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# **ANNUAL 2010 BIOVENTING SYSTEM STATUS REPORT**

**REDWOOD REGIONAL PARK  
SERVICE YARD  
OAKLAND, CALIFORNIA**

*Prepared for:*

**EAST BAY REGIONAL PARK DISTRICT  
OAKLAND, CALIFORNIA**

**January 2011**

# **ANNUAL 2010 BIOVENTING SYSTEM STATUS REPORT**

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SERVICE YARD  
OAKLAND, CALIFORNIA**

*Prepared for:*

**EAST BAY REGIONAL PARK DISTRICT  
P.O. BOX 5381  
OAKLAND, CALIFORNIA 94605**

*Prepared by:*

**STELLAR ENVIRONMENTAL SOLUTIONS  
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**January 28, 2011**

Project No. 2009-02

January 28, 2011

Mr. Jerry Wickham, P.G.  
Hazardous Materials Specialist  
Alameda County Department of Environmental Health  
1131 Harbor Bay Parkway, Suite 250  
Alameda, California 94502

Subject: Annual 2010 Bioventing System Status Report,  
Redwood Regional Park Service Yard Site, Oakland, California – RO #0000246

Dear Mr. Wickham:

This report presents the annual report related to a bioventing corrective action system at the Redwood Regional Park Service Yard, located at 7867 Redwood Road, Oakland, California. A microbial respiration test was conducted during this period, from November 18 to November 20, 2010. Per the data collected since the bioventing system start-up, Stellar Environmental is recommending the system be shut-down for six months and resampled in June/July of 2010 to determine the amount of recharge. If no measurable difference is observed, Stellar Environmental is recommending the system be decommissioned. The key regulatory agencies for this investigation are the Alameda County Department of Environmental Health, the Regional Water Quality Control Board, and the California Department of Fish and Game. I declare, under penalty of perjury, that the information and/or recommendations contained in the attached document or report is true and correct to the best of my knowledge.

If you have any questions regarding this report, please contact Mr. Matt Graul of the East Bay Regional Park District, or contact me directly at (510) 644-3123.

Sincerely,



Richard S. Makdisi, R.G., R.E.A.  
Principal and Project Manager  
District



Matt Graul, Stewardship Manager  
East Bay Regional Park

cc: Carl Wilcox - California Department of Fish and Game  
State of California GeoTracker system (electronic upload)



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## **1.0 PROJECT DESCRIPTION AND SITE HISTORY**

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### **PROJECT DESCRIPTION**

The subject property is the East Bay Regional Park District (EBRPD) 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 subsurface contamination caused by leakage from one or both of two former underground fuel storage tanks (UFSTs) that contained gasoline and diesel fuel. The Alameda County Department of Environmental Health (ACEH) has provided regulatory oversight of the investigation since its inception. Other regulatory agencies with historical involvement in site review include the Regional Water Quality Control Board – San Francisco Bay Region (Water Board) and the California Department of Fish and Game (CDFG).

Bioventing was selected as an appropriate corrective action to mitigate residual petroleum contamination, based on site conditions, residual contaminant distribution, and results from a previously conducted bioventing pilot test in 2004 (Stellar Environmental, 2004b). The bioventing system was approved by ACEH (ACEH, 2005b), and was installed and started up in December 2005 and January 2006 (Stellar Environmental, 2006a). Subsequent bioventing system operation in 2007 showed two of the three bioventing wells to be effective in the delivery of air (oxygen) to the subsurface soils and of those only one well (VW-2) to be more highly effective. The subsurface environment appears to be more saturated and/or has lower permeability sediments that suggested by the history of exploratory soil bore data. In March 2008, in an attempt to respond to the ACEH request for more aggressive corrective action, an augmentation of the bioventing system with two more wells placed in the source area was completed. This augmentation of the existing system, while not considered likely to be highly effective, was deemed worth the attempt because it had a low cost impact. However, the additional bioventing wells did not result in any appreciable improvement in bioventing effectiveness. This is attributed to soil permeability constraints, which clearly have more impediments to viable air transmission than suggested by the existing geologic logs. The area where the bioventing system has been most effective, near VMP-2, has shown continued reductions in hydrocarbon contamination in soil based on the respiration test results.





3-D TopoQuads Copyright © 1999 DeLorme Yarmouth, ME 04096 Source Data: USGS 750 ft Scale: 1 : 25,000 Detail: 13-0 Datum: WGS84



### SITE LOCATION ON U.S.G.S. TOPOGRAPHIC MAP

Redwood Reg. Park Service Yard  
Oakland, CA

By: MJC

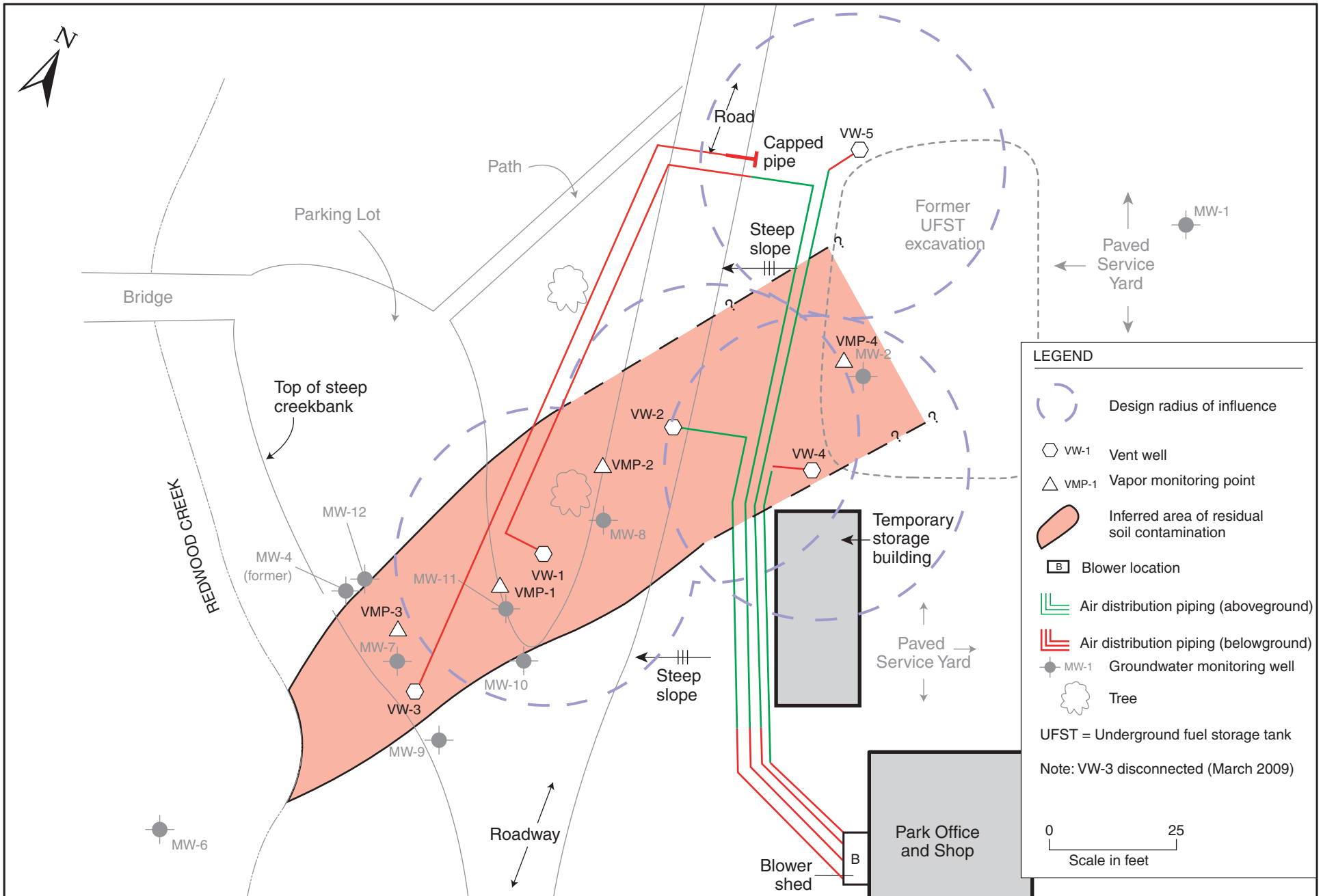
MARCH 2006

Figure 1



2006-17-01





**BIOVENTING SYSTEM DESIGN**  
**7867 Redwood Rd, Oakland, CA**

**Figure 2**

by: MJC

NOVEMBER 2009



This report documents summarizes the soil bioventing system-related activities conducted at the site throughout 2010. A microbial respiration test was conducted during the fourth quarter, from November 18 to November 20, 2010.

## **SITE DESCRIPTION**

Figure 1 presents the project site location. A site plan showing the full-scale bioventing system is provided on Figure 2.

The site slopes to the west, from an elevation of approximately 564 feet above mean sea level (amsl) at the eastern edge of the service yard to approximately 530 feet amsl at Redwood Creek, which defines the approximate western edge of the project site with regard to this investigation.

From east to west, the study area consists of:

- Flat, paved EBRPD service yard with several permanent and temporary buildings/sheds (former UFST excavation area)
- Steep slope (approximately 45 degrees) between the western edge of the service yard and the park entrance road (immediately west of MW-2)
- Hummocky terrain with low vegetation (between MW-8 and MW-11), including a large EBRPD-designated sycamore tree (adjacent to MW-8 and VMP-2)
- Flat, unpaved parking lot (between MW-11 and MW-7)
- Steep slope (approximately 45 degrees) to Redwood Creek (immediately west of MW-12, MW-7, and MW-9)

## **SITE HISTORY AND CONTAMINATION**

Contaminant corrective actions and investigations have been conducted at the site since 1993. General phases of work previously conducted include:

- Removal of UFSTs and contaminated soil.
- Installation and quarterly monitoring of groundwater monitoring wells.
- Several phases of remedial investigation-oriented exploratory borehole drilling and sampling.
- A correction action feasibility study.
- Two phases of Oxygen Releasing Compound (ORC™) injection.
- An evaluation of bioventing feasibility as a corrective action, which included a bioventing pilot test.

- Installation and startup of the bioventing system in December 2005 and January 2006 (after startup, four weekly monitoring/air flow optimization events were conducted).
- Bioventing system operation and maintenance and annual respiration tests in 2007-2010
- Installation of two additional bioventing vent wells in 2008 (VW-4 and VW-5) in the source area and disconnection of VW-3.
- An injection in to source area well MW-2 of ORC™ in February 2010 and an additional ORC™ injection around a subset of wells in March 2010.

As detailed in previous Stellar Environmental reports, the available data support the following conclusions:

- The saturated zone overlies laterally extensive bedrock, which limits downward migration of groundwater contamination.
- The unsaturated zone varies in thickness due to seasonal water level fluctuations of several feet.
- Site chemicals of concern include total petroleum hydrocarbons (TPH)—specifically as gasoline (TPHg) and diesel (TPHd); benzene, toluene, ethylbenzene, and xylenes (BTEX); and methyl *tertiary*-butyl ether (MTBE).
- Residual soil contaminant mass in the unsaturated zone is acting as a long-term source of groundwater contamination; the maximum thickness of the residual soil contamination (during lowest water level periods) is approximately 10 feet.
- Previous ORC™ injection programs resulted in apparent permanent reductions at the peripheral plume margins, but were followed by rebound to pre-injection conditions within the central portions of the plume, due to subsequent data indicating more source area residual contamination was present than previous indicated by the site data.
- Low permeability and areas of high groundwater saturation limit more favorable conditions for bioventing as a corrective action to reduce unsaturated zone soil contamination, especially in the near-source area that is inaccessible to other methods due to the hilly topography.
- The area where the bioventing system has been most effective, near VMP-2, has shown continued reductions in hydrocarbon contamination in soil based on the respiration test results between 2007 and 2010.

## **REGULATORY STATUS AND DATA REPORTING**

The lead regulatory agency for the site investigation and remediation is ACEH, with oversight provided by the Water Board. The CDFG is also involved with regard to water quality impacts

to Redwood Creek. Installation and startup of the full-scale bioventing system was approved in 2005, and implementation of the monthly bioventing O&M program with a yearly in-situ respiration test began in 2006 (ACEH, 2005b; ACEH, 2006). ACEH approved the augmentation of the existing bioventing system with two additional vent wells (VW-4 and VW-5) in the source area and the disconnection of VW-3 in 2008 (ACEH, 2008). Monthly monitoring of the system was reduced to quarterly monitoring in 2009 with the approval of ACEH; however, EBRPD staff performs system checks on a monthly basis.

The site is in compliance with the State Water Resources Control Board's GeoTracker requirements for uploading of electronic data and reports. In addition, electronic copies of all bioventing-related reports have been uploaded to the ACEH online file transfer protocol (ftp) system. Per ACEH's October 31, 2005 "Miscellaneous Administrative Topics and Procedures" directive, effective January 31, 2006, paper copies of reports are no longer required to be provided to ACEH.

## 2.0 BIOVENTING SYSTEM DESCRIPTION

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The bioventing system consists of the following components:

- Four vent wells (VWs)—VW-1, VW-2, VW-4, and VW-5—screened across both the saturated and unsaturated zones.
- Four vapor monitoring points (VMPs), each with two nested screened intervals at depths coincident with VW screened intervals.
- A regenerative-type air blower installed in a small shed on the west side of the service yard garage building. The blower is rated at 140 cubic feet per minute (cfm) and exerts a pressure of approximately 1 to 3 pounds per square inch (psi).
- Air distribution piping between the blower and the VW wellheads, including a manifold just downstream of the blower.
- Appurtenant air flow valves, pressure/vacuum gauges, and air sampling ports.

Table 1 summarizes bioventing well construction data. Figure 2 (in the previous chapter) is a site plan showing the layout of the bioventing system. Figures 3 and 4 are as-builts for typical site VMPs and VWs, respectively. Figure 5 is a flow instrumentation diagram for the blower and associated manifold. This blower system was designed and configured based on the pilot test design specifications—i.e., achieving a potential 30-foot radius of influence and a flow rate of 40 standard cubic foot per minute (scfm) to individual VWs under induced pressure conditions.



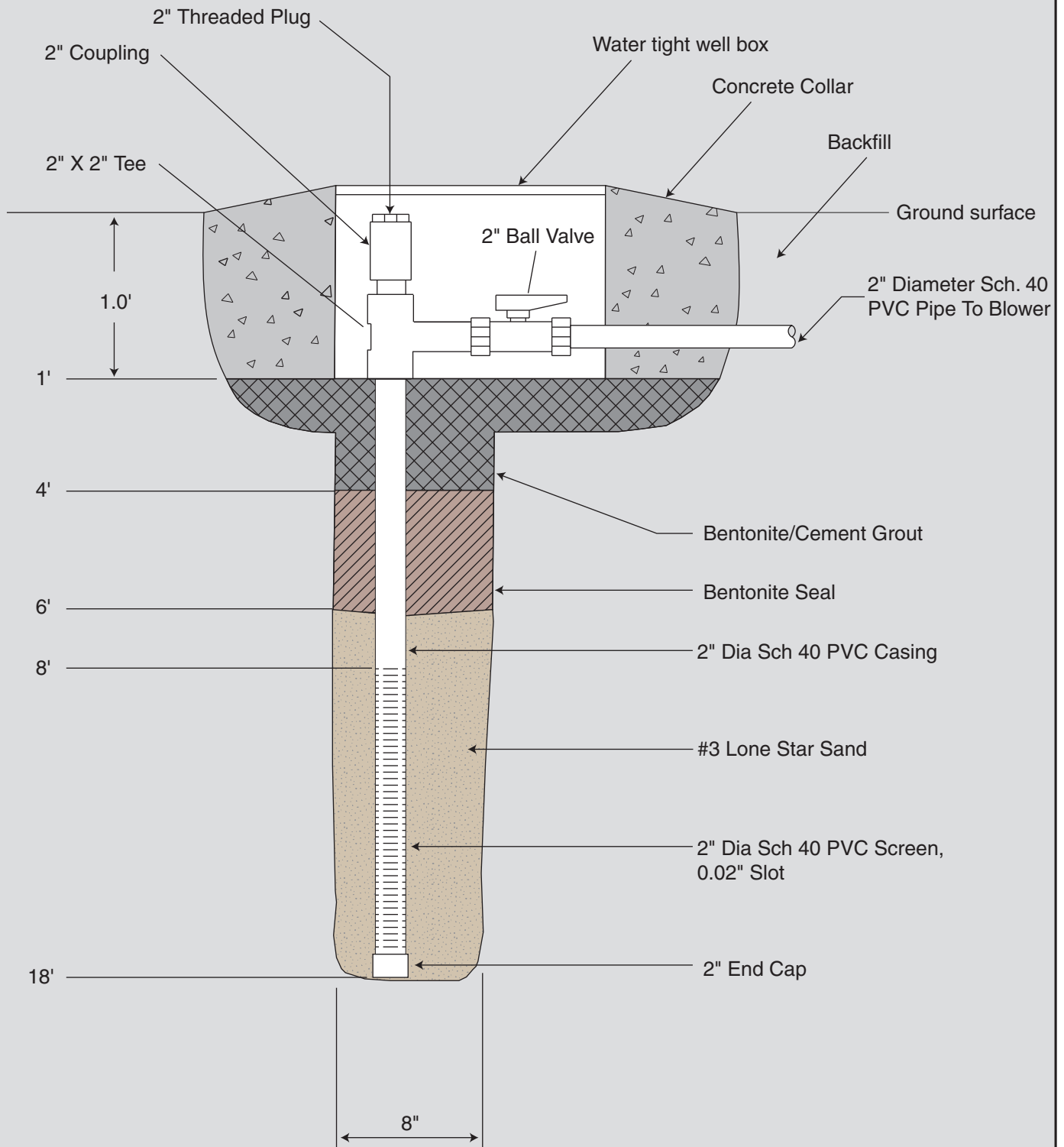
**Table 1**  
**Bioventing Well Construction Data**  
**Redwood Regional Park Service Yard, Oakland, California**

Well	Screen Interval Depth (feet)	Filter Pack Sand Depth Interval (feet)
VW-1	6 – 16	4 – 16
VW-2	8 – 18	6 – 18
VW-3 <sup>(a)</sup>	8 – 18	6 – 18
VW-4	15 – 27	14.5 – 27
VW-5	13 – 26	12.5 – 26
VMP-1	10 – 11.5	9.5 – 12
	14 – 15.5	13.5 – 16
VMP-2	10 – 11.5	9.5 – 12
	14 – 15.5	13.5 – 16
VMP-3	10 – 11.5	9.5 – 12
	12.5 – 14	12 – 14.5
VMP-4	15.5 – 17	15 – 17.5
	20.5 – 22	20 – 20.5

Notes:

<sup>(a)</sup> disconnected

All depths are in feet below top of well box (approximately ground surface).



Note: All connections threaded with gasket or teflon tape. No glues used.

NOT TO SCALE  
(well casing is actually centered in borehole)

**AS-BUILT VENT WELL CONSTRUCTION DETAILS FOR VW-2 & VW-3**

Redwood Regional Park  
Oakland, CA

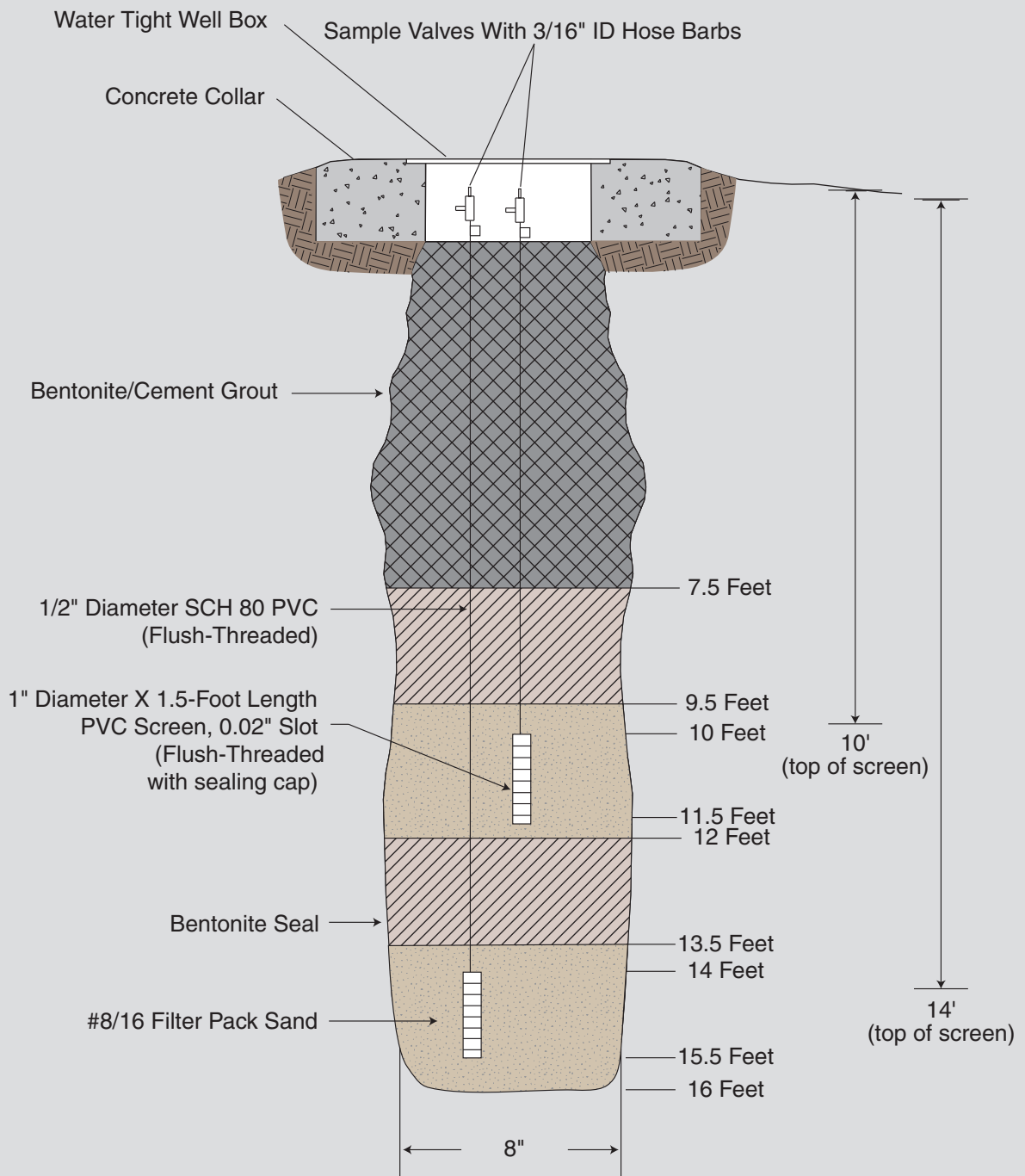
By: MJC

DECEMBER 2005

**Figure 3**

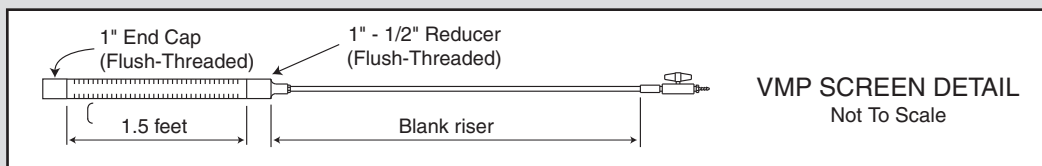


2005-66-09



Not To Scale

Note: Depts shown are applicable to VMP-1 and VMP-2. Depts in VMP-3 and VMP-4 vary.



**AS-BUILT VAPOR MONITORING POINT CONSTRUCTION DETAILS**

Redwood Regional Park  
Oakland, CA

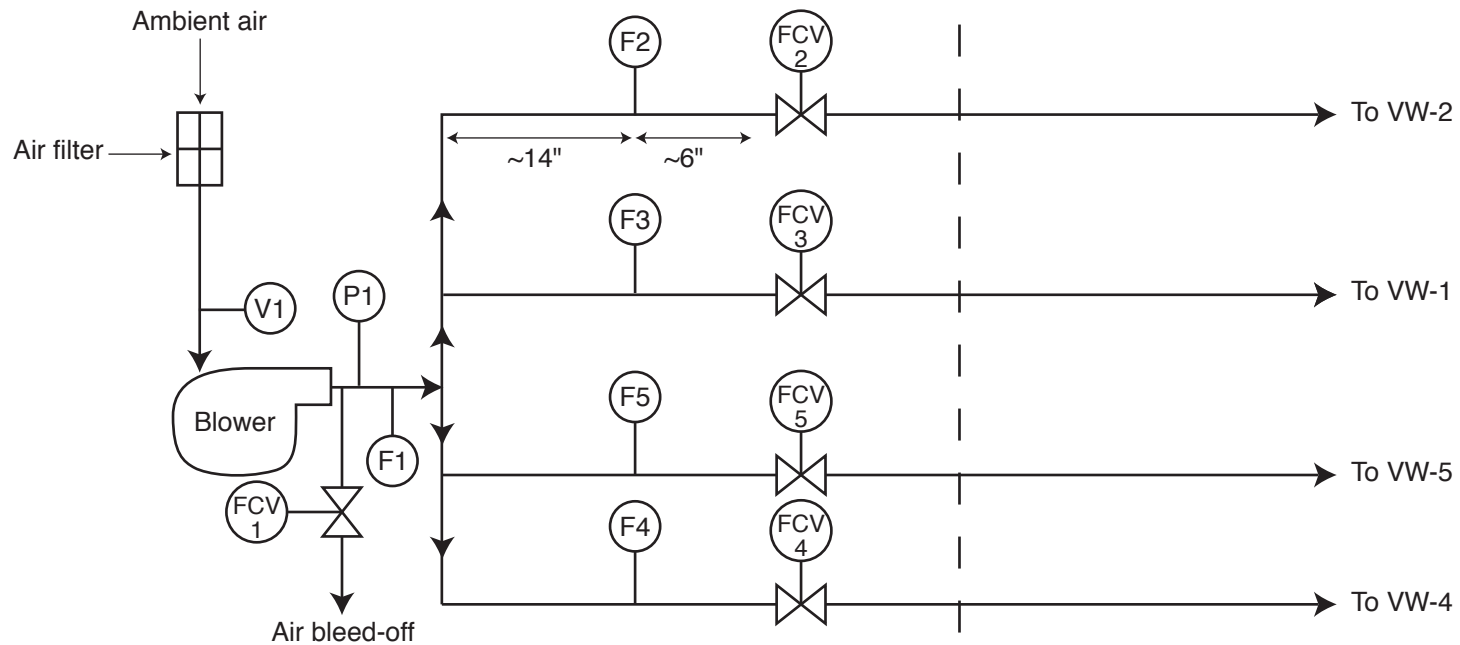
By: MJC

JUNE 2005

**Figure 4**



2005-66-10



**LEGEND**

- Pressure gauge
- Flow measurement port
- Vacuum gauge
- Flow control valve



### **3.0 ANNUAL BIOVENTING SYSTEM ACTIVITIES AND FINDINGS**

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#### **SYSTEM OPERATION**

As discussed in the bioventing system installation and startup report (Stellar Environmental, 2006a), the system was started up in January 2006, and four weekly monitoring/air flow optimization events were conducted. During that time, manifold valves were open to all three VWs; however, no measurable air injection occurred in VW-2 (fully flooded well screen) or VW-3 (partially flooded well screen). Blower outlet pressure during that period was set at 50 inches of water.

Since January 2007, the system has operated continuously with VW-1, VW-2, and VW-3 (prior to closure) fully open, except for temporary system shutdowns for monthly O&M activities. However, even after continuous monitoring and well flushing, no noticeable air flow occurred through VW-3. Two new bioventing wells (VW-4 and VW-5) were installed on March 4, 2008 in the upper portion of the plume area to augment the system, and VW-3, which historically has seen no change in pressurization, was disconnected. Since installation, VW-4 has shown no measurable air flow; however, VW-5 began having noticeable air flow in September 2010 which has continued to date.

Bioventing system operations and maintenance (O&M) events had been conducted monthly since March 2006; however, they have been reduced to quarterly events beginning in 2009. East Bay Regional Redwood Park staff has been checking the system on a weekly basis to ensure it is functioning properly, and will notify Stellar Environmental in the event of a problem.

#### **O&M ACTIVITIES**

Quarterly O&M events were conducted during the first, second, third and fourth quarters as well as during the respiration test (on March 29, June 22, September 28, November 17, and December 16) with the following objectives:

- Confirm that the system was operating within design parameters, with no system problems (e.g., leaks, non-functioning components).
- Conduct preventive maintenance (i.e., clean blower air filter).

- Continue to evaluate air flow through the VW screened intervals.

The quarterly O&M activities included:

- Measure water levels in all VMPs and VWs.
- Inspect aboveground portions of the system (i.e., blower, air distribution piping, and wellheads) for leaks or structural problems.
- Record blower outlet pressure and inlet vacuum.
- Qualitatively evaluate if air was flowing across the VW intervals. This was achieved by opening individual VW manifold wells while the blower was operating, and looking for a drop in blower pressure (a drop in outlet pressure when a valve is opened indicates that air flow is occurring).
- Inspect and clean the blower inlet filter.
- Complete an O&M checklist.

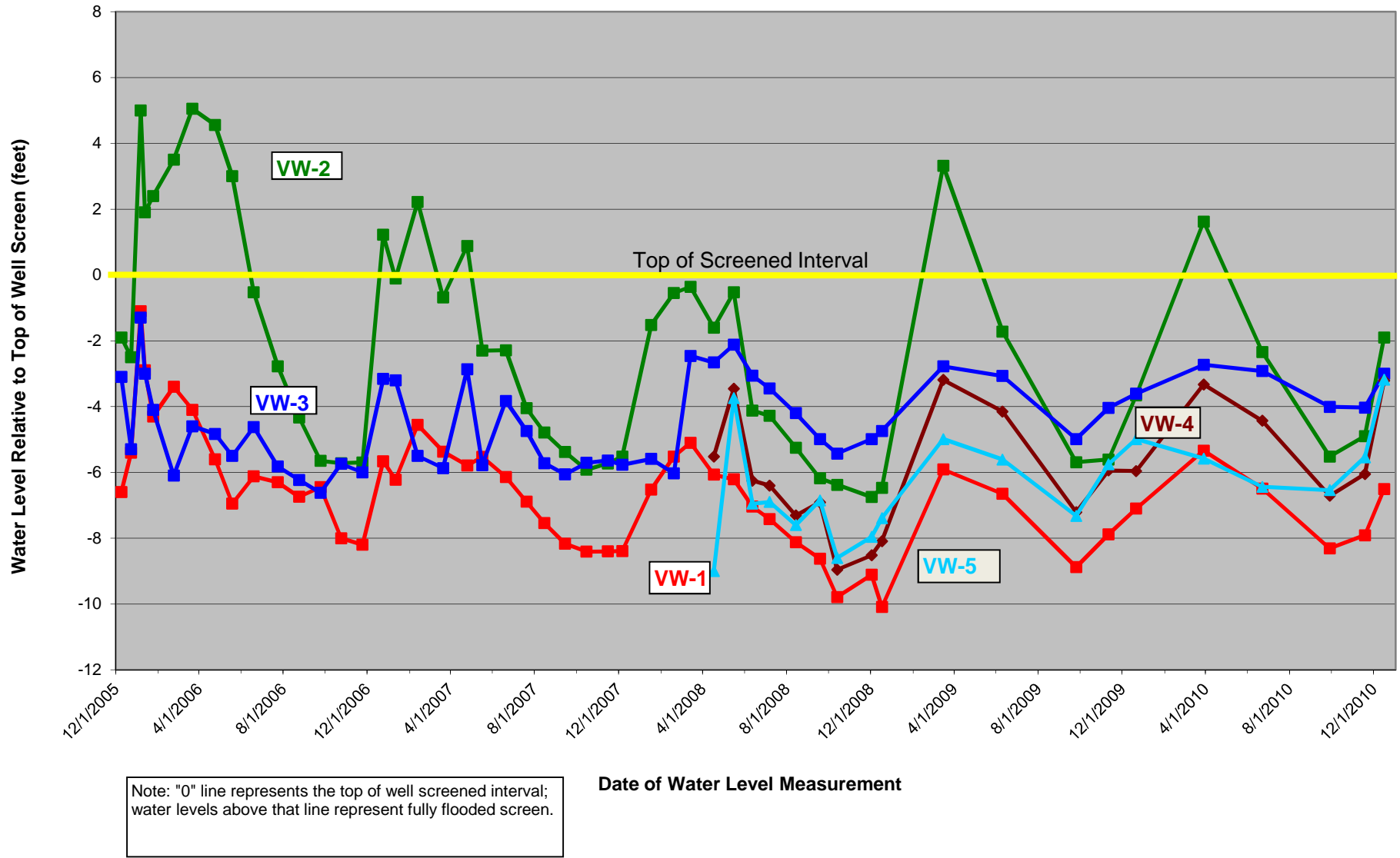
Appendix A contains the completed checklists for the year.

## **O&M FINDINGS**

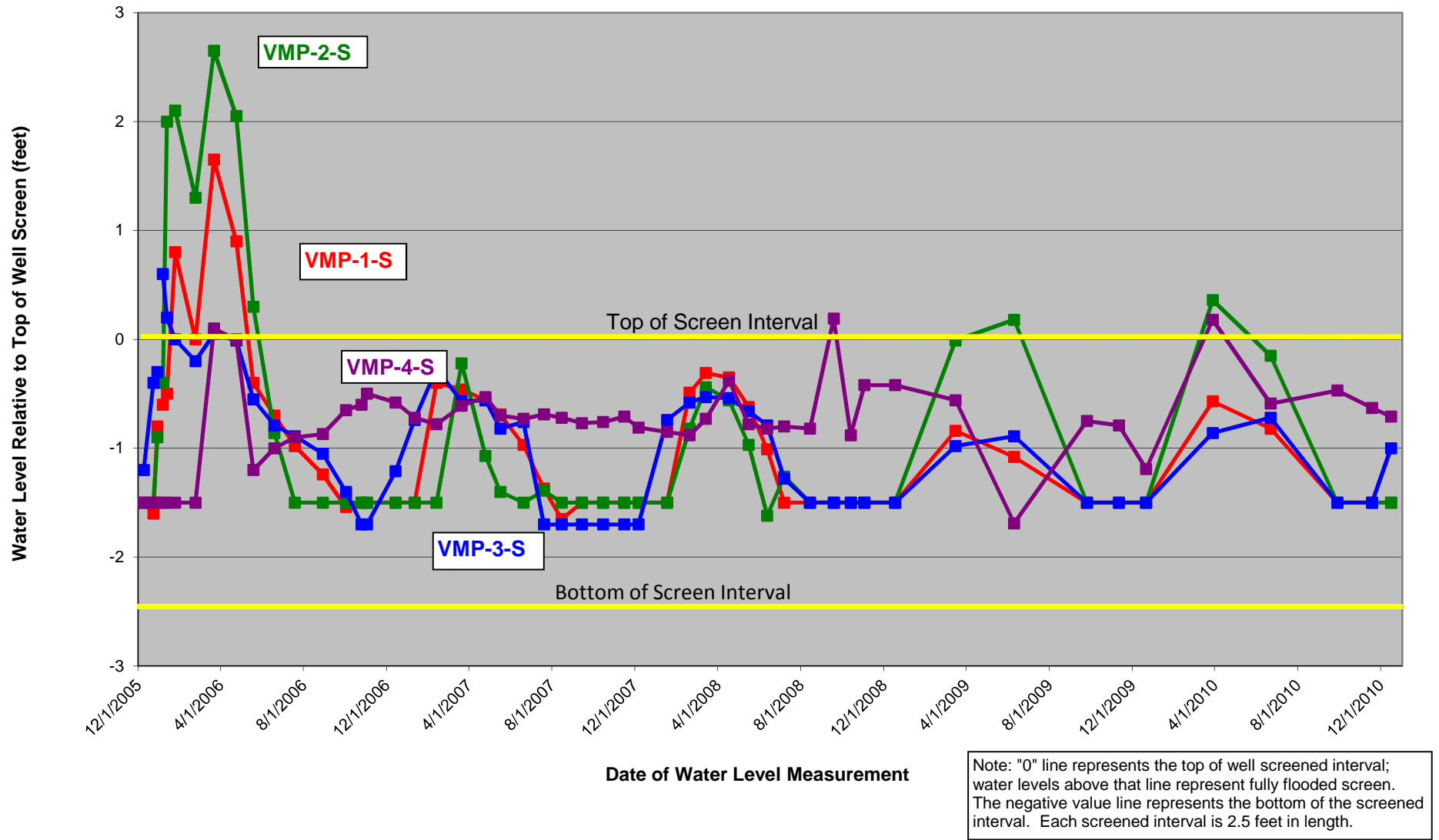
The results of the O&M activities are as follows:

- The blower is currently functioning properly, there are no significant air leaks in the piping system, and the VMP and VW wellheads and air distribution piping are in good condition.
- Water levels are approximately the same in the shallow VMPs as in the deep VMPs (at each nested well location), suggesting that both the deep and shallow VMP well screens are under similar hydraulic conditions.
- Water levels in the VWs showed a general increase after the wells were installed, resulting in partially or fully flooded well screens in VW-1, VW-2, and VW-3. VW-1 and VW-3 showed a water level decrease through September 2006; the water levels in these VWs have fluctuated since then, but have always been below top of screen. As stated previously, VW-3 was decommissioned in March 2008. The water levels in VW-4 and VW-5 have been below the wells screens since installation.

**Figure 6 - Historical Groundwater Levels Relative to Top of VW Screened Intervals  
Redwood Regional Park Service Yard - Oakland, California**

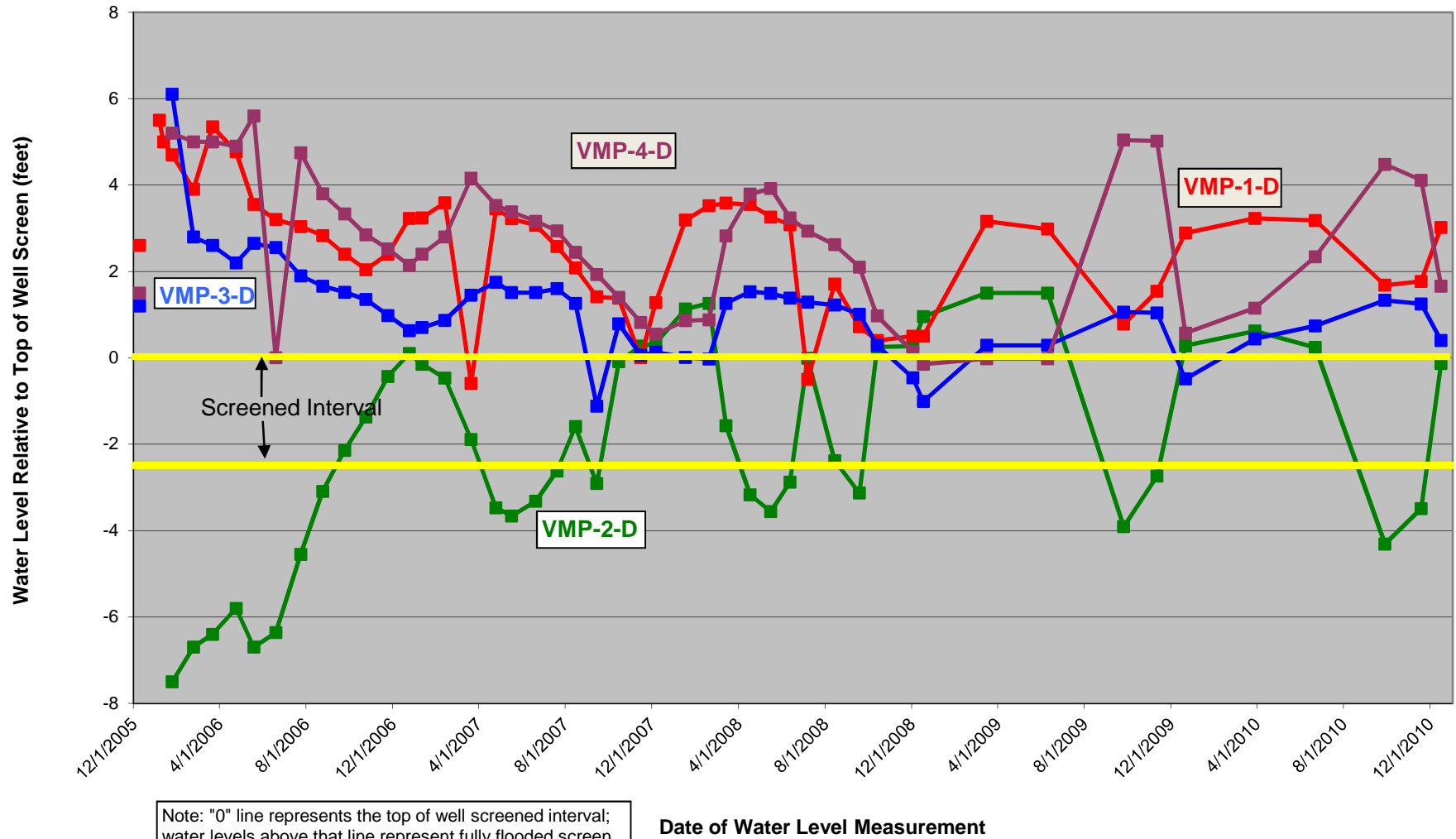


**Figure 7 - Historical Groundwater Levels Relative to Top of Shallow VMP Screened Intervals  
Redwood Regional Park Service Yard - Oakland, California**





**Figure 8 - Historical Groundwater Levels Relative to Top of Deep VMP Screened Intervals  
Redwood Regional Park Service Yard - Oakland, California**



Note: "0" line represents the top of well screened interval; water levels above that line represent fully flooded screen. The negative value line represents the bottom of the screened interval. Each screened interval is 2.5 feet in length.

- Figure 6 shows groundwater levels in VWs relative to the top of the screened interval. In general, the screen in VW-2 has historically been fully flooded during the March monitoring event but is below the screen during the next monitoring event in June. Water levels in VW-1, VW-4, and VW-5 have been below the screen intervals since installation in 2005 and 2008, respectively.
- As shown on Figure 7, groundwater levels in the shallow VMPs have fluctuated slightly since March 2006. VMPs 1 and 3 have remained below the interval since May 2006. VMP-2 was above the interval from March through June 2010, fell back below the interval until March 2009 and has since been sporadic with levels above the interval in March 2009 and March 2010. VMP-4-S was above the interval in September 2008 and March 2010, but has been below the screened interval in subsequent events.
- As shown on Figure 8, water levels in deep VMPs have been relatively stable since the VMPs were installed, with VMP wells 1, 3, and 4 and 5 remaining almost constantly saturated. The exception is VMP-2-D, which has fluctuated above and below the screened interval since September 2006. In 2010, the water level was below the screened interval from approximately June to the latest event in December.
- As in previous quarters, air is injected (and had been since system startup) in the non-flooded portion of the VW-1 and VW-2 screens during the spring (1<sup>st</sup> and 2<sup>nd</sup> quarters), but operates at an optimum level in the 3<sup>rd</sup> and 4<sup>th</sup> quarters.
- No measurable air injection has occurred in VW-4 since its installation in March 2008. The screen in this well has been partially to fully exposed since installation; however, it is screened across silty clay, which appears relatively impermeable to air flow.
- VW-5 had experienced no air injection until September of 2010 when it began operating. It has since had measurable injection to date.

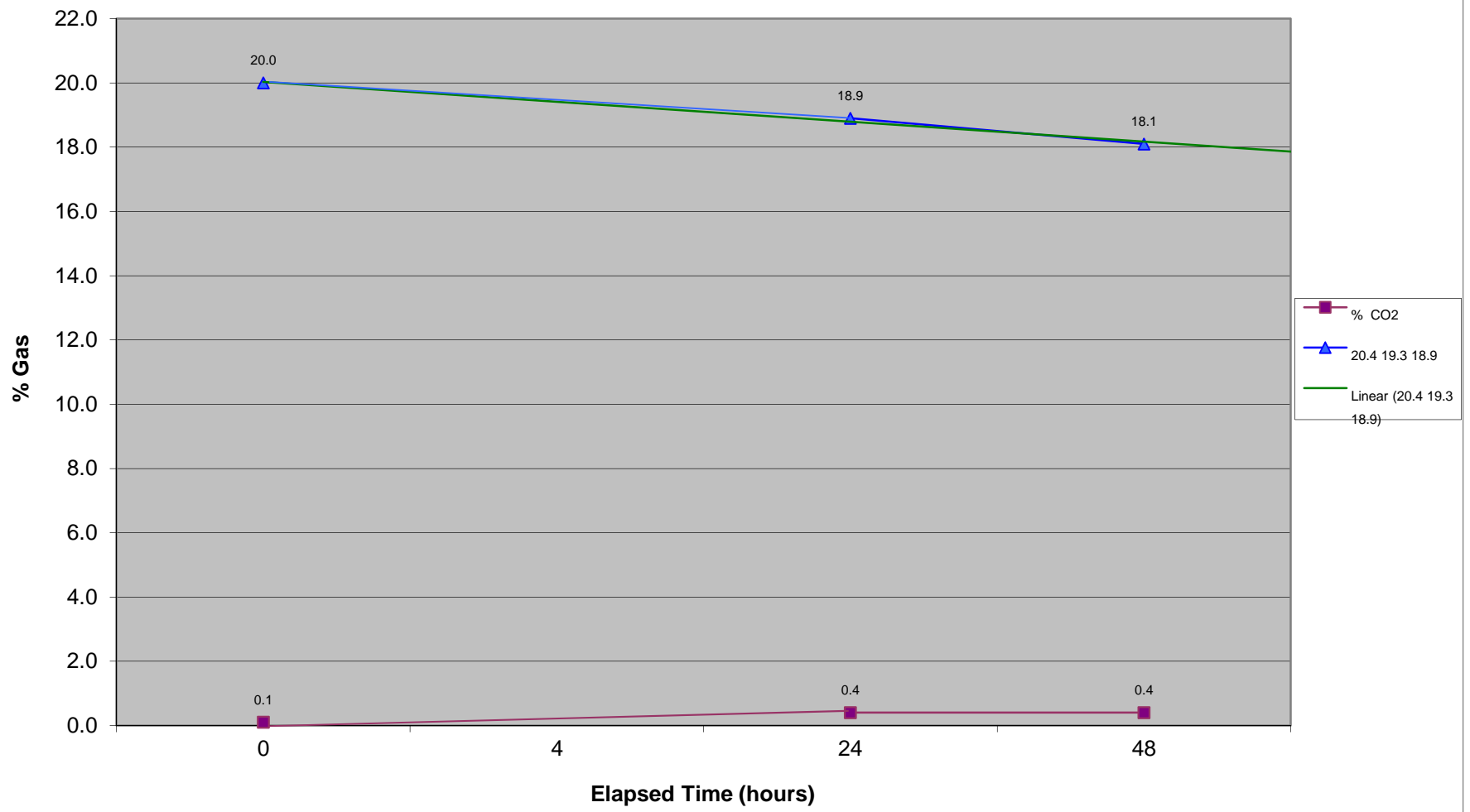
## **IN-SITU RESPIRATION TEST**

Groundwater elevations in the third and fourth quarters of 2010 decreased as compared to the second quarter, reflecting the dry season. The lowering of groundwater below the bioventing screened interval zone allowed for a microbial respiration test to be conducted.

## **RESPIRATION TEST**

A respiration test was conducted at the site to assess the degree of microbial biodegradation activity. Figure 9 is a graph of the oxygen versus carbon dioxide trendline over time. Historical site respiration tests showed microbial activity only occurs in the vapor monitoring points associated with vent wells with measurable air diffusion. Only vent well VW-1 and VW-2 showed measurable air diffusion, therefore the test was conducted utilizing the two shallow (s)

**Figure 9: Respiration Test - November 18-20, 2010**  
**VMP-2S O<sub>2</sub>-CO<sub>2</sub> Trend Plot**  
**Redwood Regional Park Service Yard, Oakland, CA**



and two deep (d) vapor monitoring points that included VMP-1s, VMP-1d, VMP-2s, and VMP-2d, for a total of four measuring points. The test consisted of measuring percent oxygen, percent carbon dioxide, and parts per million by volume air of total volatile hydrocarbons over a 48-hour period.

VMP-2s and 2d and, to a lesser extent, VMP-1s and 1d showed a marginal decrease in oxygen that indicates some microbial activity (oxygen utilization) but basically the operation of the bioventing system has worked to reduce hydrocarbons in this contaminate zone area and there is less residual hydrocarbons for microbial activity. The position of VMP-2 (nearly midway between the two vent wells) and its relatively higher elevation likely resulted in increased aeration and microbial activity at this point. The VMP-2S respiration test results, as shown in Table 2 below, shows a significant reduction in oxygen utilization, CO2 respiration and PID maximum concentrations between 2006 and 2010, although the air delivery has remained constant, indicating a real reduction in hydrocarbons has been achieved. This reduction is supported with the PID readings at VMP-2, which have decreased between 2006 and 2010.

**Table 2**  
**2006 through 2010**  
**48-hour Respiration Test Summary data for VMP-2S**  
**Redwood Regional Park Service Yard, Oakland, California**

<b>Respiration Test Year</b>	<b>O2 Utilization (24-hr decrease)</b>	<b>CO2 Respiration (increase)</b>	<b>Maximum PID Reading (in PPM TVH)</b>	<b>Extrapolation of mg/kg of Hydrocarbon utilization per year</b>
2006	6.1	1.7	1156	1,496
2007	5.8	2.1	182	884
2008	3.6	1.4	135	494
2009	1.9	0.8	25	290
2010	0.9	0.2	55	73

Notes—RP =respiration Test; TVH = Total Volatile Hydrocarbons

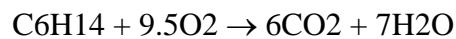
The respiration test response at VMP-2D showed a more pronounced maximum PID reading ( 1,189 PPM TVH), along with higher oxygen utilization (4.9%) and CO2 respiration (1.3%) over the 48 hour respiration test, compared with the shallower (and less hydrocarbon laden) VMP-2S.

This area of VMP-2S/D is the most critical area for bioventing, as it is the source area residual contamination that feeds the groundwater plume. The 48-hour respiration test was designed to



evaluate oxygen utilization by indigenous microorganisms as an indicator of their ability to utilize the hydrocarbons in soil as a food source. Oxygen utilization rates are determined from data obtained during the in-situ respiration test. The rates are calculated as the zero order relationship between percent oxygen and time, typically measuring the percent oxygen decrease within the first 24-hours to estimate a 24-hour utilization rate. Once oxygen concentrations drop below approximately 5 percent, utilization is considered to have ceased.

To calculate oxygen utilization rates, only the first 24-hour linear portion of the data is used because this represents utilization when the oxygen supply is unlimited, as would occur during active bioventing. To estimate hydrocarbon biodegradation rates from the oxygen utilization rates, a stoichiometric relationship for the oxidation of the contaminant is used. For hydrocarbons, hexane is used as the representative hydrocarbon. The stoichiometric relationship used to determine petroleum degradation rates is:



Based on the utilization rates (percent oxygen per day), the biodegradation rate in terms of milligrams of hexane-equivalent per kilogram of soil per day is estimated using the above equation. These terms may be derived through either direct measurement or estimation. The oxygen utilization rate,  $k_o$ , is directly measured in the in-situ respiration test. The ratio of hydrocarbons to oxygen required for mineralization,  $C$ , can be calculated based on stoichiometry (see equation for hexane), but generally will fall between 0.29 and 0.33. This neglects any conversion to biomass, which is small and difficult (if not impossible) to measure.

The respiration test results for 2010 with its marginal oxygen utilization, reflecting the drop in residual hydrocarbons and corroborated by the lower PID readings compared to previous years. The maximum oxygen utilization within the first 24 hours in the 2010 test—at well VMP-2S—is just 0.9 percent. This value is lower than the 1.9, 3.6, 5.8 and 6.1 percent oxygen utilization within the first 24 hours exhibited in the 2009, 2008, 2007, and 2006 respiration tests, respectively. The same decreasing utilizing trend occurred in the 48-hour measurement where the oxygen utilization was 2.1 percent in 2009, 6.5 percent in 2008, 11.0 percent in 2007, and 11.1 percent in 2006. Ideally, in the absence of additional hydrocarbon input from residual hydrocarbons entrained in the upgradient soil sources, the oxygen utilization rate decrease reflects a reduction in hydrocarbon mass over time.

The oxygen utilization is derived from respiration test-derived data. The remainder of the equation used to estimate the biodegradation rate,  $k_B$ , is literature derived, summarized by Leeson and Hinchee (1996) and includes soil bulk density, density of oxygen, and mass of hydrocarbon to oxygen required for mineralization (1/3.5).

The 2010 year data, using the above assumptions, shows an oxygen utilization rate of 0.9 percent of oxygen per day would correspond to a biodegradation rate of approximately 0.2 milligrams per kilogram (mg/kg) per day, or 73 mg/kg per year. This shows the trend of decreasing utilization rates since 2006. During the initial respiration test in 2006, it was found that by using the initial average TPH concentration in soil of 6,000 mg/kg (based on the average of the soil samples from the source area), the oxygen utilization was 6.1 mg/kg per day, or 1,496 mg/kg per year, which was the basis for the estimate of 4-5 years of remediation. These respiration test calculations suggest that in the area of VMP-2, the bioventing has been pretty effective in reducing the hydrocarbons in soil, but also that its operation has reached diminishing returns for contaminant mass reduction.

The respiration test calculation method can underestimate the treatment time because kB decreases over time. At the same time, this calculation overestimates treatment time because it does not consider treatment in the expanded bioreactor. Therefore, the calculation must be coupled with process monitoring to provide field-based evidence—such as reduction in the dissolved hydrocarbon fraction in the Redwood monitoring wells—to gauge whether the site will actually be remediated within this time period. An important key to the long term effective cleanup is also how much new hydrocarbon contaminant mass is being introduced into the system from upgradient of the bioventing system. Due to widely variable contaminant concentrations in the soil (from a few 100 mg/kg to 8,000 mg/kg), average biodegradation rates will not reflect actual biodegradation rates throughout the site. Biodegradation rates also may fluctuate with season and as contaminant concentrations decrease. Therefore, process monitoring is an important parameter in determining treatment time.

## **BIOVENTING SYSTEM RECOMMENDATION**

The recent test results at VW-2 suggest we have reached the limits of the bioventing system use; therefore, Stellar Environmental recommends the system should be shut down for six months. At that point a rebound test should be completed to see if pulsing the bioventing system would provide better efficiency. If no additional benefit is observed, the bioventing system should be decommissioned. The bioventing system is considered to have been as effective as it can be, given its effectiveness within a part of the hydrocarbon contaminated zone and lithologic constraints the limits its effectiveness in other parts of the contaminated zone. In 2011, we recommend it be turned on and monitored after the six month shut-down in June/July 2011 to see if any rebound has occurred.

## **4.0 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS**

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This section presents the conclusions and proposed actions with regard to continued operation of the bioventing corrective action system at the Redwood Regional Park Service Yard.

### **SUMMARY AND CONCLUSIONS**

- The blower is operating within design parameters, and there are no physical problems with the blower or air distribution piping.
- Air flow is occurring at an optimum rate in VW-1 and VW-2; with the best flow observed in VW-2 and the most air penetration associated with VMP-2.
- No measurable air injection has occurred in VW-4 since its installation in March 2008. The screen in this well has been partially to fully exposed since installation; however, it is screened across silty clay, which appears relatively impermeable to air flow.
- VW-5 had experienced no air injection until September of 2010 when it began operating. It has since had measurable injection to date.
- The area where the bioventing system has been most effective, near VMP-2, has shown continued reductions in hydrocarbon contamination in soil based on the respiration test results.
- The bioventing system is considered to have been as effective as it could be given lithologic constraints which limit its effectiveness in other parts of the contaminated zone. Therefore, it should be retired for the first half of 2011 with potential full shut down if no rebound occurs.

### **RECOMMENDATIONS/PROPOSED ACTIONS**

EBRPD proposes to implement the following actions with regard to the bioventing program:

- In 2011 the bioventing system should be shut down February 2011 and remain of for 6 months as the lower oxygen transmission (due to higher water levels) and lower utilization rates in the upper and mid plume area) does not justify the electrical use to power the bioventing system.

- The bioventing system should be restated in July 2011 after post shutdown baseline measurements are done, and the operations ceased altogether or be limited to pulse oxygenation of the most effective wells, VW-1 and VW-2 and potentially VW-5.
- To the extent that the bioventing system operates, continue to have EBRPD employees conduct monthly system O&M events. As Stellar Environmental is proposing to reduce the groundwater monitoring frequency to semi-annually in 2011, system checks would be conducted on semi-annual basis with groundwater monitoring program site work. Results would be reported in an annual bioventing report.
- All future reporting on the bioventing should be incorporated into the surface water/groundwater monitoring progress reports, until petitioning for closure of its operations is appropriate.

## 5.0 REFERENCES

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## **APPENDIX A**

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### **Quarterly System O&M Checklists**

**Redwood Regional Park Service Yard  
Bioventing Operations & Maintenance Checklist  
Vapor Monitoring Points**

Date: 3/29/2010

	Depth to Top of Screen (ft below TOC)	Water Level (ft below TOC)	Well Head in Good Condition?
VMP-1-Shallow	9.3	9.87	Yes
VMP-1-Deep	13.4	10.17	Yes
VMP-2-Shallow	9.5	9.14	Yes
VMP-2-Deep	13.9	9.59	Yes
VMP-3-Shallow	9.8	10.66	Yes
VMP-3-Deep	12.0	10.67	Yes
VMP-4-Shallow	15.1	14.92	Yes
VMP-4-Deep	20.8	16.32	Yes

TOC= Top of well Casing

**Redwood Regional Park Service Yard  
Bioventing Operations & Maintenance Checklist  
Vapor Monitoring Points**

Date: 6/22/2010

	Depth to Top of Screen (ft below TOC)	Water Level (ft below TOC)	Well Head in Good Condition?
VMP-1-Shallow	9.3	10.12	Yes
VMP-1-Deep	13.4	10.22	Yes
VMP-2-Shallow	9.5	9.65	Yes
VMP-2-Deep	13.9	10.41	Yes
VMP-3-Shallow	9.8	10.52	Yes
VMP-3-Deep	12.0	10.75	Yes
VMP-4-Shallow	15.1	15.69	Yes
VMP-4-Deep	20.8	16.69	Yes

TOC= Top of well Casing

**Redwood Regional Park Service Yard  
Bioventing Operations & Maintenance Checklist  
Vapor Monitoring Points**

Date: 9/28/2010

	Depth to Top of Screen (ft below TOC)	Water Level (ft below TOC)	Well Head in Good Condition?
VMP-1-Shallow	9.3	Dry	Yes
VMP-1-Deep	13.4	11.72	Yes
VMP-2-Shallow	9.5	Dry	Yes
VMP-2-Deep	13.9	13.77	Yes
VMP-3-Shallow	9.8	Dry	Yes
VMP-3-Deep	12.0	11.6	Yes
VMP-4-Shallow	15.1	15.57	Yes
VMP-4-Deep	20.8	19.14	Yes

TOC= Top of well Casing

**Redwood Regional Park Service Yard  
Bioventing Operations & Maintenance Checklist  
Vapor Monitoring Points**

Date: 11/17/2010

	Depth to Top of Screen (ft below TOC)	Water Level (ft below TOC)	Well Head in Good Condition?
VMP-1-Shallow	9.3	Dry	Yes
VMP-1-Deep	13.4	11.63	Yes
VMP-2-Shallow	9.5	Dry	Yes
VMP-2-Deep	13.9	14.03	Yes
VMP-3-Shallow	9.8	Dry	Yes
VMP-3-Deep	12.0	11.82	Yes
VMP-4-Shallow	15.1	15.73	Yes
VMP-4-Deep	20.8	19.1	Yes

TOC= Top of well Casing

**Redwood Regional Park Service Yard  
Bioventing Operations & Maintenance Checklist  
Vapor Monitoring Points**

Date: 12/16/2010

	Depth to Top of Screen (ft below TOC)	Water Level (ft below TOC)	Well Head in Good Condition?
VMP-1-Shallow	9.3	Dry	Yes
VMP-1-Deep	13.4	10.38	Yes
VMP-2-Shallow	9.5	Dry	Yes
VMP-2-Deep	13.9	12.92	Yes
VMP-3-Shallow	9.8	10.80	Yes
VMP-3-Deep	12.0	10.92	Yes
VMP-4-Shallow	15.1	15.81	Yes
VMP-4-Deep	20.8	16.88	Yes

TOC= Top of well Casing

**Redwood Regional Park Service Yard  
Bioventing Operation & Maintenance Checklist  
Blower and Vent Wells**

Date: 3/29/2010

	Air Flow (scfm)		Blower Inlet Vaccum (inches H <sub>2</sub> O)		Blower Outlet Pressure (inches H <sub>2</sub> O)		Depth to Top of Screen (ft below TOC)	Water Level (ft below TOC)	Well Head in Good Condition?
	Before adjustment	After adjustment	Before adjustment	After adjustment	Before adjustment	After adjustment			
Blower <sup>(a)</sup>	NM	NM	22	26	40	20			
VW-1 <sup>(b)</sup>	NM	NM					5.6	10.94	Yes
VW-2 <sup>(b)</sup>	NM	NM					8.4	6.78	Yes
VW-3 <sup>(b)</sup>	NM	NM					8.8	11.53	Yes
VW-4 <sup>(b)</sup>	NM	NM					15	18.33	Yes
VW-5 <sup>(b)</sup>	NM	NM					13	20.58	Yes

Wells on-line (valve open) at arrival 1, 2, 4, 5 Wells on-line at departure 1, 2, 4, 5

Notes:

<sup>(a)</sup> Air flow measured at sampling port between blower discharge and manifold.

<sup>(b)</sup> Air flow measured at blower manifold sampling port

TOC - Top of Casing of well      NM = Not Measured

Checklist Items

Is any airflow evident through VW-1? 20 inches H<sub>2</sub>O drop  
(Close all VW valves, set outlet pressure at 40 inches H<sub>2</sub>O, then open VW-1 valve only)

Is any airflow evident through VW-2? 0 inches H<sub>2</sub>O drop  
(Close all VW valves, set outlet pressure at 40 inches H<sub>2</sub>O, then open VW-2 valve only)

Is any airflow evident through VW-3? Not operating inches H<sub>2</sub>O drop  
(Close all VW valves, set outlet pressure at 40 inches H<sub>2</sub>O, then open VW-3 valve only)

Is any airflow evident through VW-4? 0 inches H<sub>2</sub>O drop  
(Close all VW valves, set outlet pressure at 40 inches H<sub>2</sub>O, then open VW-4 valve only)

Is any airflow evident through VW-5? 0 inches H<sub>2</sub>O drop  
(Close all VW valves, set outlet pressure at 40 inches H<sub>2</sub>O, then open VW-5 valve only)

Any audible air leaks in air distribution piping or VW wellheads? No

Blower filter removed and brushed off? Yes Blower filter replaced? No

**Redwood Regional Park Service Yard  
Bioventing Operation & Maintenance Checklist  
Blower and Vent Wells**

Date: 6/22/2010

	Air Flow (scfm)		Blower Inlet Vaccum (inches H <sub>2</sub> O)		Blower Outlet Pressure (inches H <sub>2</sub> O)		Depth to Top of Screen (ft below TOC)	Water Level (ft below TOC)	Well Head in Good Condition?
	Before adjustment	After adjustment	Before adjustment	After adjustment	Before adjustment	After adjustment			
Blower <sup>(a)</sup>	NM	NM	22	22	36	40			
VW-1 <sup>(b)</sup>	NM	NM					5.6	12.09	Yes
VW-2 <sup>(b)</sup>	NM	NM					8.4	10.74	Yes
VW-3 <sup>(b)</sup>	NM	NM					8.8	11.72	Yes
VW-4 <sup>(b)</sup>	NM	NM					15	19.43	Yes
VW-5 <sup>(b)</sup>	NM	NM					13	21.44	Yes

Wells on-line (valve open) at arrival 1, 2, 4, and 5 Wells on-line at departure 1, 2, 4, and 5

Notes:

<sup>(a)</sup> Air flow measured at sampling port between blower discharge and manifold.

<sup>(b)</sup> Air flow measured at blower manifold sampling port

TOC - Top of Casing of well      NM = Not Measured

Checklist Items

Is any airflow evident through VW-1? 20 inches H<sub>2</sub>O drop  
(Close all VW valves, set outlet pressure at 40 inches H<sub>2</sub>O, then open VW-1 valve only)

Is any airflow evident through VW-2? 2 inches H<sub>2</sub>O drop  
(Close all VW valves, set outlet pressure at 40 inches H<sub>2</sub>O, then open VW-2 valve only)

Is any airflow evident through VW-3? unconnected inches H<sub>2</sub>O drop  
(Close all VW valves, set outlet pressure at 40 inches H<sub>2</sub>O, then open VW-3 valve only)

Is any airflow evident through VW-4? 0 inches H<sub>2</sub>O drop  
(Close all VW valves, set outlet pressure at 40 inches H<sub>2</sub>O, then open VW-4 valve only)

Is any airflow evident through VW-5? 0 inches H<sub>2</sub>O drop  
(Close all VW valves, set outlet pressure at 40 inches H<sub>2</sub>O, then open VW-5 valve only)

Any audible air leaks in air distribution piping or VW wellheads? No

Blower filter removed and brushed off? Yes Blower filter replaced? No



**Redwood Regional Park Service Yard  
Bioventing Operation & Maintenance Checklist  
Blower and Vent Wells**

Date: 9/28/2010

	Air Flow (scfm)		Blower Inlet Vaccum (inches H <sub>2</sub> O)		Blower Outlet Pressure (inches H <sub>2</sub> O)		Depth to Top of Screen (ft below TOC)	Water Level (ft below TOC)	Well Head in Good Condition?
	Before adjustment	After adjustment	Before adjustment	After adjustment	Before adjustment	After adjustment			
Blower <sup>(a)</sup>	NM	NM	28	28	20	20			
VW-1 <sup>(b)</sup>	NM	NM					5.6	13.91	Yes
VW-2 <sup>(b)</sup>	NM	NM					8.4	13.92	Yes
VW-3 <sup>(b)</sup>	NM	NM					8.8	12.81	Yes
VW-4 <sup>(b)</sup>	NM	NM					15	21.71	Yes
VW-5 <sup>(b)</sup>	NM	NM					13	21.54	Yes

Wells on-line (valve open) at arrival 1,2,4,5 Wells on-line at departure 1,2,4,5

Notes:

<sup>(a)</sup> Air flow measured at sampling port between blower discharge and manifold.

<sup>(b)</sup> Air flow measured at blower manifold sampling port

TOC - Top of Casing of well      NM = Not Measured

Checklist Items

Is any airflow evident through VW-1? 20 inches H<sub>2</sub>O drop  
(Close all VW valves, set outlet pressure at 40 inches H<sub>2</sub>O, then open VW-1 valve only)

Is any airflow evident through VW-2? 20 inches H<sub>2</sub>O drop  
(Close all VW valves, set outlet pressure at 40 inches H<sub>2</sub>O, then open VW-2 valve only)

Is any airflow evident through VW-3? Not operating inches H<sub>2</sub>O drop  
(Close all VW valves, set outlet pressure at 40 inches H<sub>2</sub>O, then open VW-3 valve only)

Is any airflow evident through VW-4? 0 inches H<sub>2</sub>O drop  
(Close all VW valves, set outlet pressure at 40 inches H<sub>2</sub>O, then open VW-4 valve only)

Is any airflow evident through VW-5? 20 inches H<sub>2</sub>O drop  
(Close all VW valves, set outlet pressure at 40 inches H<sub>2</sub>O, then open VW-5 valve only)

Any audible air leaks in air distribution piping or VW wellheads? No

Blower filter removed and brushed off? Yes Blower filter replaced? No

**Redwood Regional Park Service Yard  
Bioventing Operation & Maintenance Checklist  
Blower and Vent Wells**

Date: 11/18/2010

	Air Flow (scfm)		Blower Inlet Vaccum (inches H <sub>2</sub> O)		Blower Outlet Pressure (inches H <sub>2</sub> O)		Depth to Top of Screen (ft below TOC)	Water Level (ft below TOC)	Well Head in Good Condition?
	Before adjustment	After adjustment	Before adjustment	After adjustment	Before adjustment	After adjustment			
Blower <sup>(a)</sup>	NM	NM	28	28	18	18			
VW-1 <sup>(b)</sup>	NM	NM					5.6	13.51	Yes
VW-2 <sup>(b)</sup>	NM	NM					8.4	13.30	Yes
VW-3 <sup>(b)</sup>	NM	NM					8.8	12.83	Yes
VW-4 <sup>(b)</sup>	NM	NM					15	21.05	Yes
VW-5 <sup>(b)</sup>	NM	NM					13	20.54	Yes

Wells on-line (valve open) at arrival 1,2,4,5 Wells on-line at departure 1,2,4,5

Notes:

<sup>(a)</sup> Air flow measured at sampling port between blower discharge and manifold.

<sup>(b)</sup> Air flow measured at blower manifold sampling port

TOC - Top of Casing of well      NM = Not Measured

Checklist Items

Is any airflow evident through VW-1? 20 inches H<sub>2</sub>O drop  
(Close all VW valves, set outlet pressure at 40 inches H<sub>2</sub>O, then open VW-1 valve only)

Is any airflow evident through VW-2? 22 inches H<sub>2</sub>O drop  
(Close all VW valves, set outlet pressure at 40 inches H<sub>2</sub>O, then open VW-2 valve only)

Is any airflow evident through VW-3? Not operating inches H<sub>2</sub>O drop  
(Close all VW valves, set outlet pressure at 40 inches H<sub>2</sub>O, then open VW-3 valve only)

Is any airflow evident through VW-4? 0 inches H<sub>2</sub>O drop  
(Close all VW valves, set outlet pressure at 40 inches H<sub>2</sub>O, then open VW-4 valve only)

Is any airflow evident through VW-5? 20 inches H<sub>2</sub>O drop  
(Close all VW valves, set outlet pressure at 40 inches H<sub>2</sub>O, then open VW-5 valve only)

Any audible air leaks in air distribution piping or VW wellheads? No

Blower filter removed and brushed off? Yes Blower filter replaced? No

**Redwood Regional Park Service Yard  
Bioventing Operation & Maintenance Checklist  
Blower and Vent Wells**

Date: 12/16/2010

	Air Flow (scfm)		Blower Inlet Vaccum (inches H <sub>2</sub> O)		Blower Outlet Pressure (inches H <sub>2</sub> O)		Depth to Top of Screen (ft below TOC)	Water Level (ft below TOC)	Well Head in Good Condition?
	Before adjustment	After adjustment	Before adjustment	After adjustment	Before adjustment	After adjustment			
Blower <sup>(a)</sup>	NM	NM	Off	28	Off	20			
VW-1 <sup>(b)</sup>	NM	NM					5.6	12.11	Yes
VW-2 <sup>(b)</sup>	NM	NM					8.4	10.30	Yes
VW-3 <sup>(b)</sup>	NM	NM					8.8	11.80	Yes
VW-4 <sup>(b)</sup>	NM	NM					15	18.21	Yes
VW-5 <sup>(b)</sup>	NM	NM					13	18.18	Yes

Wells on-line (valve open) at arrival Off Wells on-line at departure 1, 2, 4, & 5

Notes:

<sup>(a)</sup> Air flow measured at sampling port between blower discharge and manifold.

<sup>(b)</sup> Air flow measured at blower manifold sampling port

TOC - Top of Casing of well      NM = Not Measured

Checklist Items

Is any airflow evident through VW-1? 20 inches H<sub>2</sub>O drop  
(Close all VW valves, set outlet pressure at 40 inches H<sub>2</sub>O, then open VW-1 valve only)

Is any airflow evident through VW-2? 21 inches H<sub>2</sub>O drop  
(Close all VW valves, set outlet pressure at 40 inches H<sub>2</sub>O, then open VW-2 valve only)

Is any airflow evident through VW-3? Not operating inches H<sub>2</sub>O drop  
(Close all VW valves, set outlet pressure at 40 inches H<sub>2</sub>O, then open VW-3 valve only)

Is any airflow evident through VW-4? 0 inches H<sub>2</sub>O drop  
(Close all VW valves, set outlet pressure at 40 inches H<sub>2</sub>O, then open VW-4 valve only)

Is any airflow evident through VW-5? 20 inches H<sub>2</sub>O drop  
(Close all VW valves, set outlet pressure at 40 inches H<sub>2</sub>O, then open VW-5 valve only)

Any audible air leaks in air distribution piping or VW wellheads? No

Blower filter removed and brushed off? Yes Blower filter replaced? No

**REDWOOD REGIONAL PARK**

**RESPIRATION TEST Date: 11/18/10 - 11/20/10**

<b>VMP-1S</b>				
ELAPSED HOURS	%CO2	%O2	ppm TVH	
	Actual			
0	0	0.1	20.8	0.7
4				
24	22.33	0.2	20.5	8.6
48	47.5	0.3	19.6	79.0

<b>VMP-2S</b>				
ELAPSED HOURS	% CO <sub>2</sub>	% O <sub>2</sub>	ppm TVH	
	Actual			
0	0	0.1	20.4	55.0
4				
24	21.5	0.4	19.3	6.7
48	47.33	0.4	18.9	3.2

<b>VMP-4S</b>				
ELAPSED HOURS	% CO <sub>2</sub>	% O <sub>2</sub>	ppm TVH	
	Actual			
0				
4				
24				
48				

<b>VMP-5S</b>				
ELAPSED HOURS	% CO <sub>2</sub>	% O <sub>2</sub>	ppm TVH	
	Actual			
0				
4				
24				
48				

<b>VMP-1D</b>				
ELAPSED HOURS	%CO2	%O2	ppm TVH	
	Actual			
0	0	0.2	19.9	535.0
4				
24	22.16	0.2	20.4	152.0
48	23.5	0.3	20.1	29.0

<b>VMP-2D</b>				
ELAPSED HOURS	%CO2	%O2	ppm TVH	
	Actual			
0	0	1.1	16.2	1104
4				
24	21.5	1.8	13.4	1147
48	47.25	2.4	11.3	1189.0

<b>VMP-4D</b>				
ELAPSED HOURS	%CO2	%O2	ppm TVH	
	Actual			
0				
4				
24				
48				

<b>VMP-5D</b>				
ELAPSED HOURS	%CO2	%O2	ppmTVH	
	Actual			
0				
4				
24				
48				

<b>VW-1</b>				
ELAPSED HOURS	%CO2	%O2	ppm TVH	
	Actual			
0				
4				
24				
48				

<b>VW-2</b>				
ELAPSED HOURS	%CO2	%O2	ppm TVH	
	Actual			
0				
4				
24				
48				

<b>VW-4</b>				
ELAPSED HOURS	%CO2	%O2	ppm TVH	
	Actual			
0				
4				
24				
48				

<b>VW-5</b>				
ELAPSED HOURS	%CO2	%O2	ppm TVH	
	Actual			
0				
4				
24				
48				