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### **Madison-Kipp Corporation**

# Soil Vapor Extraction Pilot Test Summary and Phase I System Design

Madison-Kipp Corporation Madison, Wisconsin

BRRTS No. 0213001569 Facility ID No. 113125320

February 2012

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#### Soil Vapor Extraction Pilot Test Summary and Phase I System Basis of Design

Madison-Kipp Corporation Madison, Wisconsin

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#### List of Acronyms and Abbreviations

CFM	Cubic Feet per Minute
ft bgs	Feet Below Ground Surface
in.H <sub>2</sub> O	Inches of Water Column
lbs/hr	Pounds per hour
PVC	Polyvinyl Chloride
PVE	Pore volume exchanges

- ROI Radius of influence
- scfm Standard cubic feet per minute
- SVE Soil vapor Extraction
- VMP Vacuum Monitoring Point
- VOC Volatile Organic Compound
- WDNR Wisconsin Department of Natural Resources

#### Background

ARCADIS has been retained to assist the Madison-Kipp Corporation with environmental remediation activities at the facility located at 201 Waubesa Street in Madison, Wisconsin (Site) (Figure 1). Investigation and remediation activities at the Site are being conducted under the Wisconsin Department of Natural Resources (WDNR) Bureau for Remediation and Redevelopment Tracking System # 0213001569 and Facility ID # 113125320.

Chlorinated volatile organic compounds, including tetrachloroethene and trichloroethene, are present in soil and groundwater beneath the Site. Additionally, soil gas sampling results indicate vapor phase concentrations are present in the subsurface.

Soil vapor extraction (SVE) has been proposed to reduce the potential risk of vapor intrusion in nearby structures and to evaluate its application for mass reduction in the soil. This summary report has been prepared to describe the methods and results of the SVE pilot test that was conducted on February 9 and 10, 2012; and to outline the basis of design for the Phase I SVE system.

#### **Site Geology**

The subsurface at the Site is generally described as surficial asphalt overlying an approximately 4- to 10-foot thick clay layer. These clays have been classified as CH clays, meaning they are of low permeability. Beneath the clay, an approximately 15 to 20 foot fine to medium grained sand unit overlies sandstone bedrock. Fill, including foundry sand, has also been found at the Site.

#### Site Hydrogeology

The groundwater table is present from approximately 16.5 to 25 feet below ground surface (ft bgs) in either the sand unit or the sandstone. Groundwater monitoring indicates that the general direction of groundwater flow in the shallow soils is to the southwest with a southern flow direction in the deep aquifer.

#### Soil Vapor Extraction Technology Description

The SVE remedial technology involves inducing airflow in the subsurface with an applied vacuum extraction, enhancing the in-situ volatilization of contaminants and

capture of soil vapors. The SVE process uses the volatility of the contaminants to allow mass transfer from adsorbed and dissolved phases in soil and groundwater to the vapor phase, where it is removed under vacuum and discharged to the atmosphere, or treated prior to discharge depending on vapor concentrations. At this site, the purpose of the SVE system is to capture soil vapors which may be present by inducing air flow within the vadose zone.

Airflow is induced in the subsurface by a pressure gradient applied through vertical extraction wells. The negative pressure inside the extraction well will be generated by a vacuum blower, which causes soil vapors to migrate toward the well. To design a SVE system, subsurface airflow pathways and extraction flow rates must be properly understood. The airflow field developed is dependent on many factors: the level of applied vacuum, available screen interval in the vadose zone, porosity, air permeability and its spatial variation, depth to groundwater, quantification of leakage from the ground surface, and subsurface conduits. A typical process flow diagram for the mobile SVE unit is shown in Figure 2.

#### **Soil Vapor Extraction Pilot Test Results**

A SVE Pilot Test Work Plan was submitted to the WDNR on February 8, 2012 for review and approval. The work plan was subsequently approved on February 9, 2012. As outlined in the work plan, the objectives of the SVE pilot test were to:

- Collect vacuum and flow rate data to determine full-scale design parameters for a SVE system;
- Determine the effective radius of influence (ROI) for the full-scale system design.
- Collect laboratory vapor samples to estimate the discharge and potential treatment and/or permitting requirements.

#### **Extraction Wells and Monitoring Points**

The existing SVE well (SVE-1) was used as the extraction point for the pilot test. Monitoring was conducted at four existing vapor monitoring points (VP-1N, VP-2N, VP-1S and VP-2S) (Figure 3).



#### Extraction Well

Extraction Well SVE-1, located to the east of the existing facility between the building and the property line, was used as the extraction point for the SVE pilot test. The extraction well was constructed using 2-inch diameter schedule 40 polyvinyl chloride (PVC) riser pipe, and a 2-inch diameter, 10-foot long, 0.010-inch slot, schedule 40 PVC screen. The screen is installed from approximately 4.5 to 14.5 ft bgs.

Vacuum Monitoring Points (VMP)

Four existing VMPs (VP-1N, VP-2N, VP-1S and VP-2S) located along the eastern boundary of the site were used for monitoring during the pilot test. The VMP network for the pilot test consisted of the following:

Point ID	Direction	Screened Interval (ft bgs)	Distance from SVE-1 (ft)
SVE-1	NA	4.5-14.5	
VP-1N	Southeast	13-15	17.5
VP-2N	Southeast	6-8	18.5
VP-1S	Southeast	13-15	31.0
VP-2S	Southeast	6-8	33.0

Table 1. SVE-1 Vacuum Monitoring Network

#### Step Test and Constant Rate Test Summary

The SVE pilot testing consisted of three step tests, which were performed by incrementally closing the make-up air valve to determine the change in ROI at different applied vacuums and flow rates, followed by a constant rate test. Each step test was run until a minimum of three successive readings (taken on 15 minute intervals) were obtained which showed no significant change in operating conditions. Upon completion of the step test, the constant rate test began and was conducted until three successive readings (taken on 1 hour intervals) were obtained which showed no significant change in operating conditions. The following summarizes the operating conditions during the pilot testing:

- Step 1 Vacuum of 20 inches of water column (in.H<sub>2</sub>O) and a flow rate of less than 20 standard cubic feet per minute (scfm) (dilution air valve partially closed) was maintained at the Extraction Well SVE-1 wellhead for four consecutive reading (60 minutes). Note that the lowest increment on the wellhead flow meter is 20 scfm, thus an accurate measure of flow could not be obtained during the first and second steps.
- Step 2 Vacuum of 40 in.H<sub>2</sub>O and a flow rate of less than 20 scfm (dilution air valve partially closed) was maintained at the SVE-1 wellhead for three consecutive readings (45 minutes).
- Step 3 Vacuum of 68 in.H<sub>2</sub>O and a flow rate of 40 scfm (dilution air valve fully closed) was maintained at the SVE-1 wellhead for three consecutive readings (45 minutes).
- Constant Rate Test Conducted under the same conditions as the third step test (68 in.H<sub>2</sub>O and 40 scfm at SVE-1, with the dilution air valve fully closed) and was maintained for an additional 3 hours after the conclusion of the third step test.

Baseline differential pressure measurements were collected at Extraction Well SVE-1 and each VMP immediately prior to startup of the system for the first step test on February 9, 2012 and again on February 10, 2012 prior to initiation of the second step. During the step tests, vacuum measurements were taken at Extraction Well SVE-1 and each VMP on 15 minute intervals. During the constant rate test, vacuum measurements were taken at Extraction Well SVE-1 and each VMP at 1 hour intervals. The total flow rate, dilution air flow rate, and applied vacuum at the blower influent were also recorded. Data collected during the SVE pilot test is summarized in Appendix B. Measurement of system parameters during the pilot tests utilized the following equipment:

- Magnehelic vacuum gauges of varying sizes (0 to 10 in.H<sub>2</sub>O, 0 to 20 in.H<sub>2</sub>O, 0 to 50 in.H<sub>2</sub>O, and 0 to100 in.H<sub>2</sub>O) were used to monitor vacuum and pressure throughout the vacuum observation well network. The gauges were connected to air tight, valved ports connected to the top of each VMP.
- A flow manifold included an inline flowmeter, temperature gauge, sampling port, and valve. The sampling port on the flow manifold was utilized to obtain vacuum measurements and air stream vapor samples.

- A flow meter on the effluent line measured total system flow rate to account for any make up air used during the pilot study.
- A temperature gauge was used to measure the effluent temperature during operation.
- The SVE and VMP monitoring points were gauged with an electronic water level indicator prior to commencement of the pilot test. No water was detected in any of the points.

#### Vapor Sampling

Two vapor samples were collected during the pilot testing. The vapor samples were collected using summa canisters and submitted for laboratory analysis of volatile organic compound (VOCs) by United States Environmental Protection Agency Method TO-15. The first sample was collected on February 9, 2012, just prior to shutting down the system at the conclusion of the first step test (approximately 1 hour after startup of the test). The second sample was collected on February 10, 2012, just prior to shutting down the system at the conclusion of the constant rate test. The air make-up valve was fully closed during the collection of both samples to ensure that no dilution of the sample occurred. Analytical data collected during the SVE pilot test is summarized in Table C1 in Appendix C.

#### Summary of Pilot Study Data

A target vacuum of -0.01 in. $H_2O$  measured at each VMP was selected as the minimum vacuum required to show adequate response from Extraction Well SVE-1. Based on the measured vacuums, all VMPs within 33 feet of the extraction well achieved at least -0.01 in. $H_2O$  at an SVE-1 vacuum of 20, 40, and 68 in. $H_2O$ .

During the pilot test a conservative average flow rate from the system is estimated to be 60 scfm. Based on this flow rate over a duration of 8 hours, and using the pilot test vapor sampling analytical data, the estimated mass of extracted vapors was approximately 0.35 pounds for the duration of the 8 hour pilot test, or an average of approximately 0.06 pounds per hour.

Calculations for the estimated mass of the extracted vapors are provided in Table C2 in Appendix C.

#### Phase I SVE System Design

Data collected from the pilot test was used to evaluate and calculate the design parameters for the Phase I SVE system, including the required flow rate, vacuum, and ROI of each SVE extraction well. The remedial equipment was sized to match the designed flow rate from each well and vacuum required during Phase I SVE system operation. In addition, analytical data obtained from vapor samples was used to determine if effluent air treatment is required.

The proposed Phase I SVE system has been designed based on the relationship between pore volume exchange rate, ROI, extraction well flow rate, and extraction well vacuum. The pore volume exchange rate determines the air flow rate which must be extracted to achieve design goals. Typical SVE systems operate at one to two pore volume exchanges per day. At a specified pore volume exchange rate, ROI is set based on the achievable flow rate and vacuum parameters. At a larger ROI, the required flow rate and vacuum requirements increase.

In order to provide an effective vapor control system, the Phase I SVE system has been designed to meet the following parameters:

• The basis of design is extraction of two pore volume exchanges (PVE) per day at a 35-foot ROI. Operational parameters to achieve these criteria are estimated to be 32 scfm at 6 in.H<sub>2</sub>O at each of the extraction points.

The design calculation sheet for the PVE is included in Appendix D. Based on these design parameters, nine wells spaced 60 feet on center (35-foot ROI with overlap between points) are required to cover the area (Figure 4). Eight new SVE wells were installed the week of February 20, 2012; and will be used in conjunction with existing Extraction Well SVE-1. In general, all SVE wells are 2 inches in diameter and have 10-to 15-foot schedule 40 PVC, 0.010-inch slot, wire-wrapped screens installed approximately 2 to 5 feet above the water table.

In addition to utilizing properly designed ROIs for the soil conditions at the site, the following will be incorporated into the Phase I SVE system to maximize the efficiency of the system:

• Individual lines will be run to each extraction well rather than connecting the wells to a common extraction header. This will allow for maximum flow control and operational flexibility at each location.

• Strategies to minimize water in the extraction piping include sloping the conveyance lines toward the wells (where achievable) to allow gravity to drain the lines, in addition to a standard knock-out tank.

The proposed Phase I SVE system will be installed with permanent extraction wells and sub-grade piping, and a mobile SVE system trailer. The SVE trailer will be approximately 8 ft wide and 16 ft long, and will be placed south of the existing propane tanks in the area where the former propane tanks were located. The system will be fully automated and is designed to run continuously without operator oversight. The blower will be sized to provide a minimum design flow rate of 32 cfm at an applied vacuum of 6 in.H<sub>2</sub>O at each SVE well to achieve a ROI of 35 feet and two PVE's per day. A majority of the site is paved and/or overlain by a shallow clay layer which provides a surface seal. This seal will enhance the effectiveness of SVE systems by forcing air to be drawn from greater distances and limiting barometric pressure interferences to the edges of the surface seal. In addition, the pavement will minimize infiltration from rainfall, and reduce the potential for interference from water within the SVE wells.

Laboratory data collected during the pilot test was used to estimate the air discharge and evaluate if air treatment is required. Based on the sum of all detected concentrations in the vapor sample collected during the first hour of SVE pilot testing activities (344,763 micrograms per cubic meter Total VOCs), and operation of nine SVE wells at the maximum expected flow rate (288 scfm), the maximum expected discharge from the Phase I SVE system is 0.37 pounds per hour (lbs/hr). VOC emissions estimated for the design flow rate and maximum vapor concentration is included in Table E1 in Appendix E. In accordance with Wisconsin Administrative Code NR406.04 (1)(m), the SVE system is exempt from air permit requirements and will not require air treatment based on the following.

• The potential to emit organic compounds from the site is less than 5.7 lbs/hr.









Appendix A

Soil Boring Logs

State of Wisconsta Department of Natural Resources <u>Route 10:</u> 1	Vaiershed/Wastewater	Waste Mans	gement	MONITORING WELL CONSTRUCTION Form 4400-113A Rev. 7-98
Facility/Project Name	Local Grid Location of Well	⊒ğ.		Well Name VP-1S
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			3. Surface scal:	Bentonite p4 30
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Please complete both Forms 4400-113A and 4400-113B and return them to the appropriate DNR office and bureau. Completion of these reports is required by cits. 160, 281, 283, 289, 291, 292, 293, 295, and 299, Will, Statts, and ck. NR 141, Wis, Adro. Code, in accordance with cits. 281, 283, 291, 292, 293, 295, and 299, Will, Statts, failure to file these forms may result in a forferune of between \$10 and \$25,000, or imprisonment for up to new year, depending on the program and canadic involved. Personally identifiable information on these forms is not intended to be used for any other purpose. NOTE: See the instructions for more information, including where the completed forms should be sent.

State of Wisconsin Department of Natural Resources <u>Route to:</u>	Watershed/Wastewater	Wasts Management	MONITORING WELL CONSTRUCTION Fount 4400-113A Rev. 7-98
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G. Filter pack, top ft. MS	Lor4.0 ft.			b. Volume adde	d ft	3	
	60.		8, گ	Filter pack mater	tial: Manufactorer, produ	ct name & mas	sh size
H. Screen joint, top ft. MS	Lor0.0 ft.	~ <u>-</u> []-[		<u>, #40</u>			
5	8 Ja.			h. Volume adde	d <u>lbag</u> ft	3	
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	~ 80a.	ノ煎			Flush threaded PVC so	bedule 80 🔲	24
J. Filter pack, bottom IL MS					DUC	Other 🛛	
	804		10	. Screen material:	PVC		
K. Borshole, bottom	Fot			в. Зстеел туре:		Factory cut M	11
20			N.		Cont	incour slot 🏾	01
L. Borehole, diameter in.			$\mathbf{X}$		Therese	Other 🛙	
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100			N.	a sionata tenga	Li		_4 IL.
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						Other D	
I hereicy certify that the salencedion on this	Jorna is true and correct.	in the best	t on the protection	ucalite			
Simon filler the Auro	de la	rsv ə	gineerin	g, Inc., Jeffe	rson, WI		

Please complete both Forms 4400-113A and 4400-113B and return them to the appropriate DNR office and bureau. Completion of these reports it required by cits. 160, 281, 283, 289, 291, 292, 293, 295, and 299, Wis. Stats, shifter to the the conduct with cits. 281, 289, 291, 292, 293, 295, and 299, Wis. Stats, failure to the these forms may result in a forfeiture of between \$10 and \$25,000, or imprisonment for up to one year, depending on the program and conduct involved. Personally identifiable information on these form is not intended to be used for any other purpose. NOTE: Sea the instructions for more information, including where the completed forms should be sent.

. . .

State of Wiscourse Department of Natural Resources <u>Route to:</u> V	Vatershed/Wastewater	Waste Manager	meat	MONITORING WELL CONSTRUCTION Forma 4400-113A Raw, 7-98	ON
	Cenediation/Redevelopment			Wall Name	—
Modioon Kinn 04 510		<b>P</b>		VP-2D	
Mauson-Ripp 04-010		3.		We Unique Well No. INP Well ID No.	
Facility License, Permit or Monitoring No.		20. []) Ur Wi		WIS, DILIQUE WERTHO, DIRK HERTONG	•
	Lat, 1	.ong	or		
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12. USCS classification of soil near scree			1. Accusional pro		Ū,
GP C CMC CCC GW C		$    \setminus \langle \rangle$	If yes, describe	·	
SM CISC U MLCI MHLLI			Surface scal-	Bentonite A 3	10
Bedrock	8			Concrete D 0	11
13. Sieve analysis performed?	Yes 🖄 No			Other 🛛 🦉	艭
14 Drilling method used: Ro	kany 🗆 50 🛛 🎆	4. N	viaterial between	well easing and protective pipe:	
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geomrobe 0	ther D3			Other 🛛 🎽	譺
			A montain ann an	A Granulae/Chinned Bentonite X 3	13
16 Dalling Duid made Water C 02		3.6	ATTIMAT Space Ser	ar, Destantis and durate 3	15
	Nume IN 99	b.	Lbs/gaiπ	Ind Weight Bennomie-same storty	
		G C.	Lbs/gal u	nud weight Hentonite slorry 🖵 🖇	5 A .
16 Puilling additions used?	Ves MiNo	d.	% Benton	ite Benionite-cemeni grout Li 5	50
To, Diffing sources each.		.a.	<u>1089</u> Pi	volume added for any of the above	
		1	How installed:	Tremie 🗋 (	01
Describe		<b>8</b>		Tranis pumped 🛛 🔘	92
17. Source of water (attach malysis, if req	uired):			Gravity 🕅 (	80
		6.E	Bentonite seal:	a. Bentonite granules [] 3	33
		ъ	. ⊡1/4 in. ⊠	3/8 in. D1/2 in. Bentonite chips 🕅 3	32
E Rentamite and ton ft. M.	SL or 0.0 fL			Other [] \$	
The second					1.44
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	er 11.0 m		مريد مريد المريد		6,045
G. Pitter pack, top	·····			l IL <sup>+</sup>	
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H. Screen joint, top II. M.			0-10	*	
	- 15.0.0		Voltarne addeo	ft loag ft	
L Well bottomfL M	sraion la	靈術 9.1	Well casing:	Flush threaded PVC schedule 40 M	23
				Faish threaded PVC schedule 80 [] 2	24
J. Filier pack, bottomft. M	SLor15.0 ft			Other 🛛 🛔	2
		10.9	Screen material:	PVC	
K. Borehole, bottom ft. M	SL or15.0 ft		. Screen type:	Factory cut 2 1	11
				Continuous slot 🔲 🧃	6.1
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			<u> </u>	Duber LI 3	
I hereby certify that the information on thi	s form is true and correct to the	best of my knowl	edge.		
Signature ///	Fin peu	Engineering		mon MI	
fella U. C.	Fragel 100		y, mu., Jene	19011 141	_

Ξ.

Please complete both Forms 4400-113A and 4400-113B and return them to the appropriate DNR office and bareau. Completion of these reports is required by chs. 160,281, 283, 289, 291, 292, 293, 295, and 299, Wis. Stats, and ch. NR 141, Wis. Adva. Code. In accordance with chs. 281, 289, 391, 292, 293, 295, and 299, Wis. Stats, and ch. NR 141, Wis. Adva. Code. In accordance with chs. 281, 289, 391, 292, 293, 295, and 299, Wis. Stats, failure to file these forms may result in a forfeiture of between 510 and 525,000, or imprisonment. For my to one year, depending on the program and conduct involved. Personally identifiable information on these forms is not intended to be used for any other purpose. NOTE: See the instructions for more information, including where the completed forms should be sent.

Appendix B

SVE Pilot Test Field Data

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		c	

	17:10 F
n, Wisconsin.	it Start Time:
, Madiso	Pilot Tes
Corporation	
Madison-Kipp	2/9/2012
est Field Data, I	Date:
Soil Vapor Extraction Pilot T	
Table B1.	

		Date:	2/9/2012	Pilot	t Test Start Time:	17:10 PM	Am	bient Temperature:	35°F		
		Personnel:	T.Alessi / W. May	_	Weather:	Partly Cloudy	Ba	arometric Pressure:	30.06 in		
		Extraction Point		Monitori	ng Point			Ex	ctraction System		
		SVE-1	VP-1N (17 5' from EW)	VP-2N (18 5' from EW)	VP-1S (31' from EW)	VP-2S (33' from EW)	Blower Inlet Vacuum	Extraction Well Flow Rate	Dilution Air Flowrate	Blower Outlet Flow Rate	Blower Outlet Temperature
Test Designation	Date/Time	(in H <sub>2</sub> O) <sup>(1)</sup>	(cfm)	(cfm)	(cfm)	(°F)					
Pre-Startup	2/9/2012 17:10	-0.01	0.01	-0.01	-0.01	0.00		;	1		:
Step 1	2/9/2012 17:25	-20	-0.29	-0.05	-0.05	-0.02	-21	<20 <sup>(2)</sup>	>60 <sup>(2)</sup>	80	60°F
Step 1	2/9/2012 17:40	-20	-0.30	-0.06	-0.06	-0.02	-20	1	I	I	:
Step 1	2/9/2012 17:55	-20	-0.28	-0.06	-0.06	-0.02	-20	1	I		:
Step 1	2/9/2012 18:10	-20	-0.30	-0.06	-0.06	-0.01	-20	<20 (2)	>60 <sup>(2)</sup>	80	70°F
ć	с :	Date:	2/10/2012	Pilot	t Test Start Time:	8:05 AM	Am	bient Temperature:	25°F		
	7 4	Personnel:	T.Alessi		Weather:	Snow	Ba	rometric Pressure:	29.89 in		
		Extraction Point		Monitori	ng Point			Ex	draction System		
		SVE-1	VP-1N (17.5' from EW)	VP-2N (18.5' from EW)	VP-1S (31' from EW)	VP-2S (33' from EW)	Blower Inlet Vacuum	Extraction Well Flow Rate	Dilution Air Flowrate	Blower Outlet Flow Rate	Blower Outlet Temperature
Test	Date/Time	(in H <sub>2</sub> O) <sup>(1)</sup>	(cfm)	(cfm)	(cfm)	(°F)					
Pre-Startup	2/10/2012 8:05	-0.01	-0.01	-0.01	-0.01	0.00	1		I	-	1

		Extraction Point		Monitori	ng Point			ũ	ctraction System		
		L	VP-1N	VP-2N	VP-1S	VP-2S	Blower Inlet	Extraction Well	Dilution Air	Blower Outlet	Blower Outlet
Test	Date/Time	SVE-1 (in H <sub>2</sub> O) <sup>(1)</sup>	(11.5 Trom EW) (in H <sub>2</sub> O) <sup>(1)</sup>	(18.5 Trom Ew) (in H <sub>2</sub> O) <sup>(1)</sup>	(31 Trom EW) (in H <sub>2</sub> O) <sup>(1)</sup>	(in H <sub>2</sub> O) <sup>(1)</sup>	(in H <sub>2</sub> O) <sup>(1)</sup>	Flow Kate (cfm)	rlowrate (cfm)	rlow Kate (cfm)	lemperature (°F)
Pre-Startup	2/10/2012 8:05	-0.01	-0.01	-0.01	-0.01	0.00	1	1	1		
Step 2	2/10/2012 8:30	-40	-0.50	-0.10	-0.11	-0.02	-40	<20 (2)	>40 <sup>(2)</sup>	60	68°F
Step 2	2/10/2012 8:45	-40	-0.50	-0.10	-0.11	-0.02	-40	<20 (2)	>40 <sup>(2)</sup>	60	74°F
Step 2	2/10/2012 9:00	-40	-0.50	-0.10	-0.11	-0.02	-40	<20 <sup>(2)</sup>	>40 <sup>(2)</sup>	60	74°F
Step 3	2/10/2012 9:15	-68	-0.80	-0.18	-0.18	-0.05	-68	40	0.0	40	92°F
Step 3	2/10/2012 9:30	-68	-0.80	-0.19	-0.18	-0.04	-68	40	0.0	40	98°F
Step 3	2/10/2012 9:45	-68	-0.80	-0.18	-0.18	-0.05	-68	40	0.0	40	100°F
Extended Test	2/10/2012 10:00	-68	-0.90	-0.19	-0.18	-0.05	-69	40	0.0	40	98°F
Extended Test	2/10/2012 11:00	69-	-0.90	-0.18	-0.18	-0.05	-70	40	0.0	40	98°F
Extended Test	2/10/2012 12:00	-70	-0.90	-0.18	-0.18	-0.06	-70	40	0.0	40	98°F
Extended Test	2/10/2012 13:00	-70	-0.90	-0.19	-0.18	-0.05	-70	40	0.0	40	96°F
(1)	Vacuum measured w	ith a Magnehelic gauc	ge.			in H <sub>2</sub> O	inches of water col	lumn			
(2)	Flow meter low increr	ment is 20 CFM and fl	low rates from extra	action well		fpm	feet per minute				
	at less than 20 CFM v	were unable to be rec	orded.			cfm	cubic feet per minu	ute			
						1	Not monitored				

Appendix C

SVE Pilot Test Analytical Data and Estimate of Mass Removed

		Efflue	nt Concentration
Vapor Phase Constituent			
		(EFF-1)	(EFF-2)
		µg/m³	μg/m <sup>3</sup>
Tetrachloroethene		325,000	163,000
Trichloroethene		4,600	2,880
trans-1,2-Dichloroethene		563	120
cis-1,2-Dichloroethene		14,600	9,320
Acetone	<	258	11.4
Benzene	<	175	3.4
2-Butanone	<	323	4.5
Chloroform	<	532	13.1
Cyclohexane	<	366	1.5
Dichlorodifluoromethane	<	538	1.7
Ethanol	<	1,020	7.3
Ethylbenzene	<	473	2.7
n-Hexane	<	387	4.3
Methylene Chloride	<	382	16.3
Naphthalene	<	1,450	7.7
Tetrahydrofuran	<	323	3.0
Toluene	<	414	8.1
1,2,4-Trimethylbenzene	<	537	5.3
Vinyl Chloride	<	140	13.4
m&p-Xylene	<	946	6.6
o-Xylene	<	<u>473</u>	<u>2.8</u>
Total VO	Cs	349,132	175,433

# Table C1. Soil Vapor Extraction Pilot Test Analtyical Data, Madison-Kipp Corporation, Madison, Wisconsin.

< Constituent not detected above the laboratory reporting limit.

**Bold** Constituent detected above the laboratory reporting limit.

cfm Cubic feet per minute.

ppbv Parts per billion by volume.

µg/m<sup>3</sup> Micrograms per cubic meter.

lb/hr Pounds per hour.

Date	Total VOC Concentration <sup>1</sup>	System Flow Rate	Dilution Air Valve Position	Emission Rate <sup>2</sup>	Mass Removed <sup>3</sup>	Cumulative Mass Removed
	hg/m³	cfm	percent open	lb/hr	Ib/day	qI
2/9/2012 18:10	349,132	09	0	80.0	0.08	0.08
2/10/2012 13:00	175,433	60	0	0.04	0.28	0.35
		Averag	e Emission Rate	0.06	0.18	

Table C2. Estimate of Mass Removed during Soil Vapor Extraction Pilot Test, Madison-Kipp Corporation, Madison, Wisconsin.

<sup>1</sup> Total VOC concentration was based on the sum of all detected analyte concentrations in Samples EFF-1 and EFF-2.

<sup>2</sup> Emission rates were determined using the following equation:

Emission Rate = Influent Conc. \* Flow Rate \* 60 min/hr \* (1 m $^3/35.31$  ft $^3$ ) \* (1 lb/4.54x108 mg)

<sup>3</sup> Mass removed is calculated based on the average emission rate for two consecutive sample dates multiplied by the operating time between those sample date.

Mass Removed = [(Emission Rate<sub>1</sub> + Emission Rate<sub>2</sub>) / 2] \* [(Date<sub>2</sub> - Date<sub>1</sub>) \* 24]

<sup>4</sup> Emission factors were determined from detected soil gas vapor concentrations collected after completion of pilot test (Sample EFF-2).

<sup>5</sup> When compounds are not detected above the laboratory reporting limit, emissions are calculated using 1/2 the reporting limit.

Cubic feet per minute.	Pounds per day.	Pounds per hour.	Micrograms per cubic meter.
cfm	lb/day	lb/hr	hg/m <sup>3</sup>

Appendix D

Soil Vapor Extraction System Design Calculations

#### Madison Kipp Corporation Soil Vapor Extraction System Design Calculations

#### PHYSICAL PROPERTIES OF THE SOIL AND AIR

#### **Soil Porosity**

The total porosity is described by the variable  $\eta$ .

$$? := 0.3 \quad \frac{\mathrm{cm}^3}{\mathrm{cm}^3}$$

#### **Air Density**

Density for air is given for a soil temperature of 10 C.

$$?_{air} := 1.27 \cdot 10^{-3} \frac{g}{cm^3}$$

#### VAPOR EXTRACTION SYSTEM DESIGN SPECIFICATIONS

#### Vadose Zone Thickness

The value for vadose zone thickness in feet.

h := 20	ft
<u>h</u> := h·30.48	cm
h = 610	cm

#### Vapor Extraction Well Radius

The value for the SVE well radius in feet, including filter pack.

a := 0.25 ft  $a := a \cdot 30.48$  cm a = 7.6 cm

#### Pore Volume Exchange Rate

The pore volume exchange rate determines the air flow which must be applied to any soil volume, to achieve design goals. Typical vapor extraction systems achieve 1 to 2 pore volume exchanges per day.

ER := 2 Pore Volume Exchanges per day

#### **RADIAL FLOW DESIGN FUNCTIONS**

The soil vapor extraction method relies on two principal design functions. The first relates the mass air flow required to achieve the design pore volume exchange rate as a function of the soil pore volume between the well radius and the variable, outer radius, b. The second function calculates the pressure drop required to drive air flow at the design pore volume exchange rate, over the soil volume which lies between the outer radius, b, and the well bore radius, a. The data collected during the SVE pilot test have been used to determine the pressure drop in the system. The mass flow needed to meet the design specifications is calculated below.

#### The Mass Flow Function

The mass flow function was developed to express the air flow required through a target soil volume, as a function of the outer radius, b, of the target volume, and the selected pore volume exchange rate, ER. The values for vadose zone thickness, h, total porosity,  $\eta$ , and air density,  $\rho_{air}$ , were all specified above.

$$Q(b) := \frac{ER \cdot p \cdot (b^2 - a^2) \cdot h \cdot ? \cdot ?_{air}}{1440 \cdot 60} \qquad \qquad \frac{g}{sec}$$

#### Estimates of Per Well Flow Rate to Achieve Specified PVE

For the mass flow point estimate, a revised function,  $Q_1(b)$  is defined, to provide a result

in conventional air flow units ( $ft^3$ /min). The function calcaulates the minimum flow rate needed to obtain the specified PVE at an ROI (b) of 35 feet.

$$b := 35$$
 ft  
 $b := b \cdot 30.48$   
 $b = 1067$  cm

Estimated flow rate in cubic feet per minute (CFM) needed from a single well to achieve two (2) PVE's per day at a ROI of 35 feet and a vadose zone thickness of 20 feet.

$$Q_1(b) = 32$$
  $\frac{ft^3}{min}$ 

#### Appendix E

Maximum Organic Compound Emission Rate Estimated for Phase 1 SVE System

# Table E1. Maximum Estimated Organic Compound Emission Rate, Phase I Soil Vapor Extraction System, Madison-Kipp Corporation, Madison, Wisconsin.

Vent System Flow Rate (	cfm)	288
	Highest Estimated	
Vapor Phase Constituent	Effluent Concentration	Estimated Emission Rate
	μg/m <sup>3</sup>	lb/hr
Tetrachloroethene	325,000	0.350
Trichloroethene	4,600	0.005
trans-1,2-Dichloroethene	563	0.001
cis-1,2-Dichloroethene	<u>14,600</u>	<u>0.016</u>
	Maximum Estimated Organic Compound Emission Rate	0.372

1. Calculations based on an air flow rate of 32 CFM per well (9 wells total).

2. Emission factors were determined from detected soil gas vapor concentrations collected during first hour of pilot test (sample EFF-1).

cfm Cubic feet per minute.

µg/m<sup>3</sup> Micrograms per cubic meter.

lb/hr Pounds per hour.