APPENDIX A

Summary of SVE System Operation, Maintenance, Repair, and Hydrocarbon Recovery Calculations

A-1. SVE and Treatment System Maintenance Repair and Downtime Summary

A-2. SVE and Treatment System Hydrocarbon Recovery Calculations

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ACRONYMS AND ABBREVIATIONS

C	vapor concentration
CO	carbon monoxide
CO_2	carbon dioxide
K	Kelvin
KAFB	Kirtland Air Force Base
kg	kilogram
kg/m^3	kilograms per cubic meter
m^3/hr	cubic meters per hour
O_2	oxygen
ppmv	parts per million by volume
SVE	soil-vapor extraction

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A-1. SVE and Treatment System Maintenance and Repair Summary

The primary maintenance interval for the soil-vapor extraction (SVE) and treatment units 249, 335, 344, and 345 is every 360 hours (approximately 2 weeks), as recommended by the system manufacturer. Routine biweekly maintenance includes checking and changing the oil, filters, spark plugs and spark plug wires; checking the coolant level and adding coolant as needed; cleaning the air filter; and checking all belts, hose connections, battery connections and emergency contact switches. Monthly maintenance includes all bi-weekly maintenance, and includes replacing distributer caps, rotors, polyvinyl chloride valves and cleaning the radiators. All bi-weekly and monthly maintenance requires each unit being serviced, to be shut down for approximately 4 hours.

1.1 Scheduled Maintenence

During the reporting period, biweekly maintenance was performed on the SVE and treatment systems on the following dates:

- April 4, 2011
- April 5, 2011
- April 20, 2011
- April 21, 2011
- May 2, 2011
- May 3, 2011
- May 16, 2011
- May 17, 2011
- May 27, 2011
- May 28, 2011
- June 13, 2011
- June 14, 2011
- June 27, 2011
- June 28, 2011

During the reporting period, monthly maintenance was performed on the SVE and treatment systems on the following dates:

- April 20, 2011
- April 21, 2011
- May 27, 2011
- May 28, 2011
- June 27, 2011
- June 28, 2011

1.2 Non-scheduled Maintenance and Repairs

During this reporting period, in addition to the standard biweekly and monthly planned maintenance activities, the following maintenance or repairs were performed on the SVE units.

ST-106 Unit 249:

- April 14, 2011 – Replaced ignition switch on engine 1 of Unit 249.
- April 27, 2011 – Replaced alternators on engines 1 and 2 of Unit 249.

KAFB-1065 Unit 335:

- May 2, 2011 – Replaced spark plug wires, distributor cap and rotor.
- May 3, 2011 – Replaced ignition module on engine 1 of Unit 335.
- June 13, 2011 – Replaced catalyst, checked and adjusted timer.
- June 14, 2011 – Replaced oxygen sensors on all engines of units (249, 335, 345, and 344).
- June 13 and 14, 2011 – Performed source tests on all units (249, 335, 345, and 344).

KAFB-1066 Unit 345:

- April 20, 2011 – Replaced starter solenoids on engines 1 and 2 of Unit 345.
- June 3, 2011 – Replaced alternator on engine 2 of Unit 345.
- June 13, 2011 – Replaced catalyst, checked and adjusted timer.
- June 14, 2011 – Replaced oxygen sensors on all engines of unit 345.
- June 13 and 14, 2011 – Performed source tests on all units (249, 335, 345, and 344).

KAFB-1068 Unit 344:

- June 13, 2011 – Replaced catalyst, checked and adjusted timer.
- June 14, 2011 – Replaced oxygen sensors on all engines of unit 344 .
- June 13 and 14, 2011 – Performed source tests on all units (249, 335, 345, and 344).

A-2. SVE and Treatment System Hydrocarbon Recovery Calculations

As part of the ongoing Stage 2 abatement action for ST-106 and the interim remedial actions for SS-111, vapor samples from the SVE and treatment systems' inlets and exhausts are regularly analyzed on site using a Horiba Mexa 554J emissions analyzer for petroleum hydrocarbon concentration in parts per million by volume (ppmv) and for percent oxygen (O_2), carbon monoxide (CO), and carbon dioxide (CO_2). The hydrocarbon concentrations from the SVE system influent as measured in the field with the Horiba instrument are used in the hydrocarbon recovery calculations. Described below are the basic equations and constants that are used, along with the Horiba field measurements, to calculate total hydrocarbon recovery volumes.

For the SVE and treatment system associated with the Stage 2 abatement action at ST-106, the Horiba-measured influent hydrocarbon vapor concentration is used along with the molecular weight of the influent vapor stream, the gas constant, and the standard temperature to calculate the vapor concentration (C) in kilogram per cubic meter (kg/m^3). Vapor stream concentrations are measured by the Horiba instrument in parts per million by volume (ppmv), which can be converted into kg/m^3 for use in the following equation:

$$C = \frac{(Conc)(MW)}{\mathrm{RT}}$$

where:

Conc	=	vapor concentration (Horiba ppmv reading x 10^{-6})
MW	=	molecular weight of the vapor (120)
R	=	gas constant (0.0821) (L·atm/mol·K)
T	=	temperature (Kelvin [K]) (290)

The measured well gas inlet flow rate (cubic meters per hour [m^3/hr]) and hours of operation are then used to calculate recovered mass. Mass removal is estimated using the following conversion:

$$M = CQT$$

where:

M	=	mass removed (kilogram [kg])
C	=	vapor concentration (kg/m^3)
Q	=	extraction flow rate (m^3/hr)
T	=	operational period (hour)

The recovered mass is then converted to equivalent gallons.

The hydrocarbon recovery is calculated for each engine, and cumulatively summed over the operational period.

As an example, the mass (kg) of recovered hydrocarbons for engine E1 during a given period can be calculated using the measured influent vapor concentration from a measurement date in that period (such as 32,400 ppm_v), the well-gas inlet flow rate (such as 74.8 m^3/hr), the engine E1 operational hours during the period (539.9 hours), and the constants defined above as follows:

$$C = \frac{(32{,}400 \times 10^{-6}) \times 120)(0.0821 \times 290)}{} = 0.163\ {}^{kg}/_{m^3}$$

$$M = (0.163) \cdot (74.8) \cdot (539.9) = 6{,}594.8\ kg = 14{,}541\ lbs$$

The NAPL-equivalent gallons of hydrocarbon recovery are calculated by multiplying the recovery mass in pounds (lbs) time a density of 6.2 lbs/gallon NAPL.

$$Volume\ (gal.) = 6{,}594.8\ kg \cdot \frac{(2.205\ \text{lbs})}{1\ \text{kg}} \cdot \frac{1\ \text{gal}}{6.2\ \text{lbs}} = 2{,}345\ gal.$$

The mass of petroleum hydrocarbon biodegradation can be estimated by using the following equation published by the Air Force Center for Engineering and the Environment (AFCEE) guidance to account for the attenuation of petroleum hydrocarbons by bioventing (Leeson et al., 1996a,b):

$$HC_{Bio} = (C_{V,bkgd} - C_{V,O2})/100 \text{ x } Q \text{ x } C \text{ x } \rho_{O2} \text{ x } MW_{O2} \text{ x } (kg/1{,}000g) \text{ x } (1{,}440 \text{ min/day})$$

Where:

HC_{Bio}	=	Mass of hydrocarbons biodegraded (kilograms per day)
$C_{V,bkgd}$	=	Concentration of oxygen in background, uncontaminated area (%)
$C_{V,O2}$	=	Concentration of oxygen in extracted off-gas (%)
Q	=	Flowrate (cubic feet per minute [cfm])
C	=	Mass ratio of hydrocarbon to oxygen degraded based on stoichiometry[2] (1/3.5)
ρ_{O2}	=	density of oxygen (moles/liter)
MW_{O2}	=	Molecular weight of oxygen (grams/mole)

Based on this equation and an average oxygen deficit in the ICE influent vapor, the amount of biodegradation occurring at ST-106 (unit 249) and SS-111 (Units 335, 345, and 344 at wells KAFB-1065, 1066, and 1068, respectively) were estimated and included in Table A-1.

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APPENDIX A

Tables

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Table A-1

Calculation of NAPL Mass Degraded by Bioventing

January 2011 through June 2011[a, c]

Kirtland Air Force Base, Bernalillo County, New Mexico

		Unit 249 (ST-106)			Unit 335 (Well KAFB-1065)			Unit 345 (Well KAFB-1066)			Unit 344 (Well KAFB-1068)			All Units
Date	Background Oxygen (%)	Oxygen Inlet[b] (%)	Mass Degraded (lbs/period)	Mass Degraded (gal/period)	Oxygen Inlet[b] (%)	Mass Degraded (lbs/period)	Mass Degraded (gal/period)	Oxygen Inlet[b] (%)	Mass Degraded (lbs/period)	Mass Degraded (gal/period)	Oxygen Inlet[b] (%)	Mass Degraded (lbs/period)	Mass Degraded (gal/period)	Total Mass Degraded (gal/period)
1/31/2011			4,454	718		2,125	343		3,972	641		5,379	868	2,569
2/28/2011			4,743	765		1,577	254		5,116	825		5,454	880	2,724
3/31/2011	18.8	12.3	5,555	896	14.3	1,196	193	16.0	1,650	266	17	1,427	230	1,585
4/30/2011	18.9	19.9	0	0	14.3	1,140	184	20.3	0	0	15	2,756	445	628
5/31/2011	18.7	11.0	7,023	1,133	15.4	540	87	20.2	0	0	16	2,555	412	1,632
6/30/2011	17.2	11.0	5,470	882	11.9	1,030	166	14.4	1,082	174	16	694	112	1,335
Total 1/11 to 3/2011			14,751	2,379		4,898	790		10,738	1,732		12,260	1,977	6,879
Total 4/11 to 6/2011			12,493	2,015		2,709	437		1,082	174		6,005	969	3,595
Total 1/11 to 6/2011			27,244	4,394		7,607	1,227		11,820	1,906		18,265	2,946	10,474

Notes:

a. All operating values are based on RSI-ICE System PLC (computer program) technical data.

b. Oxygen concentrations are based on field measurements during the March 2011 through June 2011 sampling events.

c. Calculations are based on equation described in the appendix text.

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