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Completion of One-Year Bioventing Tests: . . .

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DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
BROOKS AIR FORCE BASE TEXAS

13 April 1995

MEMORANDUM FOR SM-ALC/EMR
ATTN: MR. MARIO IERARDI

FROM: HQ AFCEE/ERT
8001 Arnold Drive
Brooks AFB TX 78235-5357

SUBJECT: Completion of One Year Bioventing Tests: Tank Farm #2; Tank Farm #4; SA-6; PRL-T46; Davis Global Communications

The Air Force Center for Environmental Excellence Technology Transfer Division (AFCEE/ERT) one-year bioventing test and evaluation projects at the above sites have been completed. The executive summary is: 1) Bioventing works at McClellan And Davis; 2) As per McClellan's request AFCEE/ERT will conduct closure sampling at Tank Farm #4; 3) Tank Farm #2 and #4, SA-6, and PRL-T46 are currently full-scale; 4) As per McClellan's request, AFCEE/ERT will expand the Davis system to full-scale; 5) AFCEE/ERT requests McClellan provide additional site data to confirm full-scale designations and to select an alternate bioventing site; 6) AFCEE/ERT appreciates McClellan's support of the AFCEE/ERT Bioventing Initiative.

The attached Figure 1 provides general site information and Table 1 provides a summary of initial, six-month, and one-year fuel biodegradation rates measured at designated monitoring points at each site. Table 2 provides a summary of initial and final soil and soil gas sampling results for total recoverable petroleum hydrocarbons (TRPH) and benzene, toluene, ethylbenzene, and xylenes (BTEX). Based on results from your site and 120 other sites, currently under operation, bioventing is cost-effectively remediating fuel contamination in a reasonable time frame. Based on the attached results, bioventing stands as viable and cost-effective technology for the above sites and similar sites. In general AFCEE/ERT recommends that the applicability of bioventing be based on a site-specific review according to the criteria in the AFCEE Test Plan and Technical Protocol for a Field Treatability Test for Bioventing, May 1992, including Addendum One, February, 1994. These documents are found in the AFCEE/ERT "Tool Box" sent previously. Specific recommendations for the above sites follow.

The objective of the one year sampling effort was not to collect the large number of samples required for comprehensive statistical analysis. It was conducted to give a qualitative indication of changes in contaminant mass at each site within the Bioventing Initiative. Soil gas samples are somewhat similar to composite samples in that they are collected over a wider area. Thus, they provide a good indication of changes in soil gas profiles and volatile contaminant mass (See Addendum One to Test Plan and Technical Protocol for a Field Treatability Test for Bioventing - Using Soil Gas Surveys to Determine Bioventing Feasibility and Natural Attenuation Potential, February 1994). Soil samples, on the other hand, are discrete point samples subject to large variabilities over small distances/soil types. Given this variability coupled with known sampling and analytical variabilities, a large number of samples would have to be collected to conclusively determine "real" changes in soil contamination. Because of the limited number of samples, these results should not be viewed as conclusive indicators of bioventing progress or evidence of the success or failure of this technology. In situ respiration tests are considered to be better indicators of hydrocarbon remediation than limited soil sampling.

Site-specific Results:

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Tank Farm #2:

Conceptual Site Model:

The conceptual site model for Tank Farm #2 includes low volatility fuel contamination in the upper 30 feet of soil which includes excavated material that was returned to the excavation pit. Residual contamination has not impacted the ground water which is approximately 105 feet below the ground surface (bgs.). See the AFCEE/ERT *Bioventing Pilot Test Workplan/Interim Test results for Tank Farm #2; Tank Farm #4; SA-6; PRL-T46; Davis Global Communications*, February 1994.

Air Permeability Radius of Influence:

Using standard in situ air permeability testing methods, an in situ pressure response in excess of 2 inches of water was measured at all nine individual vapor monitoring points to include vapor monitoring point cluster 3 (VMP-3) which is 50 feet from the vent well (Appendix D). Thus, at an air permeability test air injection rate of 30 scfm (100 inH_2O), there is a significant pressure response 50 feet from the injection well.

Oxygen Radius of Influence:

At a long-term air injection rate of 50 scfm, the initial oxygen radius of influence was greater than 15 feet on 27 Jul 1993 and extended to greater than 30 feet by 31 Aug 1993 (Table 3.2). Thus, since there is a significant pressure differential at a radius of 50 feet, as respiration or oxygen utilization rates decrease, the oxygen radius of influence will likely increase to greater than 50 feet. This can be confirmed with O_2 measurements at all VMPs.

Trends in Hydrocarbon Concentrations and Degradation Rates:

Soil Gas:

Total volatile hydrocarbons (TVH) soil gas levels were relatively high prior to bioventing (22,000 - 35,000 ppmV). After bioventing, TVH soil gas concentrations in VW1 and VMP1-20 were reduced by roughly two orders of magnitude despite the fact that all bioventing systems at McClellan AFB were shut-off one month prior to sampling in order to include any rebound effects. Soil gas concentrations at VMP3-13 did not change significantly over a one year period. However, degradation rates increased significantly. There appeared to be a increase in soil temperatures which could explain the increased rates. Another contributing my be the expanding treatment zone wherein outer points increase in activity as oxygen is made available. Reductions in BTEX soil gas levels are very prominent across all McClellan sites.

Soil:

Soil concentrations were low across the site. The highest concentrations ever reported include sample S3 (2900 mg/kg, 20' bgs.). Bioventing VMP1 was installed very near the S3 sampling location. Hydrocarbon degradation rates were higher in this area. Sample VMP1-20 was collected during bioventing system installation and was nondetect for TRPH and 202 mg/kg during a 1-year sampling event. Thus, the trend in TRPH started low and ended low. A more clear cut trend is the presence of enhanced hydrocarbon degradation and the preferential removal of BTEX compounds. This is evidenced in the many cases where TRPH values may increase due to natural variability. However, BTEX concentrations have been reduced dramatically in all instances.

Zone of Treatment:

The bottom-line is that the treatment zone at Tank Farm #2 continues to display significant hydrocarbon degradation and will extend beyond a 50 foot radius of influence as treatment progresses. This system should provide treatment of any hydrocarbon contamination roughly within the fenced area of Tank Farm #2 which includes the entire tank cavity and surrounding area. Based on site characterization data sent to AFCEE/ERT, this system is full-scale in the sense that sample/boring locations S1-S9, borings 15, 16, 17, 18 are within the current treatment zone. Further confirmation is based on sampling and analysis conducted by AFCEE/ERT's contractor, Engineering Science. Initial (July 1993) and 1-year contaminant levels were relatively low for the contaminants of concern (BTEX < 6 mg/kg) and dramatically low for Total Recoverable Petroleum Hydrocarbons (TRPH < 202 mg/kg). Initial conditions at the site included relatively high soil gas concentrations (See attached Table 2). One-year soil gas results were dramatically lower. VMP3-13 was an exception. This result at VMP3-13 is probably one of the best reasons to continue to operate the system since biodegradation rates have increased at this location and this is consistent with the expanding zone of oxygenation that occurs as contaminant levels are reduced in the center-most regions. The quantitative reduction of soil gas represents a preferential treatment of the higher potential risk compounds. Also, the vertical extent of contamination has been delineated within this study (Table 1.1). If contamination is known to be present outside this area, AFCEE/ERT recommends that McClellan contact AFCEE/ERT to discuss options and update the AFCEE/ERT full-scale designation assigned this site.

AFCEE/ERT Recommendation:

AFCEE/ERT recommends continued operation of the Tank Farm #2 system with closure sampling to be completed when respiration rates drop to near background levels. The decision to return excavated material to the tank excavation was a good one since in situ bioventing treatment is far more cost-effective than off-site treatment and/or disposal and provides treatment of the remaining subsurface contamination.

Tank Farm #4:

Conceptual Site Model:

The contamination profile for Tank Farm #4 includes the 9 out of 11 nondetects for total petroleum hydrocarbons (TPH) each analyzed by three different TPH analytical methods and 6 out of eleven nondetects for BTEX analyzed by EPA method SW8020 (See Table 2.2). These samples were taken from the bottom of the excavated pit. Once again excavated materials were placed back in the tank pit. Mr. Marc Garcia, SM-ALC/EMR, was present during the tank removal and noted that fuel residuals were present. Thus, Tank Farm #4 was considered a typical fuel storage site and accepted into the AFCEE/ERT Bioventing Initiative.

Air Permeability Radius of Influence:

Using standard in situ air permeability testing methods, an in situ pressure response in excess of 2 inches of water was measured at all nine individual vapor monitoring points to include vapor monitoring point cluster 3 (VMP-3) which is 30 feet from the vent well (Appendix D). Thus, at an air permeability test air injection rate of 17 scfm (133 inH_2O) there is a significant, relatively rapid pressure response 30 feet from the injection well.

Oxygen Radius of Influence:

At an air injection rate of 25 scfm, the initial oxygen radius of influence was greater than 15 feet on 03 Aug 1993 and extended to greater than 30 feet by 09 Sep 1993 (Table 3.6). The in situ air permeability test was conducted for 7.5 hours and oxygen levels increased slightly at

VMP3-10, 20, 25. By 03 Aug 1993, oxygen levels had risen significantly enough to meet the oxygen demand of the site. Thus, the current zone of treatment exceeds 30 feet (radius).

Trends in Hydrocarbon Concentrations and Degradation Rates:

Hydrocarbon degradation rates were overall highest at VMP1-17.5 and VMP2-10. Soil and soils gas samples collected at VMP1-17.5 displayed the highest readings (See attached Table 2). Thus, not surprisingly higher contamination yielded higher degradation rates. The major point of importance is that BTEX (and TRPH) concentrations decreased during a 1 year treatment timeframe.

Zone of Treatment:

Since the bioventing air injection well was emplaced in the tank cavity in the zone of highest known contamination, it has the potential to treat the bulk of the contamination. The zone of treatment is greater than a 30 foot radius of influence.

AFCEE/ERT Recommendation:

Five soil borings were drilled and sampled at Tank Farm #4 (McClellan: Jacobs Engineering, 1993). Results have been requested by AFCEE/ERT. Mr. Alex Johnson reported that there were a total of 22 soil boring conducted in this area. These data should be utilized to determine if additional contamination is present to the north of the current bioventing system. Judging from the highest concentration values and the site surface conditions it would appear that this site is a low risk site. This bioventing trial has demonstrated that this system can satisfy the oxygen demand imposed by site contaminants. AFCEE recommends that this site be slated for closure unless significant contamination is detected in the borings mentioned above. Since the overall oxygen demand at this site appears low, it is quite likely that natural aeration will prevent any unacceptable contaminant migration at this site. At the request of McClellan AFB EMR, AFCEE/ERT has funded and will complete closure sampling at Tank Farm #4.

SA-6:

Conceptual Site Model:

This site is literally the typical gas station scenario. Underground storage tank leakage appears to be centered around the 20' bgs level. Contamination appears to extend to the water table and ground water has been impacted. BTEX contamination is the key contaminant of concern. Two gasoline underground storage tanks (USTs) and two diesel USTs were present at the site prior to removal in 1990 - 1991.

Air Permeability Radius of Influence:

Using standard in situ air permeability testing methods, an in situ pressure response of approximately 2 inches of water was measured at all twelve individual vapor monitoring points to include VPN20 which is 30 feet from the vent well (Appendix D). Thus, at an air permeability test air injection rate of 38 scfm (28 inH_2O) there is a significant relatively rapid pressure response 30 feet from the injection well. After 9 hours of injection at this rate in situ pressures had not reached steady state conditions. Thus, the long term radius of influence of the system, which includes air injection into two vent wells at a combined flow rate of 110 scfm, is likely to be significantly greater than a 30 foot radius of influence from each injection well.

Oxygen Radius of Influence:

After 9 hours, at an air injection rate of 38 scfm, the initial oxygen radius of influence was greater than 10 feet on 31 Aug 1993 and extended to greater than 30 feet by 09 Sep 1993 (Table 3.6). By 09 Sep 1993, oxygen levels had risen significantly enough to meet the oxygen demand of the site. Thus, the zone of treatment exceeded 30 feet given the above one well injection rate. The long term two well 110 scfm injection rate should extend the radius of influence significantly past the 30 radius. This should provide full coverage of the contaminated region.

Trends in Hydrocarbon Concentrations and Degradation Rates:

Soil Gas:

The soil gas profiling conducted during the bioventing systems installation consisted of the collection of subsurface soils in plastic bags, equilibration, and analysis via a field flame ionization and a photoionization detectors (See Section 2, Table 1.5). This technique provided vertical contaminant profiling that correlated very strongly with other data. Overall, soil gas concentrations were relatively high 15 - 25 feet bgs prior to bioventing operation. The highest soil gas concentrations were measured at VMP1-17, 130,000 ppmV (TO-03), prior to bioventing and were reduced to 3,300 ppmV after 1 year of bioventing (>97% reduction). All bioventing systems were shut off 1 month prior to the "1-year" sampling effort which would encourage any soil gas rebound. Similar reductions were exhibited at all soil gas monitoring points. The volatile fraction has been dramatically reduced at this site as a result of bioventing.

AFCEE/ERT Recommendation:

The system at SA6 is considered a full-scale two injection well system. This system should continue to operate since oxygenation and resultant enhanced biodegradation has been conclusively demonstrated. Hydrocarbon degradation rates are still significant. Bioventing will continue to reduce BTEX concentrations to the point where there is no source of fuel contamination to ground water and any residual ground water will remediate via natural attenuation. Based on data that AFCEE has received, all fuels related contamination appears to be within the radius of treatment. AFCEE/ERT requests that McClellan AFB EMR provide additional data on this site. At the request of McClellan AFB EMR, AFCEE/ERT has funded the expansion of the existing SA6 system to a full-scale bioventing system. However, data received and collected by AFCEE/ERT indicates that no significant fuel contamination exists outside the current bioventing treatment zone. Thus, AFCEE/ERT suggests that this site be considered full-scale until data to the contrary is provided. AFCEE/ERT requests that McClellan AFB EMR, provide an appropriate candidate site for expansion. AFCEE/ERT stands ready to implement an additional system at McClellan. However, if McClellan AFB EMR has no significantly contaminated fuel sites requiring remediation, please notify AFCEE/ERT immediately so that the project can be realigned to another installation.

Based on the data within the zone of treatment, bioventing has successfully treated a relativlely high soil gas site. Thus, bioventing is recommended over soil vapor extraction. Bioventing was developed, in part, to overcome costly off-gas treatement. This site is a good case history of the efficacy of treating a higher volatility site with bioventing.

PRL-T46:

Conceptual Site Model

Site consists of residual contamination from an oil water separator that was removed in November 1990. The 16 - 18 foot deep excavation was backfilled with clean soil. Residual contamination is centered around the former oil/water separator tank or Soil Borings B21, B22, and B23 (See Table 2.4a,b). Residual contamination appears to be bounded within a 50 foot radius from soil boring B22 and vertically to 30 feet bgs. The bioventing system is situated in the geometric center of contamination.

Air Permeability Radius of Influence:

Using standard in situ air permeability testing methods, an in situ pressure response of approximately 1.7 inches of water was measured at all twelve individual vapor monitoring points to include VPN3 which is 40 feet from the vent well (Appendix D). Thus, at an air permeability test air injection rate of 41 scfm (36 inH_2O) there is a significant relatively rapid pressure response 40 feet from the injection well. After 5 hours of injection at this rate, in situ pressures had not reached steady state conditions. Thus, long term radius of influence of the system, which includes air injection into one vent well at a flow rate of 68 scfm, is likely to be significantly greater than a 40 foot radius of influence, which will fully encompass the oil/water separator related contamination.

Oxygen Radius of Influence:

After 9 hours at an air injection rate of 68 scfm, the oxygen radius of influence was greater than 40 feet by 09 Sep 1993 (Table 3.12). The in situ air permeability test was conducted for 5 hours and oxygen levels at VMP3-30 at the 40 foot radius increased noticeable during that time. By 09 Sep 1993, oxygen levels had risen significantly enough to meet the oxygen demand of the site. The long-term 68 scfm injection rate should extend the radius of influence significantly past the 40 foot radius. This should provide full coverage of the contaminated region.

Trends in Hydrocarbon Concentrations and Degradation Rates:

Soil Gas:

The highest soil gas concentrations were measured at VMP1-10, 19,000 ppmV (TO-03), prior to bioventing and were reduced to 1,900 ppmV after 1 year of bioventing (90% reduction). Even though all bioventing systems were shut off for 30 days prior to sampling, to encourage rebound, similar reductions were exhibited at all soil gas monitoring points. Concentrations around VMP3-10 did not display a statistically significant decrease. Since these points are 40 feet from the vent well, continued operation should provide adequate treatment based on air permeability results and the trend toward a overall lower oxygen demand at the site.

Soil:

The highest soil concentration was collected within the injection vent well boring (See attached Table 2:TRPH: 5,280 mg/kg). The risk-based contaminants of concern, BTEX, were overall low at this site. Overall concentrations decreased below detection limits. Detection limits are cited in attached Table 2 and are below expected levels of concern.

Zone of Treatment:

Based on the air permeability and oxygen response data, the treatment zone should extend beyond a 40 foot radius of influence. Hydrocarbon degradation rates were highest at VMP1-15 and VPM2-12.5 (See Attached Table 1). Significant hydrocarbon degradation rates have been measured at almost all points where contamination is still measurable. Hydrocarbon degradation rates were not significant at the vent well after one year of treatment. This result is most likely due to sampling artifacts associated with collecting vapor samples from a 38 foot long screen. Soil concentrations appeared to have dropped below detectable levels. However, limited soil sampling prevents a conclusive determination.

AFCEE/ERT Recommendation:

The system at PRL-T46 is considered a full-scale system. This system should continue to operate since oxygenation and resultant enhanced biodegradation has been conclusively demonstrated. Hydrocarbon degradation rates are still significant. Based on data that AFCEE has received, all fuels related contamination appears to be within the radius of treatment.

Davis Global Communications Site:

Conceptual Site Model:

The site consists of diesel contamination associated with three 25,000 gallon underground storage tanks that were removed in 1988. The approximately 70 by 60 foot area of excavation provides a rough boundary of fuel contaminated soils. Fuel supply lines from the tanks to Building 4710 are also likely sources of contamination. Fuel contamination appears to highest around the 25 feet bgs. level and decrease downward to the water table that fluctuates seasonally from 30 to 70 feet bgs. Residual fuel contamination has been detected at 62 feet bgs. Chlorinated hydrocarbons are not present in significant concentrations within the fuel contaminated area.

Air Permeability Radius of Influence:

Using standard in situ air permeability testing methods, an in situ pressure response of approximately 0.7 inches of water was measured at all twelve individual vapor monitoring points to include VPN3 which is 50 feet from the vent well (Appendix D). Pressure responses during the second air permeability test were rapid. Hence, the steady state response method was used to estimate air permeability. Thus, at an air permeability test air injection rate of 30 scfm (50 inH_2O) there was a significant, relatively rapid pressure response 50 feet from the injection well. The long term radius of influence of the system, which includes air injection into one vent well at a flow rate of 54 scfm, is likely to be significantly greater than a 50 foot radius of influence which provides treatment of most of the contaminated region.

Oxygen Radius of Influence:

After three weeks at an air injection rate of 54 scfm, the oxygen radius of influence was greater than 55 feet by 08 Sep 1993 (Table 3.15). By 08 Sep 1993, oxygen levels had risen significantly enough to meet the oxygen demand 55 feet from the injection well.

Trends in Hydrocarbon Concentrations and Degradation Rates:

Soil Gas:

As expected, the lower volatility nature of diesel fuel resulted in relatively low soil gas concentrations at the site. The highest soil gas measurements were below the excavation (See attached Table 2: VMP1, VMP2). Soil gas BTEX concentrations were at low to nondetectable levels.

Soil:

Although limited soil samples were collected, the apparent reductions in soil concentrations are dramatic (See attached Table 2). BTEX concentrations were below detection limits at the majority of points before and after bioventing.

Zone of Treatment:

Hydrocarbon degradation rates were significant across the sites (See attached Table 1). The zone of treatment is controlled by the seasonal fluctuations in ground water levels. However, hydrocarbon degradation rates in previously saturated regions are quite high. Although, bioventing treatment is limited in these areas during high water conditions, the low solubility nature of these contaminants should not pose a significant off-site risk and treatment by any other technology, such as soil vapor extraction, would be ineffective. Air injection bioventing is the most viable technology since hydrocarbon degradation rates are very favorable despite interruptions due to high water table events.

AFCEE/ERT Recommendation:

AFCEE/ERT recommends that the bioventing system at the Davis site be expanded to provide more complete coverage of the fuel impacted area. The efficacy of bioventing has been conclusively demonstrated. Since the contamination at Building 4710 site consists of low volatility diesel constituents, bioventing is particularly effective whereas technologies like soil vapor extraction are ineffective in the removal of diesel fuel contamination. At the request of McClellan AFB EMR staff, AFCEE/ERT has funded and plans to complete the expansion of the existing system to a full-scale bioventing system. Seasonal groundwater fluctuations provide the opportunity to biovent lower soil units. Even though this is not maintained throughout the year, removal rates of the more mobile and toxic fuel constituents will be significant with the removal of the heavier fractions occurring at a lower rate. Dewatering of the site is not recommended. AFCEE/ERT would recommend that subsequent bioventing venting well(s) be completed 5 - 10 feet below the lowest expected ground water level. This will promote treatment of residual hydrocarbon contamination during seasonal lows.

Building 720:

Site work was terminated at this site due to water saturated soil conditions that interfered with system installation. Conditions were extreme enough to suggest that the air permeability of these water saturated soils would preclude soil aeration (bioventing). The water on the site was attributed to a leaking water pipe. McClellan staff were notified. Fuel contamination was detected in near surface soils. However, no information is available regarding deeper soils. This site would be considered for bioventing implementation if McClellan has additional information to suggest this site requires remediation and that water saturated conditions no longer exist.

Please contact Patrick E. Haas, AFCEE/ERT, DSN: 240-4314, COM: 210-536-4314, to discuss technical options for closure sampling and full-scale expansion.

Data from your base and many others indicate that BTEX compounds are preferentially biodegraded over TPH. Since BTEX compounds represent the most toxic and mobile fuel constituents, a BTEX standard is a risk-based standard. We strongly encourage its use over an arbitrary TPH standard. Within the AFCEE Risk-based Petroleum Hydrocarbon "Tool Box", the report entitled, "Using Risk-based Standards will Shorten Cleanup Time at Petroleum Contaminated Sites", summarizes the BTEX/TPH issue and will assist you in negotiating for a BTEX cleanup standard. In conclusion, a risk-based approach will expedite site closure while reducing overall costs. Please contact Patrick E. Haas, AFCEE/ERT, DSN: 240-4314, COM: 210-536-4314, for details.

In general, quantitative destruction of BTEX will occur over a 1 to 2 year bioventing period. Soil gas surveys and respiration tests can be used as BTEX destruction indicators. If a non-risk-based/TPH cleanup is chosen, the pilot and full-scale systems should be operated until respiration rates approach background rates. We recommend that confirmatory soil sampling be conducted 4-6 months after background respiration rates are approached.

Because this is a streamlined test and evaluation project, our contract does not provide for additional reports to the base on pilot study results. The interim results report dated February 1994 contains as-builts and initial data. This letter summarizes all data collected and provides next step recommendations. AFCEE is no longer responsible for the operation, maintenance, or monitoring of the above bioventing systems. We are initiating a project to extend monitoring at some sites beyond the initial one year test. Monitoring will include soil gas and respiration tests to document hydrocarbon degradation, but will also include the collection of sufficient final soil samples to statistically demonstrate site cleanup. AFCEE recommends continued operation of all bioventing systems. If you are interested, please call us.

The blower and accessories are now base property and should continue to be used on this or other bioventing sites. Although current equipment is explosion proof, under no circumstances should it be used for soil vapor extraction unless appropriate explosion-proof wiring is provided. If the base does not want to keep the blower or if you have further questions, please contact us at DSN 240-4331 or commercial 210-536-4331.

On behalf of the AFCEE/ERT staff , I would like to thank you for your support of this bioventing test and evaluation project. The information gained from each site will be invaluable in evaluating this technology and will promote its successful application on other DOD, government, and private sites. I have attached a customer satisfaction survey. Please take a few minutes to fill it out and tell us how we did. We look forward to hearing from you.

ROSS N. MILLER, Lt Col, USAF, BSC
Chief, Technology Transfer Division

Attachments:
1. AFCEE Bioventing Initiative Site Map
2. Bioventing data, Tables 1 & 2
3. Customer Survey

cc: AFCEE/ERD
HQ AFMC/CEVR
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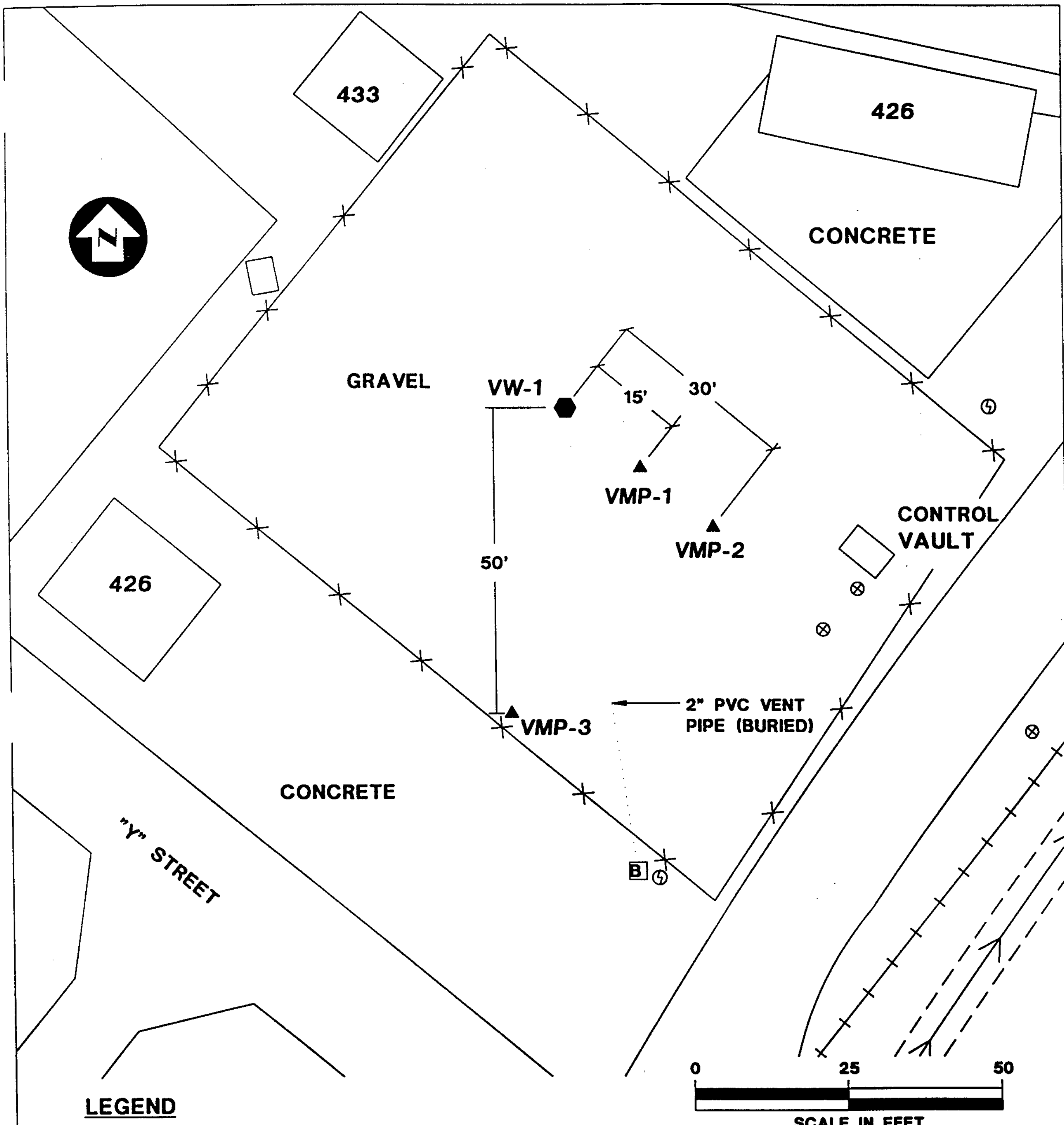


LEGEND

B	BLOWER LOCATION
VW-1	VENT WELL
VMP-2	VAPOR MONITORING POINT
⊗	VALVES
	UNLINED DRAINAGE CHANNEL
	RAILROAD TRACKS
	FENCE
	POWER POLE

SOURCE:MODIFIED FROM JACOBS ENGINEERING, 1992

FIGURE 1

AS BUILT VENT WELL, MONITORING POINT, AND BLOWER LOCATIONS TANK FARM #2

McClellan AFB, California

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

C257-18, 02/14/95

TABLE 1
TANK FARM #2
RESPIRATION AND DEGRADATION RATES
McCLELLAN AFB, CALIFORNIA

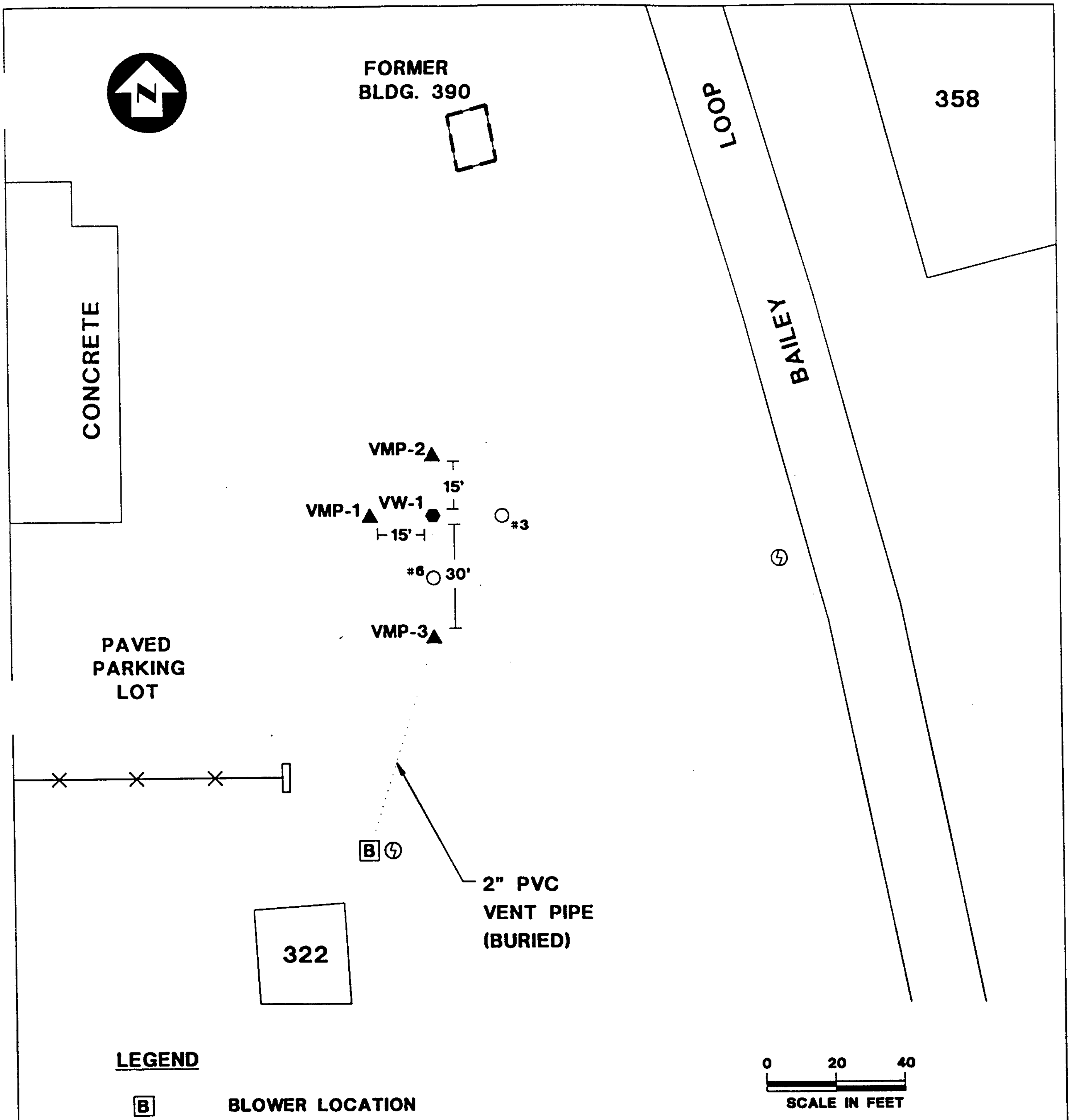
Location–Depth (feet below ground surface)	Initial (Jul. 1993)			6–Month (Mar. 1994)[b]			1–Year (Sep. 1994)		
	K_o (% O_2/min)	Degradation Rate (mg/kg/year)[a]	Soil Temperature (°C)	K_o (% O_2/min)	Degradation Rate (mg/kg/year)	Soil Temperature (°C)	K_o (% O_2/min)	Degradation Rate (mg/kg/year)	Soil Temperature (°C)
VW1	NC[c]	NC	NS[d]	0.000030	10	NS	0.00015	30	NS
VMP1–15	0.0018	230	NS	0.0027	460	NS	NC	NC	NS
VMP1–20	0.0017	180	NS	0.00012	10	NS	0.00025	20	NS
VMP1–28	0.0073	910	NS	0.00013	20	NS	0.00032	70	NS
VMP2–15	0.0043	540	21.2	NC[d]	NC	21.3	NC	NC	24.7
VMP2–21	0.0047	580	NS	0.00014	20	NS	0.00025	60	NS
VMP2–35	0.0065	800	21.0	0.00022	40	21.5	0.00035	80	21.1
VMP3–13	0.0078	590	NS	0.00070	80	NS	0.0057	960	NS
VMP3–20	0.0073	910	NS	0.00033	60	NS	0.0012	270	NS
VMP3–32	NC	NC	NS	0.00012	20	NS	0.00028	60	NS

[a] Milligrams of hydrocarbons per kilogram of soil per year.
[b] Assumes moisture content of the soil is average of initial and final moistures.
[c] NC = Not calculated.
[d] NS = Not sampled.

TABLE 2
TANK FARM #2
INITIAL AND 1-YEAR SOIL AND SOIL GAS ANALYTICAL RESULTS
McCLELLAN AFB, CALIFORNIA

Analyte (Units)[a/]	Sample Location-Depth (feet below ground surface)					
	VW1		VMP1-20		VMP3-13	
Soil Gas Hydrocarbons	Initial[b/]	1-Year[c/]	Initial	1-Year	Initial	1-Year
TVH (ppmv)	31,000	160	22,000	530	34,000	35,000
Benzene (ppmv)	<1.0	<0.034	<1.1	<0.010	<2.1	<2.0
Toluene (ppmv)	58	0.12	22	<0.010	<2.1	<2.0
Ethylbenzene (ppmv)	5.3	0.34	6.8	0.60	11	20
Xylenes (ppmv)	61	2.3	11	2.1	16	34
	VW1-22.5		VMP1-20		VMP2-21	
Soil Hydrocarbons	Initial[d/]	1-Year[e/]	Initial	1-Year	Initial	1-Year
TRPH (mg/kg)	100	34.4	<12	202	<12	57.4
Benzene (mg/kg)	<0.001	<0.057	0.004	<0.060	<0.03	<0.056
Toluene (mg/kg)	0.027	<0.057	0.28	<0.060	4.4	<0.056
Ethylbenzene (mg/kg)	0.013	<0.057	0.054	0.270	0.29	<0.056
Xylenes (mg/kg)	0.11	<0.110	0.2	<0.120	1.4	<0.110
Moisture (% by wt.)	13	12.1	17	17.5	16	11.0

a/ TRPH=total recoverable petroleum hydrocarbons; mg/kg=milligrams per kilogram;
TVH= total volatile hydrocarbons; ppmv=parts per million, volume per volume.
b/ Initial soil gas samples collected on 7/26/93, 7/27/93, and 7/30/93.
c/ 1-Year soil gas samples collected on 9/12/94.
d/ Initial soil samples collected on 7/6/93, 7/7/93, and 7/8/93.
e/ 1-Year soil samples collected on 9/29/94.



LEGEND

B BLOWER LOCATION

VW-1 VENT WELL

VMP-1 VAPOR MONITORING POINT

#3 ABANDONED SOIL BORING

POWER POLE

FENCE

SOURCE: MODIFIED FROM RADIAN (1990)

FIGURE 1

AS BUILT VENT WELL, MONITORING POINT, AND BLOWER LOCATIONS TANK FARM #4

McClellan AFB, California

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

C257-19, 02/14/95

TABLE 1
TANK FARM #4
RESPIRATION AND DEGRADATION RATES
McCLELLAN AFB, CALIFORNIA

Location–Depth (feet below ground surface)	Initial (Aug. 1993)			6–Month (Mar. 1994)[b]			1–Year (Sep. 1994)		
	K_o (% O_2/min)	Degradation Rate (mg/kg/year)[a]	Soil Temperature (°C)	K_o (% O_2/min)	Degradation Rate (mg/kg/year)	Soil Temperature (°C)	K_o (% O_2/min)	Degradation Rate (mg/kg/year)	Soil Temperature (°C)
VW1	NC[c]	NC	NS[d]	0.00014	<10[e]	NS	NC	NC	NS
VMP1–10	0.0045	260	26.2	0.00033	10	19.0	0.00092	10	29.3
VMP1–17.5	0.0047	840	NS	0.00068	140	NS	0.0015	320	NS
VMP1–25	0.00093	100	20.4	0.000035	<10	22.9	0.000072	<10	22.0
VMP2–10	0.011	1,100	NS	NC	NC	NS	0.011	550	NS
VMP2–20	0.0022	40	NS	0.00027	<10	NS	0.00043	<10	NS
VMP2–25	0.00032	30	NS	0.000035	<10	NS	0.00032	10	NS
VMP3–10	0.015	840	NS	0.000016	<10	NS	0.00035	<10	NS
VMP3–20	NC	NC	NS	0.000077	10	NS	0.00013	10	NS
VMP3–25	NC	NC	NS	0.000010	<10	NS	0.00018	10	NS

[a] Milligrams of hydrocarbons per kilogram of soil per year.
[b] Assumes moisture content of the soil is average of initial and final moistures.
[c] NC = Not calculated.
[d] NS = Not sampled.
[e] Although limited oxygen utilization was measured in these points, high levels of soil moisture reduced the air–filled porosity of the soil and limited oxygen supply to soil bacteria.

TABLE 2
TANK FARM #4
INITIAL AND 1-YEAR SOIL AND SOIL GAS ANALYTICAL RESULTS
McCLELLAN AFB, CALIFORNIA

Analyte (Units)[a/]	Sample Location-Depth (feet below ground surface)					
	VW1		VMP1-17.5		VMP3-20	
Soil Gas Hydrocarbons	Initial[b/]	1-Year[c/]	Initial	1-Year	Initial	1-Year
TVH (ppmv)	1,900	12	5,200	48	10	20
Benzene (ppmv)	<0.11	<0.002	<0.53	<0.002	<0.002	<0.005
Toluene (ppmv)	<0.11	<0.002	<0.53	<0.002	0.011	<0.005
Ethylbenzene (ppmv)	4.8	0.044	11	<0.002	<0.002	0.093
Xylenes (ppmv)	5.0	0.098	12	0.12	0.021	0.22
	VW1-12.5		VMP1-17.5		VMP2-20	
Soil Hydrocarbons	Initial[d/f/]	1-Year[e/]	Initial[f/]	1-Year	Initial	1-Year
TPH - g (mg/kg)	46	<5	76	<5	<10	<4.9
Benzene (mg/kg)	<0.05	<0.069	<0.05	<0.057	<0.05	<0.068
Toluene (mg/kg)	<0.05	<0.069	0.062	<0.057	<0.05	<0.068
Ethylbenzene (mg/kg)	<0.05	<0.069	<0.05	<0.057	<0.05	<0.068
Xylenes (mg/kg)	2.7	<0.140	0.47	<0.110	<0.2	<0.140
Moisture (% by wt.)	27	27.9	13	11.6	22	27.9

a/ TPH-g=total petroleum hydrocarbons as gasoline; mg/kg=milligrams per kilogram;
TVH= total volatile hydrocarbons; ppmv=parts per million, volume per volume.

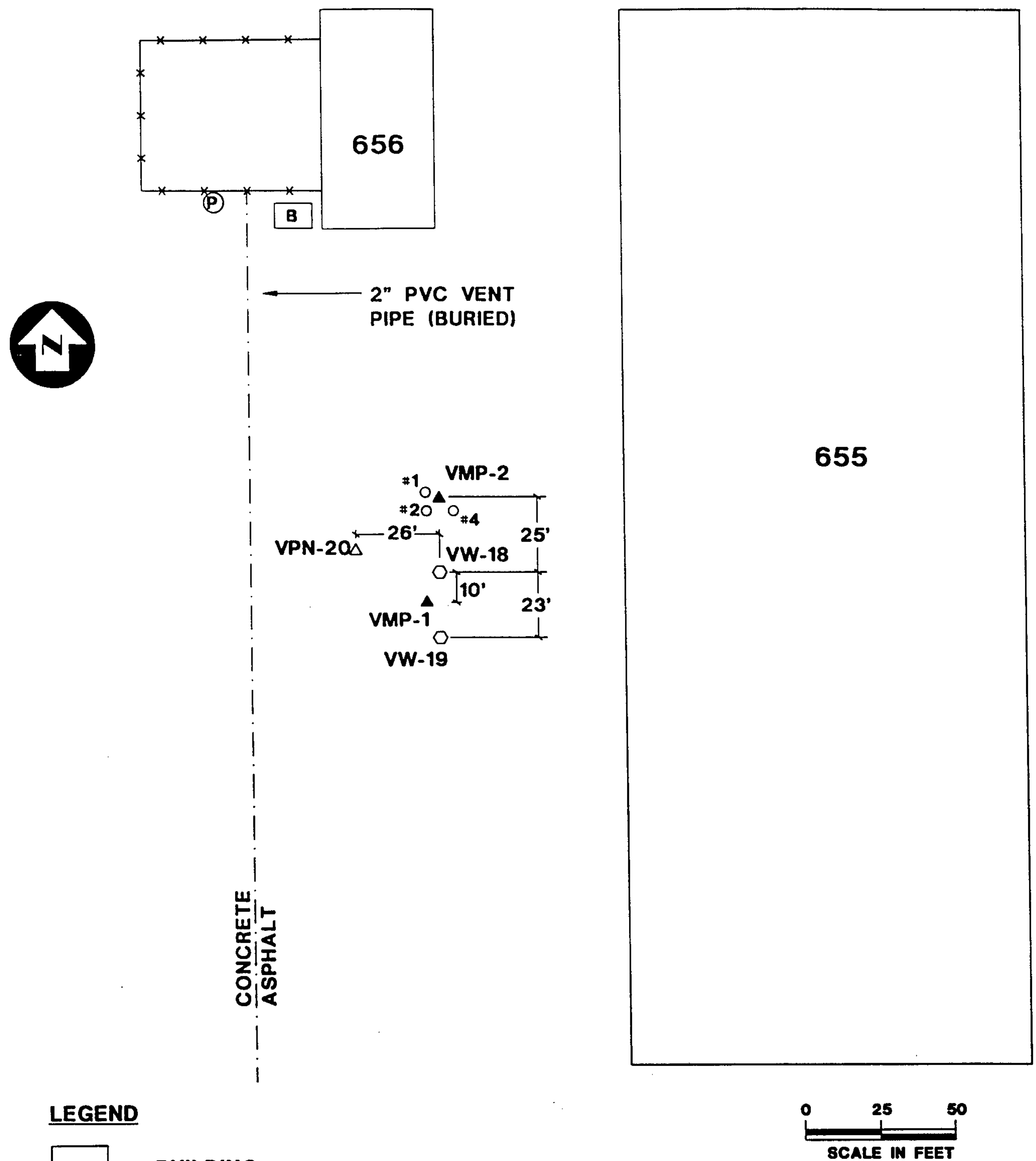
b/ Initial soil gas samples collected on 8/2/93.

c/ 1-Year soil gas samples collected on 9/12/94.

d/ Initial soil samples collected on 7/8/93, 7/9/93, and 7/12/93.

e/ 1-Year soil samples collected on 9/27/94.

f/ Initial samples analyzed for gasoline components; the hydrocarbons present in these samples did not match the profile of the laboratory standard.



LEGEND

656	BUILDING
—·—	CONCRETE/ASPHALT BORDER
Ⓟ	POWER LINE
B	BLOWER LOCATION
△ VPN-20	PRE-EXISTING VAPOR MONITORING POINT (VAPOR PIEZOMETER NEST)
⬡ VW-18	PRE-EXISTING VENT WELL
▲ VMP-1	VAPOR MONITORING POINT
○ #4	ABANDONED BOREHOLES
—x—x—	FENCE

FIGURE 1

AS BUILT VENT WELL, MONITORING POINT, AND BLOWER LOCATIONS SITE SA 6

McClellan AFB, California

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

C257-05, 02/14/95

TABLE 1
SITE SA6
RESPIRATION AND DEGRADATION RATES
McCLELLAN AFB, CALIFORNIA

Location–Depth (feet below ground surface)	Initial (Jul.and Sep. 1993)			6–Month (Mar. 1994)[b]			1–Year (Sep. 1994)		
	K_o (% O_2/min)	Degradation Rate (mg/kg/year)[a]	Soil Temperature (°C)	K_o (% O_2/min)	Degradation Rate (mg/kg/year)	Soil Temperature (°C)	K_o (% O_2/min)	Degradation Rate (mg/kg/year)	Soil Temperature (°C)
VW–18	0.00098	140	NS[c]	0.0000067	<10 [d]	NS	0	0	NS
VW–19	0.0040	490	NS	0.00016	20	NS	0	0	NS
VMP1–17	0.0070	620	27.0	NS	NC	26.0	0.0068	270	29.5
VMP1–30	0.023	2,500	NS	0.00042	30	NS	0.00063	30	NS
VMP1–54	NC[e]	NC	26.9	0.000022	<10	21.1	0	0	22.9
VMP2–19.5	0.0068	720	NS	NC	NC	NS	0.012	600	NS
VMP2–30	NC	NC	NS	0.0016	110	NS	NC	NC	NS
VMP2–49	0.0025	220	NS	0	0	NS	0	0	NS
VPN20–24	0.0085	1,200	NS	0.00073	80	NS	0.0028	240	NS
VPN20–37	0.0018	260	NS	0.00012	10	NS	0.0005	40	NS
VPN 20–49	0.0037	390	NS	0.000045	<10	NS	0	0	NS
VPN 20–57	0.00028	40	NS	0	0	NS	0	0	NS
VPN 20–75	0.00093	130	NS	0	0	NS	0	0	NS
VPN 20–99	NC	NC	NS	0	0	NS	0.000011	<10	NS

[a] Milligrams of hydrocarbons per kilogram of soil per year.
[b] Assumes moisture content of the soil is average of initial and final moistures.
[c] NS = Not sampled.
[d] Although limited oxygen utilization was measured in these points, high levels of soil moisture reduced the air–filled porosity of the soil and limited oxygen supply to soil bacteria.
[e] NC = Not calculated.

TABLE 2
SITE SA 6
INITIAL AND 1-YEAR SOIL AND SOIL GAS ANALYTICAL RESULTS
McCLELLAN AFB, CALIFORNIA

Analyte (Units)[a]	Sample Location-Depth (feet below ground surface)							
	VW18		VW19		VMP1-17		VPN20-24	
Soil Gas Hydrocarbons	Initial[b]	1-Year[c]	Initial	1-Year	Initial	1-Year	Initial	1-Year
TVH (ppmv)	14,000	220	55	6.0	130,000	3,300	13,000	68
Benzene (ppmv)	130	0.21	<0.004	<0.002	490	15	38	0.11
Toluene (ppmv)	140	1.6	0.13	0.033	320	27	35	0.33
Ethylbenzene (ppmv)	9.4	1.0	0.051	0.022	34	18	6.6	0.20
Xylenes (ppmv)	130	11	0.35	0.096	170	130	22	2.0

	VMP1-17.5	
Soil Hydrocarbons	Initial[d]	1-Year[e]
TPH-g (mg/kg)	1,210	<12.5
Benzene (mg/kg)	4.2	0.098
Toluene (mg/kg)	18	0.110
Ethylbenzene (mg/kg)	14	0.510
Xylenes (mg/kg)	27	1.100
Moisture (% by wt.)	17	20.1

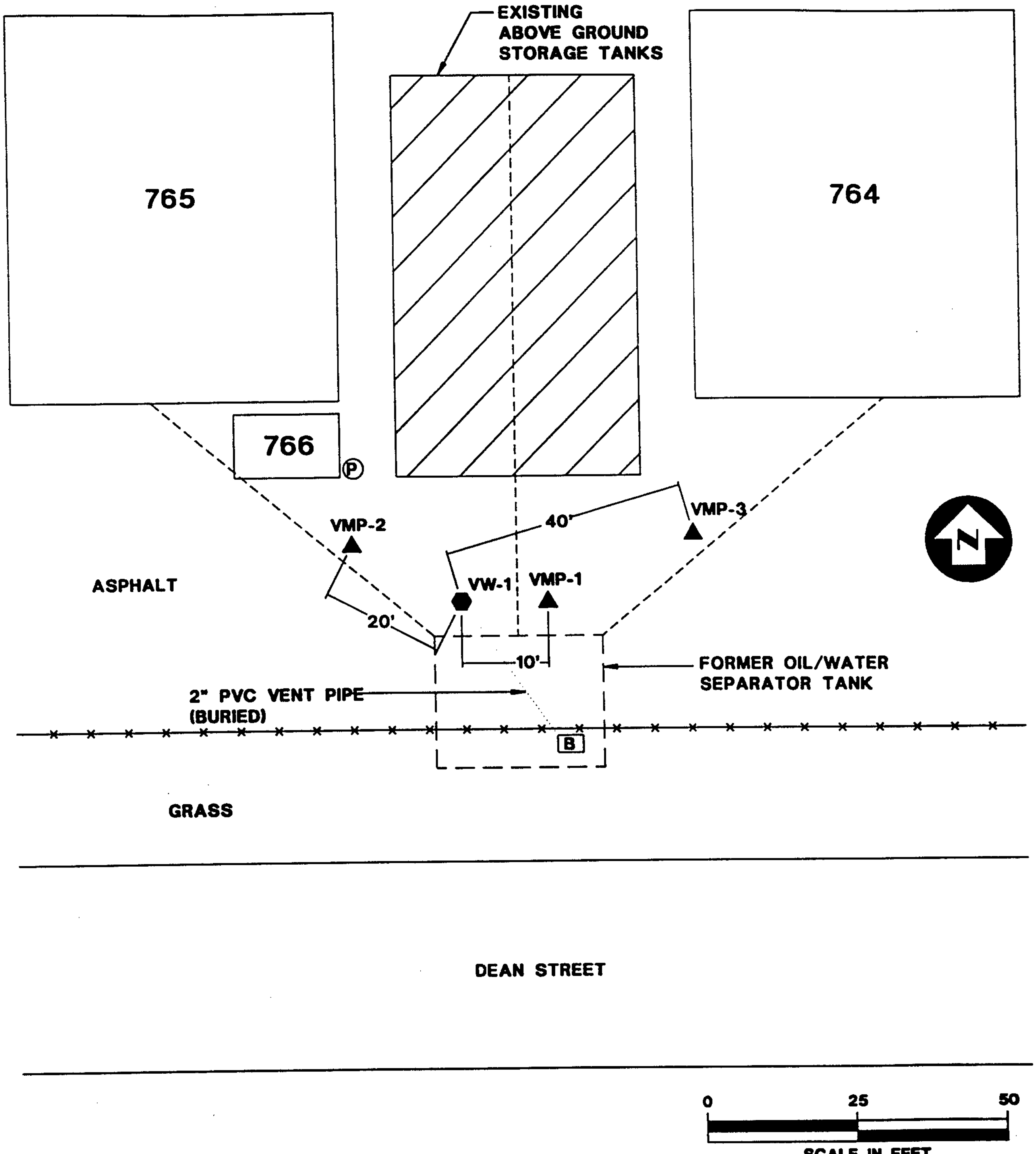
a/ TPH-g=total petroleum hydrocarbons as gasoline; mg/kg=milligrams per kilogram;
TVH= total volatile hydrocarbons; ppmv=parts per million, volume per volume.

b/ Initial soil gas samples collected on 7/7/93 and 8/30/93. A leak appeared to have occurred in the initial sampling of VW18 on 7/7/93; results for initial testing of VW18 are from resampling onf 8/30/93.

c/ 1-Year soil gas samples collected on 9/19/94.

d/ Initial soil samples collected on 7/20/93.

e/ 1-Year soil samples collected on 9/28/94.



LEGEND

B	BLOWER LOCATION
P	POWER LINE
VMP-3 ▲	VAPOR MONITORING POINT
⬢ VW-1	VENT WELL
—×—×	FENCE
------	DRAIN LINE

SOURCE: MODIFIED FROM RADIAN (1993).

FIGURE 1

AS BUILT VENT WELL, MONITORING POINT, AND BLOWER LOCATIONS SITE PRL T-46

McClellan AFB, California

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

C257-06, 02/14/95

TABLE 1
SITE PRL T-46
RESPIRATION AND DEGRADATION RATES
McCLELLAN AFB, CALIFORNIA

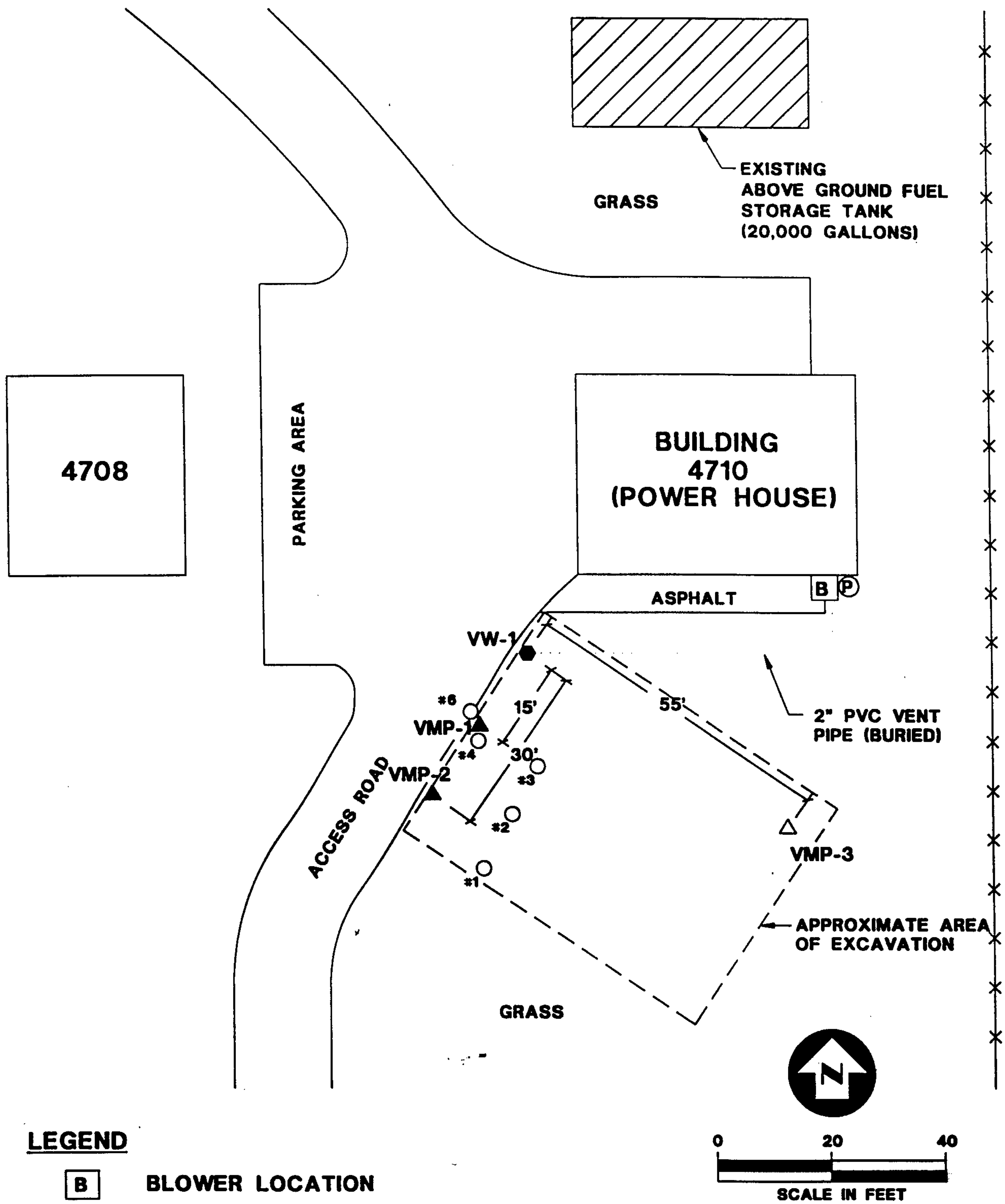
Location-Depth (feet below ground surface)	Initial (Aug. 1993)			6-Month (Mar. 1994)[b]			1-Year (Sep. 1994)		
	K_o (% O_2/min)	Degradation Rate (mg/kg/year)[a]	Soil Temperature (°C)	K_o (% O_2/min)	Degradation Rate (mg/kg/year)	Soil Temperature (°C)	K_o (% O_2/min)	Degradation Rate (mg/kg/year)	Soil Temperature (°C)
VW-1	0.022	770	NS[d]	0.0033	200	NS	0	0	NS
VMP1-5	0.0088	460	29.1	0.011	550	22.6	0.026	1,600	32.2
VMP1-10	0.028	530	NS	0.0092	1,900	NS	0.014	5,600	NS
VMP1-15	0.015	1,300	NS	0.0053	500	NS	0.011	1,000	NS
VMP1-28	NC[c]	NC	NS	0.0025	130	NS	NC	NC	NS
VMP1-40	NC	NC	22.6	0.000043	<10[e]	17.6	0.00018	20	24.3
VMP2-5	NC	NC	NS	NC	NC	NS	NC	NC	NS
VMP2-12.5	0.030	2,100	NS	0.0057	290	NS	0.01	400	NS
VMP2-20	0.0068	360	NS	0.00025	10	NS	0.0016	100	NS
VMP2-30	NC	NC	NS	0.00017	10	NS	0.00022	10	NS
VMP3-10	0.010	530	NS	0.0013	70	NS	0.0047	280	NS
VMP3-18	0.00058	40	NS	0	0	NS	0.000072	18	NS
VMP3-30	NC	NC	NS	0	0	NS	0.000033	<10	NS

[a] Milligrams of hydrocarbons per kilogram of soil per year.
[b] Assumes moisture content of the soil is average of initial and final moistures.
[c] NC = Not calculated.
[d] NS = Not sampled.
[e] Although limited oxygen utilization was measured in these points, high levels of soil moisture reduced the air-filled porosity of the soil and limited oxygen supply to soil bacteria.

TABLE 2
SITE PRL T−46
INITIAL AND 1−YEAR SOIL AND SOIL GAS ANALYTICAL RESULTS
McCLELLAN AFB, CALIFORNIA

Analyte (Units)[a]	Sample Location−Depth (feet below ground surface)					
	VW1		VMP1−10		VMP3−10	
Soil Gas Hydrocarbons	Initial[b]	1−Year[c]	Initial	1−Year	Initial	1−Year
TVH (ppmv)	1,900	210	19,000	1,900	600	680
Benzene (ppmv)	<0.051	0.13	<1.0	0.50	<0.052	0.40
Toluene (ppmv)	<0.051	0.84	<1.0	4.3	<0.052	4.0
Ethylbenzene (ppmv)	2.5	0.58	7.0	7.6	0.31	0.36
Xylenes (ppmv)	2.8	5.7	20	9.9	0.71	2.4
	VW1−17.5		VMP1−10		VMP2−12.5	
Soil Hydrocarbons	Initial[d]	1−Year[e]	Initial	1−Year	Initial	1−Year
TRPH (mg/kg)	5,280	<12.1	570	171	3,320	<12.6
Benzene (mg/kg)	<0.002	<0.061	<0.07	<0.052	<0.04	<0.062
Toluene (mg/kg)	<0.002	<0.061	<0.07	<0.052	<0.04	<0.062
Ethylbenzene (mg/kg)	0.01	<0.061	2.82	<0.052	<0.04	<0.062
Xylenes (mg/kg)	0.027	<0.120	3.4	<0.100	0.2	<0.120
Moisture (% by wt.)	21	18.0	24	3.9	19	20.8

a/ TRPH=total recoverable petroleum hydrocarbons; mg/kg=milligrams per kilogram;
TVH= total volatile hydrocarbons; ppmv=parts per million, volume per volume.
b/ Initial soil gas samples collected on 8/23/93.
c/ 1−Year soil gas samples collected on 9/19/94.
d/ Initial soil samples collected on 7/13/93.
e/ 1−Year soil samples collected on 9/28/94.



LEGEND

B	BLOWER LOCATION
P	POWER LINE
● VW-1	VENT WELL
▲ VMP-1	VAPOR MONITORING POINT
#1 ○	ABANDONED SOIL BORING
—×—×—×—	FENCE

SOURCE: MODIFIED FROM CH2M HILL, 1993

FIGURE 1

AS BUILT VENT WELL, MONITORING POINT, AND BLOWER LOCATIONS DAVIS SITE

McClellan AFB, California

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

C257-04, 02/14/95

TABLE 1
DAVIS GLOBAL COMMUNICATIONS SITE
RESPIRATION AND DEGRADATION RATES
McCLELLAN AFB, CALIFORNIA

Location–Depth (feet below ground surface)	Initial (Aug. 1993)			6–Month (Mar. 1994)[b]			1–Year (Sep. 1994)		
	K_o (% O_2/min)	Degradation Rate (mg/kg/year)[a]	Soil Temperature (°C)	K_o (% O_2/min)	Degradation Rate (mg/kg/year)	Soil Temperature (°C)	K_o (% O_2/min)	Degradation Rate (mg/kg/year)	Soil Temperature (°C)
VW–1	NC[c]	NC	NS[d]	0.000010	<10[e]	NS	NC	NC	NS
VMP1–15	0.0028	250	18.8	NC	NC	20.2	NC	NC	23.6
VMP1–25	0.0060	620	NS	0.0062	720	NS	0.0097	1,200	NS
VMP1–37.5	0.0077	160	NS	NS[f]	NC	NS	0.010	500	NS
VMP1–48	0.0063	690	18.7	NS[f]	NC	19.0	0.013	1,700	20.4
VMP2–15	NS[f]	NC	NS	NS	NC	NS	NC	NC	NS
VMP2–32	0.0015	100	NS	NS[f]	NC	NS	0	0	NS
VMP2–43	0.0037	260	NS	NS[f]	NC	NS	0	0	NS
VMP2–49	0.020	1,100	NS	NS[f]	NC	NS	0.050	4,200	NS
VMP3–10	NC	NC	NS	0.00027	20	NS	0	0	NS
VMP3–26.5	0.0040	270	NS	0.00012	10	NS	0	0	NS
VMP3–35	0.0033	350	NS	NC	NC	NS	0.0035	440	NS
VMP3–45	0.0067	450	NS	NC	NC	NS	NS	NC	NS
P5S–(18–20)	NC	NC	NS	0	0	NS	0	0	NS
P5D–(45–55)	NC	NC	NS	NC	NC	NS	0.0047	440	NS
CH5–(28–38)	NC	NC	NS	0.0058	680	NS	NC	NC	NS

a/ Milligrams of hydrocarbons per kilogram of soil per year.
b/ Assumes moisture content of the soil is average of initial and final moistures.
c/ NC = Not calculated.
d/ NS = Not sampled.
e/ Although limited oxygen utilization was measured in these points, high levels of soil moisture reduced the air–filled porosity of the soil and limited oxygen supply to soil bacteria.
f/ VMP screen was below water table.

TABLE 2
DAVIS GLOBAL COMMUNICATIONS SITE
INITIAL AND 1-YEAR SOIL AND SOIL GAS ANALYTICAL RESULTS
DAVIS, CALIFORNIA

Analyte (Units)[a/]	Sample Location-Depth (feet below ground surface)							
	VW1		VMP1-37.5		VMP2-49		VMP3-45	
Soil Gas Hydrocarbons	Initial[b/]	1-Year[c/]	Initial	1-Year	Initial	1-Year	Initial	1-Year
TVH (ppmv)	84	22	380	45	NS[f/]	610	270	NS[g/]
Benzene (ppmv)	0.005	<0.002	<0.011	<0.002	NS	<0.011	<0.011	NS
Toluene (ppmv)	<0.002	0.002	<0.011	0.007	NS	<0.011	<0.011	NS
Ethylbenzene (ppmv)	0.013	0.003	0.55	0.007	NS	1.6	0.62	NS
Xylenes (ppmv)	0.029	0.065	1.1	0.14	NS	2.1	0.88	NS

	VW1-32.5		VMP1-15		VMP2-50	
Soil Hydrocarbons	Initial[d/]	1-Year[e/]	Initial	1-Year	Initial	1-Year
TRPH (mg/kg)	15,500	3,150	1,370	330	1,210	90.8
Benzene (mg/kg)	<0.4	<0.061	<0.2	<0.059	<0.2	<0.061
Toluene (mg/kg)	<0.4	<0.061	<0.2	<0.059	<0.2	<0.061
Ethylbenzene (mg/kg)	<0.4	<0.061	<0.2	<0.059	<0.2	0.170
Xylenes (mg/kg)	<0.7	<0.120	<0.4	<0.120	<0.4	0.190
Moisture (% by wt.)	17	17.6	18	17.1	20	18.2

a/ TRPH=total recoverable petroleum hydrocarbons; mg/kg=milligrams per kilogram;
TVH= total volatile hydrocarbons; ppmv=parts per million, volume per volume.

b/ Initial soil gas samples collected on 8/16/93, 8/17/93, and 8/27/93.

c/ 1-Year soil gas samples collected on 9/26/94.

d/ Initial soil samples collected on 7/21/93 and 7/22/93.

e/ 1-Year soil samples collected on 9/30/94.

g/ Soils were too tight to collect sample; sample collected instead from closest monitoring point VMP2-49.

f/ NS = Not sampled.