-110	9		21

Surrogate	%Rec	Limits
Hexacosane	160*	53-136

Column to be used to flag recovery and RPD values with an asterisk
* Values outside of QC limits
RPD: 0 out of 1 outside limits
Spike Recovery: 2 out of 2 outside limits

STELLAR ENVIRONMENTAL SOLUTIONS

Chain of Custody Record

135658

Lab job no.:
Date
Page ___ of ___

Laboratory: Curtis & Tompkins, Ltd.
Address: 2323 Fifth Street, Berkeley CA 94710

Method of Shipment:
Shipment No.:
Airbill No.:
Cooler No.:

Client: Stellar Environmental Solutions
Address: 2110 Sixth Street, Berkeley CA 94710

Project Manager: Bruce Rucker
Telephone No.: 510/644-3123
Fax. No.: 510/644-3859

Project Name: Redwood Regional Park
Project Number: 98031
Samplers: (Signature) B.M. Rucker

Analysis Required: Filtered √; No. of Containers; TPH-Diesel (8015); TPH-Gasoline (8015); BTEX (EPA 8020)

Field Sample Number	Location/ Depth	Date	Time	Sample Type	Type/Size of Container	Preservation Temp.	Preservation Chemical	Filtered √	No. of Containers	TPH-Diesel (8015)	TPH-Gasoline (8015)	BTEX (EPA 8020)								Remarks	
MW-2 Pre		9/18/98	915	H2O	40 ml VOA + 1 liter		HCl/none		3	x	x	x								MW-2 Pre	-1
MW-2 Post		↓	925	↓	↓		↓		3	x	x	x								MW-2 Post	-2
MW-4 Pre		↓	849	↓	↓		↓		3	x	x	x								MW-4 Pre	-3
MW-4 Post		↓	900	↓	↓		↓		3	x	x	x								MW-4 Post	-4
MW-5 Pre		↓	830	↓	↓		↓		3	x	x	x								MW-5 Pre	-5
MW-5 Post		↓	840	↓	↓		↓		3	x	x	x								MW-5 Post	-6
MW-OA		↓	910	↓	↓		↓		2		x	x								MW-OA	-7

Sample ID look OK

Relinquished by:	Date	Received by:	Date	Relinquished by:	Date	Received by:	Date
Signature: [signature]	9/18/98	Signature: Bruce M. Rucker	9/18/98	Signature: B.M. Rucker	9/18/98	Signature: Tracy Babjar	9/18
Printed: Mark Spandler	Time	Printed: Bruce M. Rucker	Time	Printed: Bruce Rucker	Time	Printed: Tracy Babjar	Time
Company: STS	940	Company: Stellar Environmental	940	Company: Stellar Environmental	1036	Company: C&T	10:37
Reason:				Reason: drop off at lab			

Comments:

Relinquished by:	Date	Received by:	Date
Signature:		Signature:	
Printed:	Time	Printed:	Time
Company:		Company:	
Reason:			

Curtis & Tompkins, Ltd., Analytical Laboratories, Since 1878
2323 Fifth Street, Berkeley, CA 94710, Phone (510) 486-0900, Fax (510) 486-0532

ANALYTICAL REPORT

Prepared for:

Stellar Environmental Solutions
2110 6th Street
Berkeley, CA 94710

Date: 13-OCT-98
Lab Job Number: 135668
Project ID: 98031
Location: Redwood Regional Park

Reviewed by: ____________

Reviewed by: ____________

Curtis & Tompkins Ltd.

TEH-Tot Ext Hydrocarbons

Client: Stellar Environmental Solutions	Analysis Method: EPA 8015M
Project#: 98031	Prep Method: EPA 3520
Location: Redwood Regional Park	

Sample #	Client ID	Batch #	Sampled	Extracted	Analyzed	Moisture
135668-001	SW-3	43602	09/18/98	09/24/98	09/30/98	
135668-002	SW-2	43602	09/18/98	09/24/98	09/30/98	
135668-003	SW-1	43602	09/18/98	09/24/98	09/30/98	

Matrix: Water

Analyte Diln Fac:	Units	135668-001 1	135668-002 1	135668-003 1
Diesel C12-C22	ug/L	<50	<50	<50
Surrogate				
Hexacosane	%REC	79	76	89

Lab #: 135668

BATCH QC REPORT

TEH-Tot Ext Hydrocarbons

Client: Stellar Environmental Solutions	Analysis Method: EPA 8015M
Project#: 98031	Prep Method: EPA 3520
Location: Redwood Regional Park	

METHOD BLANK

Matrix: Water	Prep Date: 09/24/98
Batch#: 43602	Analysis Date: 09/28/98
Units: ug/L	
Diln Fac: 1	

MB Lab ID: QC80813

Analyte	Result	
Diesel C12-C22	<50	
Surrogate	**%Rec**	**Recovery Limits**
Hexacosane	95	53-136

Lab #: 135668

BATCH QC REPORT

TEH-Tot Ext Hydrocarbons

Client: Stellar Environmental Solutions	Analysis Method: EPA 8015M
Project#: 98031	Prep Method: EPA 3520
Location: Redwood Regional Park	

BLANK SPIKE/BLANK SPIKE DUPLICATE

Matrix: Water	Prep Date: 09/24/98
Batch#: 43602	Analysis Date: 09/30/98
Units: ug/L	
Diln Fac: 1	

BS Lab ID: QC80814

Analyte	Spike Added	BS	%Rec #	Limits
Diesel C12-C22	2475	1827	74	58-110

Surrogate	%Rec	Limits
Hexacosane	91	53-136

BSD Lab ID: QC80815

Analyte	Spike Added	BSD	%Rec #	Limits	RPD #	Limit
Diesel C12-C22	2475	1724	70	58-110	6	21

Surrogate	%Rec	Limits
Hexacosane	90	53-136

Column to be used to flag recovery and RPD values with an asterisk
* Values outside of QC limits
RPD: 0 out of 1 outside limits
Spike Recovery: 0 out of 2 outside limits

Curtis & Tompkins, Ltd.

TVH-Total Volatile Hydrocarbons

Client:	Stellar Environmental Solutions	Analysis Method:	EPA 8015M
Project#:	98031	Prep Method:	EPA 5030
Location:	Redwood Regional Park		

Sample #	Client ID	Batch #	Sampled	Extracted	Analyzed	Moisture
135668-001	SW-3	43581	09/18/98	09/25/98	09/25/98	
135668-002	SW-2	43581	09/18/98	09/25/98	09/25/98	
135668-003	SW-1	43581	09/18/98	09/25/98	09/25/98	

Matrix: Water

Analyte	Units	135668-001	135668-002	135668-003
Diln Fac:		1	1	1
Gasoline C7-C12	ug/L	<50	<50	<50
Surrogate				
Trifluorotoluene	%REC	112	112	112
Bromofluorobenzene	%REC	120	122	121

BTXE

Client: Stellar Environmental Solutions	Analysis Method: EPA 8020A
Project#: 98031	Prep Method: EPA 5030
Location: Redwood Regional Park	

Sample #	Client ID	Batch #	Sampled	Extracted	Analyzed	Moisture
135668-001	SW-3	43581	09/18/98	09/25/98	09/25/98	
135668-002	SW-2	43581	09/18/98	09/25/98	09/25/98	
135668-003	SW-1	43581	09/18/98	09/25/98	09/25/98	

Matrix: Water

Analyte	Units	135668-001	135668-002	135668-003
Diln Fac:		1	1	1
MTBE	ug/L	<2	<2	<2
Benzene	ug/L	<0.5	<0.5	<0.5
Toluene	ug/L	<0.5	<0.5	<0.5
Ethylbenzene	ug/L	<0.5	<0.5	<0.5
m,p-Xylenes	ug/L	<0.5	<0.5	<0.5
o-Xylene	ug/L	<0.5	<0.5	<0.5
Surrogate				
Trifluorotoluene	%REC	108	109	109
Bromofluorobenzene	%REC	118	120	120

Curtis & Tompkins, Ltd.

Lab #: 135668 BATCH QC REPORT

BTXE

Client: Stellar Environmental Solutions	Analysis Method: EPA 8020A
Project#: 98031	Prep Method: EPA 5030
Location: Redwood Regional Park	

METHOD BLANK

Matrix: Water	Prep Date: 09/24/98
Batch#: 43581	Analysis Date: 09/24/98
Units: ug/L	
Diln Fac: 1	

MB Lab ID: QC80717

Analyte	Result
MTBE	<2.0
Benzene	<0.5
Toluene	<0.5
Ethylbenzene	<0.5
m,p-Xylenes	<0.5
o-Xylene	<0.5

Surrogate	%Rec	Recovery Limits
Trifluorotoluene	105	53-124
Bromofluorobenzene	100	41-142

BTXE

Client: Stellar Environmental Solutions	Analysis Method: EPA 8020A
Project#: 98031	Prep Method: EPA 5030
Location: Redwood Regional Park	

BLANK SPIKE/BLANK SPIKE DUPLICATE

Matrix: Water	Prep Date: 09/24/98
Batch#: 43581	Analysis Date: 09/24/98
Units: ug/L	
Diln Fac: 1	

BS Lab ID: QC80718

Analyte	Spike Added	BS	%Rec	#	Limits
MTBE	20	18.8	94		65-135
Benzene	20	15.7	79		69-109
Toluene	20	18.85	94		72-116
Ethylbenzene	20	20.14	101		67-120
m,p-Xylenes	40	40.69	102		69-117
o-Xylene	20	20.48	102		75-122

Surrogate	%Rec	Limits
Trifluorotoluene	108	53-124
Bromofluorobenzene	114	41-142

BSD Lab ID: QC80719

Analyte	Spike Added	BSD	%Rec #	Limits	RPD #	Limit
MTBE	20	19.03	95	65-135	1	20
Benzene	20	16.05	80	69-109	2	11
Toluene	20	19.51	98	72-116	3	11
Ethylbenzene	20	20.75	104	67-120	3	12
m,p-Xylenes	40	41.8	105	69-117	3	11
o-Xylene	20	21.07	105	75-122	3	12

Surrogate	%Rec	Limits
Trifluorotoluene	108	53-124
Bromofluorobenzene	116	41-142

Column to be used to flag recovery and RPD values with an asterisk
* Values outside of QC limits
RPD: 0 out of 6 outside limits
Spike Recovery: 0 out of 12 outside limits

TVH-Total Volatile Hydrocarbons

Client: Stellar Environmental Solutions	Analysis Method: EPA 8015M
Project#: 98031	Prep Method: EPA 5030
Location: Redwood Regional Park	

METHOD BLANK

Matrix: Water	Prep Date: 09/24/98
Batch#: 43581	Analysis Date: 09/24/98
Units: ug/L	
Diln Fac: 1	

MB Lab ID: QC80717

Analyte	Result	
Gasoline C7-C12	<50	
Surrogate	**%Rec**	**Recovery Limits**
Trifluorotoluene	96	59-162
Bromofluorobenzene	93	59-162

TVH-Total Volatile Hydrocarbons

Client: Stellar Environmental Solutions	Analysis Method: EPA 8015M
Project#: 98031	Prep Method: EPA 5030
Location: Redwood Regional Park	

MATRIX SPIKE/MATRIX SPIKE DUPLICATE

Field ID: ZZZZZZ	Sample Date: 09/15/98
Lab ID: 135615-001	Received Date: 09/16/98
Matrix: Water	Prep Date: 09/24/98
Batch#: 43581	Analysis Date: 09/24/98
Units: ug/L	
Diln Fac: 1	

MS Lab ID: QC80720

Analyte	Spike Added	Sample	MS	%Rec #	Limits
Gasoline C7-C12	2000	<50	2149	107	71-131

Surrogate	%Rec	Limits
Trifluorotoluene	150	59-162
Bromofluorobenzene	136	59-162

MSD Lab ID: QC80721

Analyte	Spike Added	MSD	%Rec #	Limits	RPD #	Limit
Gasoline C7-C12	2000	2135	107	71-131	1	26

Surrogate	%Rec	Limits
Trifluorotoluene	151	59-162
Bromofluorobenzene	137	59-162

Column to be used to flag recovery and RPD values with an asterisk
* Values outside of QC limits
RPD: 0 out of 1 outside limits
Spike Recovery: 0 out of 2 outside limits

Lab #: 135668 BATCH QC REPORT Curtis & Tompkins, Ltd. Page 1 of 1

TVH-Total Volatile Hydrocarbons

Client: Stellar Environmental Solutions	Analysis Method: EPA 8015M
Project#: 98031	Prep Method: EPA 5030
Location: Redwood Regional Park	

LABORATORY CONTROL SAMPLE

Matrix: Water	Prep Date: 09/24/98
Batch#: 43581	Analysis Date: 09/24/98
Units: ug/L	
Diln Fac: 1	

LCS Lab ID: QC80716

Analyte	Result	Spike Added	%Rec #	Limits
Gasoline C7-C12	1826	2000	91	80-119

Surrogate	%Rec	Limits
Trifluorotoluene	121	59-162
Bromofluorobenzene	99	59-162

Column to be used to flag recovery and RPD values with an asterisk
* Values outside of QC limits
Spike Recovery: 0 out of 1 outside limits

STELLAR ENVIRONMENTAL SOLUTIONS
Chain of Custody Record

Lab job no.: ______
Date ______
Page ____ of ____

135668

Laboratory: Curtis + Tompkins
Address: 2323 Fifth Street, Berkeley CA 94710

Client: Steller Environmental Solutions
Address: 2110 Sixth Street, Berkeley CA

Project Name: Redwood Regional Park Service Yard
Project Number: 98031

Method of Shipment: hand delivered
Shipment No.
Airbill No.
Cooler No.
Project Manager: Bruce Rucker
Telephone No.: 510/644-3123
Fax. No.: 510/644-3859
Samplers: (Signature) [signature]

Analysis Required: Filtered √ | No. of Containers | TPH-diesel (8015) | TPH-gasoline (8015) | BTEX (EPA 8020)

	Field Sample Number	Location/ Depth	Date	Time	Sample Type	Type/Size of Container	Preservation Temp.	Preservation Chemical	Filtered √	No. of Containers		TPH-diesel (8015)		TPH-gasoline (8015)		BTEX (EPA 8020)	Remarks
-1	SW-3		9/18/98	910	H2O	40ml VOA + 1 liter amber glass		HCl/none		3		X		X		X	
-2	SW-2		↓	920	↓	↓		↓		3		X		X		X	
-3	SW-1		↓	930	↓	↓		↓		3		X		X		X	

Relinquished by:
Signature: [signature]
Printed: Bruce M. Rucker
Company: Stellar Environmental
Reason: lab drop-off.
Date: 9/18/98
Time: 1036

Received by:
Signature: [signature]
Printed: Tracy Babjar
Company: C&T
Date: 9/18/98
Time: 10:37

Relinquished by:
Signature
Printed
Company
Reason
Date
Time

Received by:
Signature
Printed
Company
Date
Time

Relinquished by:
Signature
Printed
Company
Reason
Date
Time

Received by:
Signature
Printed
Company
Date
Time

Comments:

SES-2110 Sixth Street, Berkeley, CA 95710

CALIFORNIA STREAM BIOASSESSMENT PROCEDURE

(HABITAT ASSESSMENT AND BIOLOGICAL SAMPLING)

The California Stream Bioassessment Procedure (CSBP) is a standardized protocol for assessing physical and biological conditions of wadable streams in California. There are two companion documents for this procedure: "California Stream Bioassessment Procedure (Macroinvertebrate Laboratory and Data Analyses)" and "California Stream Bioassessment Procedure (Field and Laboratory Quality Assurance/Control)". The CSBP is a regional adaptation of the national Rapid Bioassessment Protocols described in "Rapid Bioassessment Protocols for use in Streams and Rivers: Benthic Macroinvertebrates and Fish" (EPA 444/4-89-001).

This document describes procedures for habitat assessment and biological sampling of wadable streams using benthic macroinvertebrates. Developing aquatic bioassessment techniques for California is an iterative process; contact the California Department of Fish and Game's Water Pollution Control Laboratory (WPCL) at (916) 358-2858, e-mail: jharr@sna.com or visit the California Aquatic Bioassessment Web Site (http://www.dfg.ca.gov/cabw/cabwhome.html) for the most current version of the CSBP.

MONITORING STRATEGIES

The CSBP can be used to detect aquatic impacts from point and non-point source pollution and for biological assessment of ambient water quality. This field sampling procedure was designed for collecting benthic macroinvertebrates from individual riffles chosen as part of an appropriately designed monitoring program. ***The CSBP may not be appropriate for all aquatic monitoring programs - contact WPCL for advice on proper application of the CSBP.*** The following bioassessment strategies can be employed for:

Point Sources of Pollution - There will be discernable perturbations, impacting structures or discharges into the stream with point sources of pollution. The affected section of stream and an upstream unaffected section should be surveyed for riffles having relatively similar gradient, substrate and physical/habitat condition. Each riffle becomes a potential sampling site for benthic macroinvertebrates. At least one riffle in the unaffected section should be sampled as a control. One or more riffles should be sampled in the affected section depending on the amount of detail that is required on downstream recovery. At least three samples should be collected at each riffle depending on the necessary level of statistical accuracy required for the project.

Non-point Sources of Pollution - There will be no obvious perturbations or discharges into the stream with non-point sources of pollution. The stream or stream section of interest should be surveyed for similar riffles, and then at least three riffles should be chosen at random for collecting benthic macroinvertebrates. Only one sample from the upstream third of the riffle is necessary as long as the riffles are chosen randomly. However, collecting three or more samples as described in the point source protocol will provide additional statistical information and accuracy. The number of riffles sampled depends on the homogeneity of the stream or stream section and necessary level of statistical accuracy required for the project. A reference stream or condition is recommended for assessing possible impacts from non-point source pollution. A reference stream or stream section must be similar in physical/habitat condition and be within the same ecoregion or watershed as the impacted site. Historical data or expert consensus on biological and physical condition could be substituted if a reference stream is unavailable.

Ambient Water Quality Conditions - Biological assessment of ambient water quality for a stream or stream section provides base-line information on biological conditions, aquatic species composition and natural community variability. This information can be used to establish reference streams and reference conditions and to develop Biological Criteria as outlined by the U.S. Environmental Protection Agency in "Biological Criteria: National Program Guidance for Surface Waters" (EPA 440/5-90-004). Biological assessment for ambient water quality should be conducted seasonally (spring and/or fall) and continued on a regular basis to establish historic data and provide a management tool to detect possible changes in water quality. The monitoring strategy can be similar to that described for both point and non-point source pollution with riffles being chosen from similar reaches and/or located above and below areas of particular interest (e.g., suspected impact, physical/habitat structure, hydrologic zones, etc.).

EQUIPMENT AND SUPPLIES

D-shaped kick net (0.5mm mesh)
Wide-mouth plastic or glass jars
White enameled pan
Watershed topographic map
Measuring Tape (100 meter)
Standard size 35 (0.5 mm) testing sieve
California Stream Bioassessment Worksheet (CSBW)
WPCL Chain of Custody Form (COC)
Thermometer
Forceps
95% ethanol
Pencil
Water-proof paper

PROCEDURES

Biological Sampling

1. The project supervisor should conduct a reconnaissance survey of the stream or stream section to determine appropriate sample reaches. The ideal sampling reach is a riffle at least 10 meters long with a homogenous gravel/cobble substrate and swift water velocity. However, ideal situations rarely exist. In choosing sampling reaches, emphasis should be placed on homogenous reaches that are wadable and best

resemble a riffle or run condition. Follow the monitoring strategies outlined in this document or contact the WPCL for advice on selecting individual riffles for collecting benthic macroinvertebrates.

CAUTION: Avoid walking in stream when conducting a reconnaissance survey. Each riffle used for biological assessment must be approached from downstream and no portion of the riffle disturbed until all sampling is complete. Habitat assessment should be conducted after macroinvertebrates have been collected.

2. Fill out a CSBW for each riffle section. Enter watershed name, sample identification number, date, time and names of crew members. Locate the site on the watershed topographic map using the sample identification number and enter GPS coordinates, if possible.

3. To select a transect, place the measuring tape along the bank of the entire riffle section. Each meter (3 ft) mark represents a possible transect location. Select a transect from all possible meter marks along the measuring tape using the table of random numbers. If only one transect is to be sampled, then select one meter mark in the top one-third of the riffle. To select a random number, place a finger on the page with eyes closed. From that number, go down the columns looking at the first two digits (for up to 99 transect numbers) until a usable number(s) is selected. Record the meter mark on the CSBW for each transect.

4. Once a transect is randomly selected, the objective is to collect benthic macroinvertebrates from several locations along the transect and combine them into one sample. If possible, choose three locations; the two side margins and the center of the stream. If the riffle is not ideal, then make adjustments to accommodate prevailing conditions. When making adjustments, such as increasing or reducing the number of locations for collecting organisms or sampling substrate that is not gravel/cobble, try to sample similar conditions at each reach.

5. Starting from the downstream transect, collect macroinvertebrates by placing the D-shaped kick-net on the substrate and disturbing a one by two foot section of substrate upstream of the kick-net to approximately 4-6 inches in depth. Pick-up and scrub large rocks by hand under water in front of the net. Maintain a consistent sampling effort (approximately 1-3 minutes) at each site. Combine the three collections within the kick-net. Measure and record stream temperature.

6. Place the contents of the kick-net in a standard size 35 (0.5 mm) testing sieve. Remove large organic material by hand while carefully inspecting for clinging organisms. Using the forceps, place all remaining material in the 95% ethanol filled jar. When there is considerable debris in the net, the white enameled pan is useful for inspecting the sample. However, rinse material from the pan through the sieve before placing it in the jar.

7. Using a pencil, write the following information on a piece of water-proof paper and place in the jar: sample identification number followed by -01, -02 (to identify each transect sampled from a riffled), watershed name, date and sampler's initials.

Habitat Assessment

The habitat assessment portion of this procedure should be used if a more comprehensive physical assessment is not planned. Habitat assessments can be used without biological sampling, but whenever biological sampling occurs, there must be a habitat assessment conducted for every riffle sampled.

8. Conduct a rapid assessment of physical conditions for an entire stream reach using the habitat parameters (last two pages of the CSBW) as described while walking in an upstream direction from the bottom to the top of the stream reach. The score should reflect the average conditions for the entire stream reach. Record habitat parameter scores on the cover page of a separate CSBW and make comments on any habitat impairments not covered by the habitat parameters.

9. For biological sampling, habitat parameters 1 through 3 should be used to evaluate the average condition along the transacts sampled for benthic macroinvertebrates. Habitat parameters 4 through 7 should be used to assess conditions for a larger area upstream of the riffle section. Habitat parameters 8 through 10 should be used to assess each bank immediately upstream of the riffle section. Record habitat parameter scores on the cover page of each CSBW used for biological sampling.

Sample Handling, Storage and Transfer

10. At the end of the field day, record the following information on a COC for each (or group of) biological samples: program name; watershed name; field ID numbers; sampling dates; and name, address, telephone number and signature of one of the crew members collecting the sample.

11. Verification samples and COCs must remain in a locked sample depository until a decision has been made to send them to a bioassessment laboratory for processing.

12. When transporting to a bioassessment laboratory, each (or group of) sample must be accompanied by a COC. Upon delivery, a Bioassessment Laboratory Number will be assigned to each sample. Record this number on the COC and each individual CSBW along with the name and address of the bioassessment laboratory. When all verification samples listed on the COC are accounted for, then the individual delivering the samples will sign the "Released By" portion and the laboratory personnel will sign the "Received By" portion of the COC. The original COC will remain at the laboratory and a copy will be retained by the project supervisor.

CALIFORNIA STREAM BIOASSESSMENT PROCEDURE
FIELD WORKSHEET

WATERSHED: ____________________

DATE: ____________________

SAMPLE ID: ____________________

TIME: ____________________

CREW MEMBERS:

____

____

____

WATER TEMP: ____________

RIFFLE LENGTH: ____________

TRANSECT 1: ____________

TRANSECT 2: ____________

TRANSECT 3: ____________

GPS COORDINATES

LONG: ____________

LAT: ____________

HABITAT ASSESSMENT PARAMETERS

1. INSTREAM COVER: ________
2. EPIFAUNAL SUBSTRATE: ________
3. EMBEDDEDNESS: ________
4. CHANNEL ALTERATION: ________
5. SEDIMENT DEPOSITION: ________
6. RIFFLE FREQUENCY: ________
7. CHANNEL FLOW: ________
8. BANK VEGETATION: L:____ R:____
9. BANK STABILITY: L:____ R:____
10. RIPARIAN ZONE: L:____ R:____

COMMENTS: ____________________

____

____

____

BIOASSESSMENT LABORATORY INFORMATION

Bioassessment Laboratory Number: ____________

Bioassessment Laboratory Name and Address:

____

____

____

____

CDFG - WPCL
2005 Nimbus Rd. Rancho Cordova, Ca. 95670
(916) 358-2858 FAX (916) 985-4301 e-mail: jharr@sna.com
Bioassessment homepage - http://www.dfg.ca.gov/cabw/cabwhome.html

48461	14952	72619	73689	52059	37086	60050	86192	67049	64739	58237	81333	12573	36161	84900	39614	61303	05086	97670	07961
76534	38149	49692	31166	52093	15422	20498	33901	10319	43397	54789	75554	36795	42649	02971	97584	38223	52643	25027	56849
70437	25861	38504	14752	23757	59660	67844	78815	23758	86814	55373	14272	62729	25659	84359	02654	08409	52703	88803	31919
59584	03370	42806	11393	71722	93804	09095	07856	55589	46020	74251	66100	10773	71393	80972	45092	07932	83065	06585	16454
04285	58554	16085	51555	27501	73881	33427	33343	45507	50063	86077	90904	14779	75116	50267	52217	08539	08345	52750	22815
77340	10412	69189	85171	29082	44785	83638	02583	96483	76553	13506	84170	08716	28894	20133	99489	87768	55582	96081	20774
59183	62687	91778	80354	23512	97219	65921	02035	59847	91403	13226	41411	16074	15438	68840	17064	96917	25404	47708	17861
91800	04281	39979	01927	82564	28777	59049	97532	54540	79472	01642	25456	69804	29277	99473	07912	90488	73325	88266	18082
12066	24817	81099	48940	69554	55925	48379	12866	51232	21580	23715	70933	37381	20388	34929	96585	14146	81617	36664	25060
69907	91751	53512	23748	65906	91385	84983	27915	48491	91068	98436	61100	45346	94664	30677	18677	99524	70767	39525	34023
80467	04873	54053	25955	48518	13815	37707	68687	15570	08890	96571	81879	50387	77316	18874	00763	99457	70858	79674	95618
78057	67835	28302	45048	56761	97725	58438	91528	24645	18544	70677	59632	22985	95166	54904	61995	63423	65335	13807	56638
05648	39387	78191	88415	60269	94880	58812	42931	71899	61534	33725	31717	04704	13669	91697	00107	33667	24770	60044	49107
22304	39246	01350	99451	61862	78688	30339	60222	74052	25740	40910	75631	56653	42858	85768	21254	01295	21507	33687	02404
61346	50269	67005	40442	33100	16742	61640	21046	31909	72641	67947	27522	14066	14943	19696	93933	52432	90569	14856	30580
66793	37696	27965	30459	91011	51426	31006	77468	61029	57108	41797	38840	68744	59348	05120	30184	35212	14348	37661	51451
86411	48809	36646	42453	85061	43769	39948	87031	30761	13951	41770	94218	52578	36238	40575	16793	77152	23382	11570	87276
62098	12825	81744	28832	27369	68183	65846	92545	09065	22655	34918	50080	97862	84932	57596	33749	78745	73377	72328	63074
68775	06261	54265	16203	23340	84750	16317	88686	86842	00879	47898	91359	10606	33735	46812	96239	23815	36757	17882	96143
52679	19595	13687	74872	89181	01939	18447	10787	76246	80072	45021	03882	94463	96369	56001	16348	89408	84563	66422	62636
84096	87152	20719	25215	04349	54434	72344	93008	83282	31670	92752	67479	72696	20645	78439	11224	17405	27884	15573	12490
63964	55937	21417	49944	38356	98404	14850	17994	17161	98981	13229	29631	01944	76916	30063	98507	11345	29576	20215	53972
31191	75131	72386	11689	95727	05414	88727	45583	22568	77700	39111	13161	85208	70213	24016	04960	46728	60292	24831	06403
30545	68523	29850	67833	05622	89975	79047	27142	99257	32349	50972	92325	72258	57577	32886	56062	62370	99461	64680	38080
52573	91001	52315	26430	54175	30122	31796	98942	37600	26025	08190	28700	87859	03684	83762	03810	12325	75445	41946	36470
16586	81842	01076	99414	31574	94719	34656	80018	86988	79234	98140	55201	89156	99277	78211	78692	96992	80163	67882	36674
81841	88481	61191	25013	30272	23388	22463	65774	10029	58376	14110	02500	54140	43371	06930	26853	56025	73530	97542	19287
43563	66829	72838	08074	57080	15446	11034	98143	74989	26885	35106	03726	35458	69204	47084	22676	62125	66443	73712	82879
19945	84193	57581	77252	85604	45412	43556	27518	90572	00563	04446	93672	24118	40480	79678	51259	37345	49666	08518	04251
79374	23796	16919	99691	80276	32818	62953	78831	54395	30705	42890	46488	42713	76138	82275	59529	98821	60243	51840	02294
48503	26615	43980	09510	78289	66679	73799	48418	12647	40044	64856	84896	77627	86920	59181	24162	34918	77203	55518	17174
32049	65541	37937	41105	70106	89706	40829	40789	59547	00781	29739	02885	14169	81125	59048	59396	35494	25220	91424	94750
18547	71562	75493	34112	76835	46766	96395	31718	48702	45893	70750	97663	18316	16741	75016	01404	78331	76908	68195	18714
03180	96742	61486	43305	34183	99605	67803	13441	09243	29557	28695	56066	21108	23021	31950	37840	33674	81877	92490	35488
94822	24738	67749	83748	59799	25210	31093	62925	72061	69991	58892	85844	04181	58470	13348	64277	43838	50362	08531	83388
34330	60599	85828	19152	68499	27977	35611	96240	62747	89529	79508	78596	96537	20553	41148	37805	14553	09919	11490	70231
43770	81537	59527	95674	76692	86420	69930	10020	72881	12532	13617	66975	68598	95450	06285	84134	62474	22329	82134	08283
56908	77192	50623	41215	14311	42834	80651	93750	59957	31211	15123	55351	28631	77941	90178	35876	27833	92494	88899	41558
32787	07189	80539	75927	75475	73963	11796	72140	48944	74156	34604	18686	05179	31756	47258	14945	98839	82051	86608	07022
52441	78392	11733	57703	29133	71164	55355	31006	25526	55790	51863	00432	27846	54577	84476	06652	88250	40187	29735	32621
22177	54723	18227	28449	04570	18882	00023	67101	06895	08915	65489	54535	60256	91285	81743	48426	58351	89166	52478	23935
18376	73460	88841	39602	34049	20589	05701	08249	74213	25220	86119	57900	04979	16358	06281	25469	02454	20658	08869	29293
53201	28610	87957	21497	64729	64983	71551	99016	87903	63875	01963	62421	86788	54260	61287	69893	56446	11608	04760	85532
34919	78901	59710	27396	07593	05665	11964	44134	00277	76358	52164	39397	60568	88382	01561	78861	02849	31033	76875	08260
33617	92159	21971	16901	57383	34262	41744	60891	57624	06962	91444	35684	80387	44627	71027	16850	04079	02394	49058	60509
70010	40964	99780	72418	52571	18415	64362	90636	38034	04909	09881	00351	14759	58624	50470	03348	23703	10959	39733	84954
19282	68447	35665	31530	59832	49181	21914	65742	89815	39231	09345	29309	17864	27687	21691	59354	56599	99135	57626	55645
91429	73328	13266	54878	68795	40948	80808	63887	89939	47738	13036	51186	32490	45564	53813	25529	66293	50352	41356	44697
97637	78391	33021	05867	86520	45363	43066	00948	64040	09803	96114	75971	70563	31203	85747	86469	78133	40310	48223	85933
95150	07625	05255	83254	93943	52325	93230	62668	79529	65964	47657	02006	33820	89370	60192	08248	10721	27754	31373	59019

DATE: ______________

SAMPLE ID: ______________

Habitat Parameter	Category			
	Optimal	Suboptimal	Marginal	Poor
1. Instream Cover (Fish)	Greater than 50% mix of snags, submerged logs, undercut banks, or other stable habitat.	30-50% mix of stable habitat; adequate habitat for maintenance of populations.	10-30% mix of stable habitat; habitat availability less than desirable.	Less than 10% mix of stable habitat; lack of habitat is obvious.
SCORE ____	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Epifaunal Substrate	Well-developed riffle and run; riffle is as wide as stream and length extends two times the width of stream; abundance of cobble.	Riffle is as wide as stream but length is less than two times width; abundance of cobble; boulders and gravel common.	Run area may be lacking; riffle not as wide as stream and its length is less than 2 times the stream width; gravel or large boulders and bedrock prevalent; some cobble present.	Riffles or runs virtually nonexistent; large boulders and bedrock prevalent; cobble lacking.
SCORE ____	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE ____	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Channel Alteration	Channelization or dredging absent or minimal; stream with normal, sinuous pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	New embankments present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted.
SCORE ____	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from coarse gravel; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, coarse sand on old and new bars; 30-50% of the bottom affected; sediment deposits at obstruction, constriction, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE ____	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Habitat Parameter	Category			
	Optimal	Suboptimal	Marginal	Poor
6. Frequency of Riffles	Occurrence of riffles relatively frequent; distance between riffles divided by the width of the stream equals 5 to 7; variety of habitat.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream equals 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is between ratio >25.
SCORE ___	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Channel Flow Status	Water reaches base of both lower banks and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE ___	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Vegetative Protection (score each bank) Note: determine left or right side by facing downstream.	More than 90% of the streambank surfaces covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption, through grazing or mowing, minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 2 inches or less in average stubble height.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
9. Bank Stability (score each bank)	Banks stable; no evidence of erosion or bank failure; little potential for future problems.	Moderately stable; infrequent, small areas of erosion mostly healed over.	Moderately unstable; up to 60% of banks in reach have areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0