Monitoring and Modeling of ROG at California Dairies

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CSU Fresno Air Quality Projects Related to Dairy Operations

ROG Sampling and Analysis for Dairies and Natural Soil/Vegetation In California
Principle Investigators: Charles Krauter and Dave Goorahoo, CIT
Cooperators: Derek Dormedy, CSU Fresno Chemistry Department and Chris Potter and Steve Klooster, Ames Research Center - NASA, Moffet Field
Begun 5/1/02, to be completed 6/30/04
Funded by the California Air Resources Board

Monitoring Ammonia, Methane and Other Emissions In Real Time At Dairies and Other Agricultural Operations
Principle Investigators: Dave Goorahoo and Charles Krauter, CSUF-CIT
Begun 7/1/02, to be completed 12/31/06
Funded by the CSU-Agricultural Research Initiative

Dairy Air Quality Monitoring–An Investigation of the Occurrence and Mitigation of Ammonia, Particulates and Ozone Precursors Associated With California Dairies
Principle Investigators: Charles Krauter, California State University Fresno, CA; and Theresa Cassel, Crocker Nuclear Engineering Lab, UC Davis, CA
Cooperators: Dave Goorahoo, Center for Irrigation Technology, CSU Fresno
Derek Dormedy, Chemistry Department, CSU Fresno
Steven Klooster, California State University Monterey Bay, CA
John Pisano, Center for Environmental Research, UC Riverside, CA
Christopher Potter, NASA Ames Research Center, Moffett Field, CA
Begun 7/1/03, to be completed 6/30/07 Funded by the CSU-ARI

Very Preliminary Conclusions

Some initial hypotheses are supported by these first data sets:

- The animal holding areas (free-stalls and exercise corrals) are a larger source of ROG than the lagoons by a factor of 2 - 4.
- The seasonal variability of ROG emissions may not be as large as the summer vs. winter levels of ammonia.
- Dairy management may be linked to ROG emissions from both the corrals and the lagoon.

ROG sampling and modeling at selected dairies in the San Joaquin Valley

- 1. Select dairies – about 2000 cows with flush-lane, free stall, lagoon systems.

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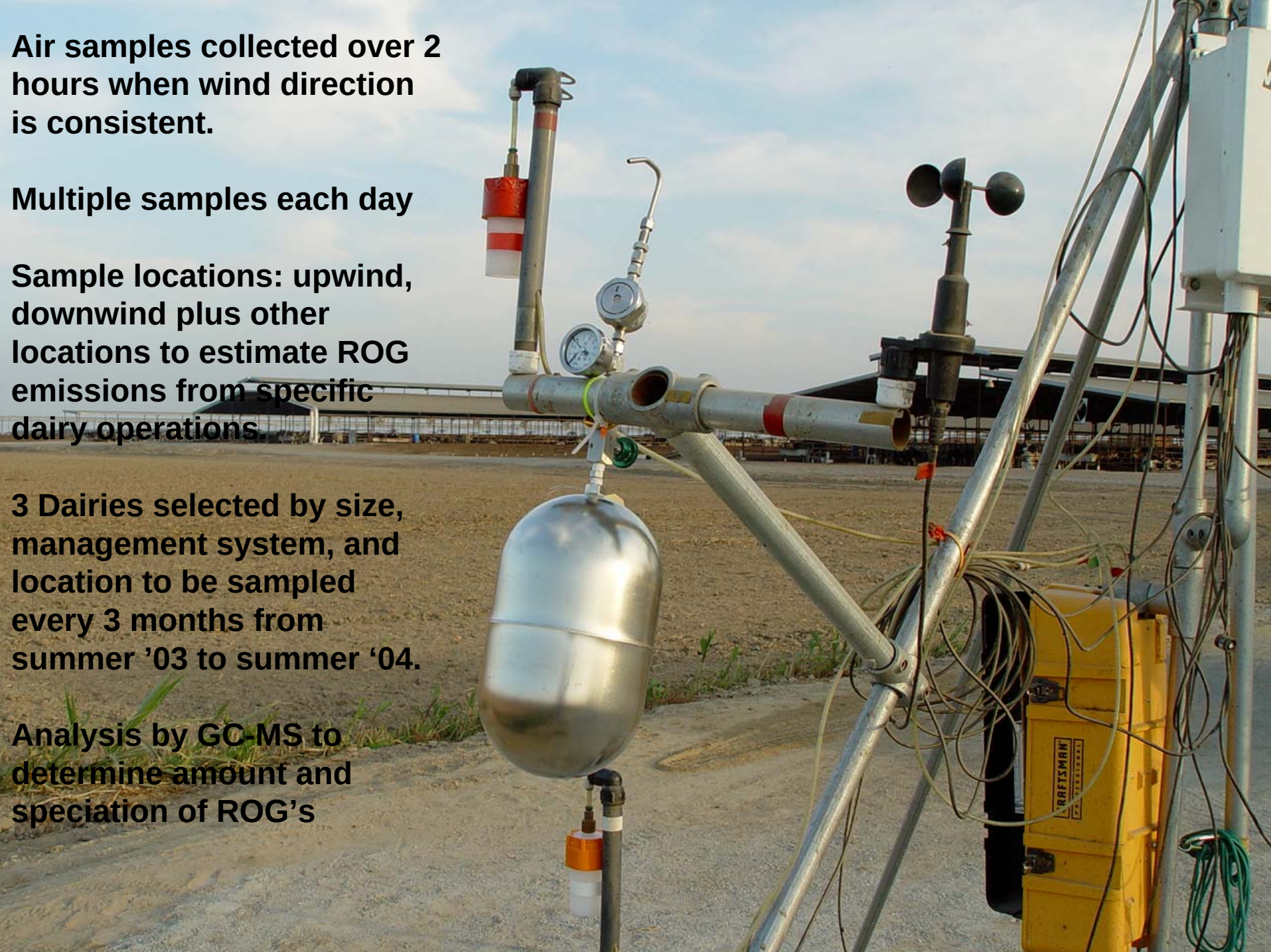


Air samples collected over 2 hours when wind direction is consistent.

Multiple samples each day

Sample locations: upwind, downwind plus other locations to estimate ROG emissions from specific dairy operations.

3 Dairies selected by size, management system, and location to be sampled every 3 months from summer ’03 to summer ‘04.

Analysis by GC-MS to determine amount and speciation of ROG’s

Kings County Dairy
Sampling Locations:

Upwind

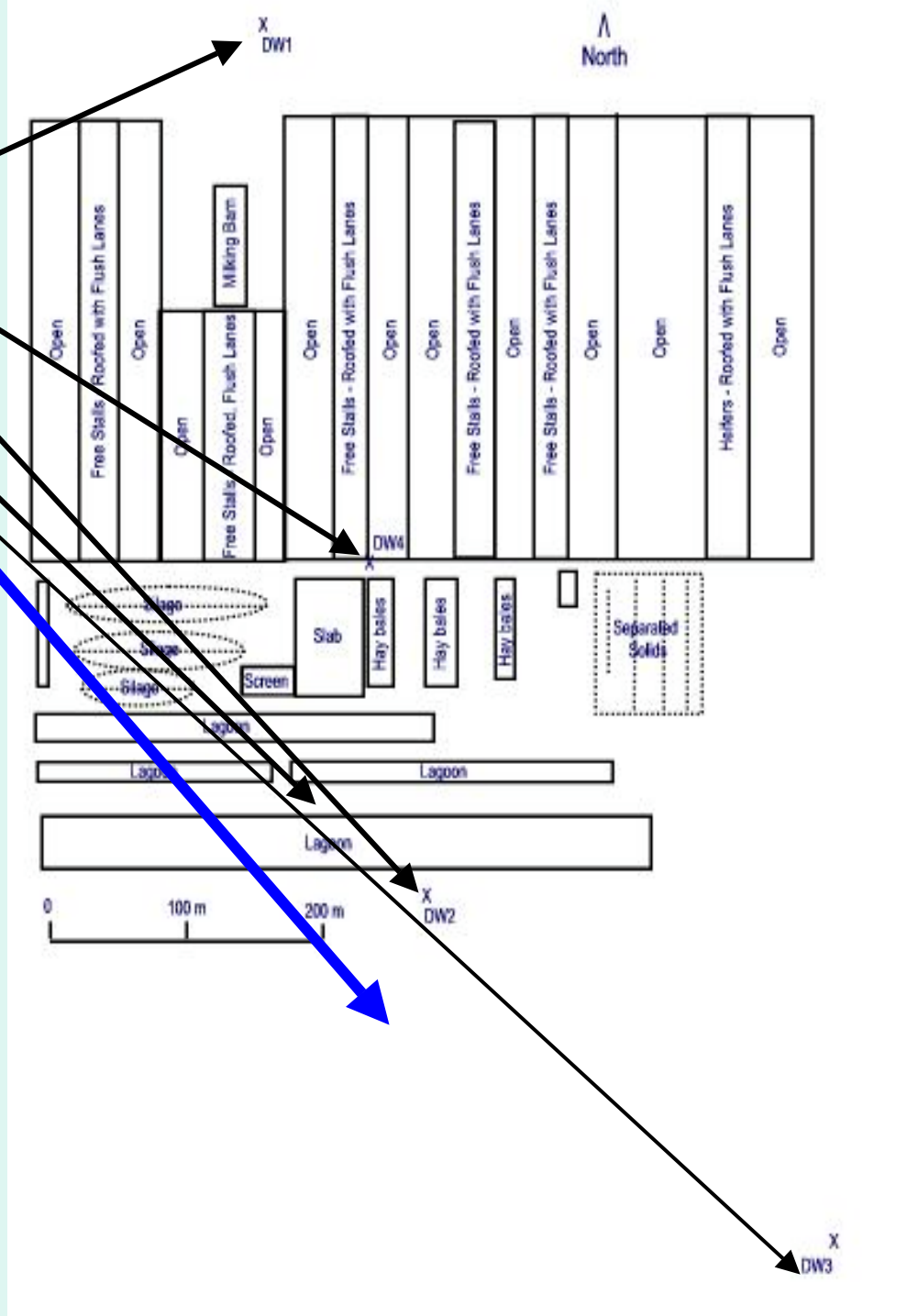
Downwind of the Free Stalls

Downwind of the Storage Lagoon

Downwind of the First Lagoon

Far Downwind for NH_3 only

Prevailing wind = 320 degrees



ROG sampling and modeling at selected dairies in the San Joaquin Valley

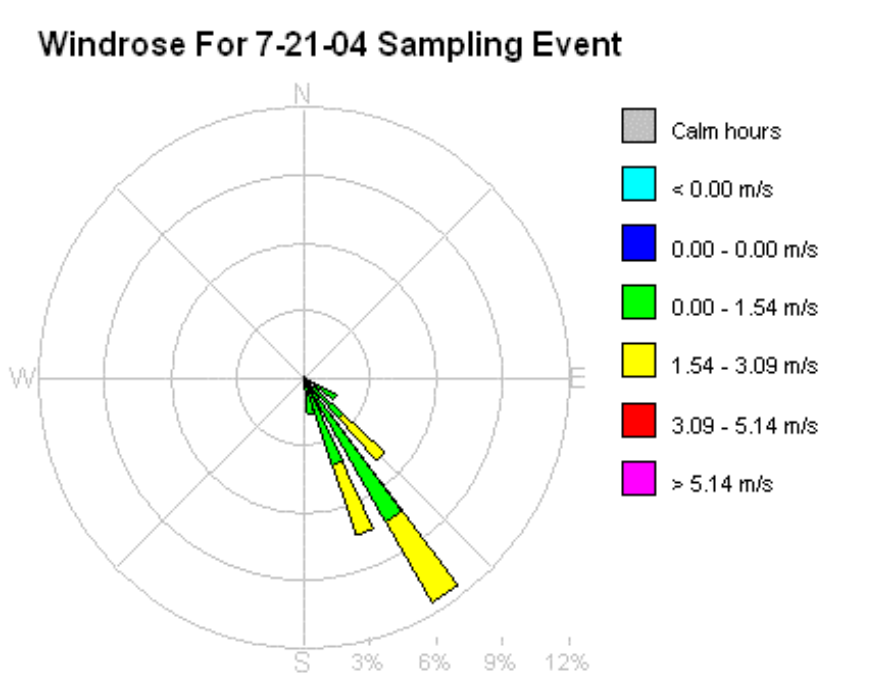
- 1. Select dairies – about 2000 cows with flush-lane, free stall, lagoon systems.
- 2. Determine sampling procedure – collect air samples upwind of the dairy and downwind of each significant dairy process.
- 3. Analyze samples – GCMS analysis of each field sample utilizing an appropriate standard to identify and determine the quantity of each gas.
- 4. Model emissions – estimate emissions from each dairy process by determining the net concentration from the upwind-downwind difference and model the emission using a Gaussian plume model (ISC-STv3)

Kings County Dairy

7/21/2004 1300 to 1530

Summer Dairy 2	Measured TO-15 Concentration	Net TO-15 Concentration	Emission Rate
	µg/m³	µg/m³	#/hd/yr
Freestall	72.7	21.5	1.3
Initial Lagoon	55.9	27.7	0.2
Storage Lagoon	52.4	10.3	0.4

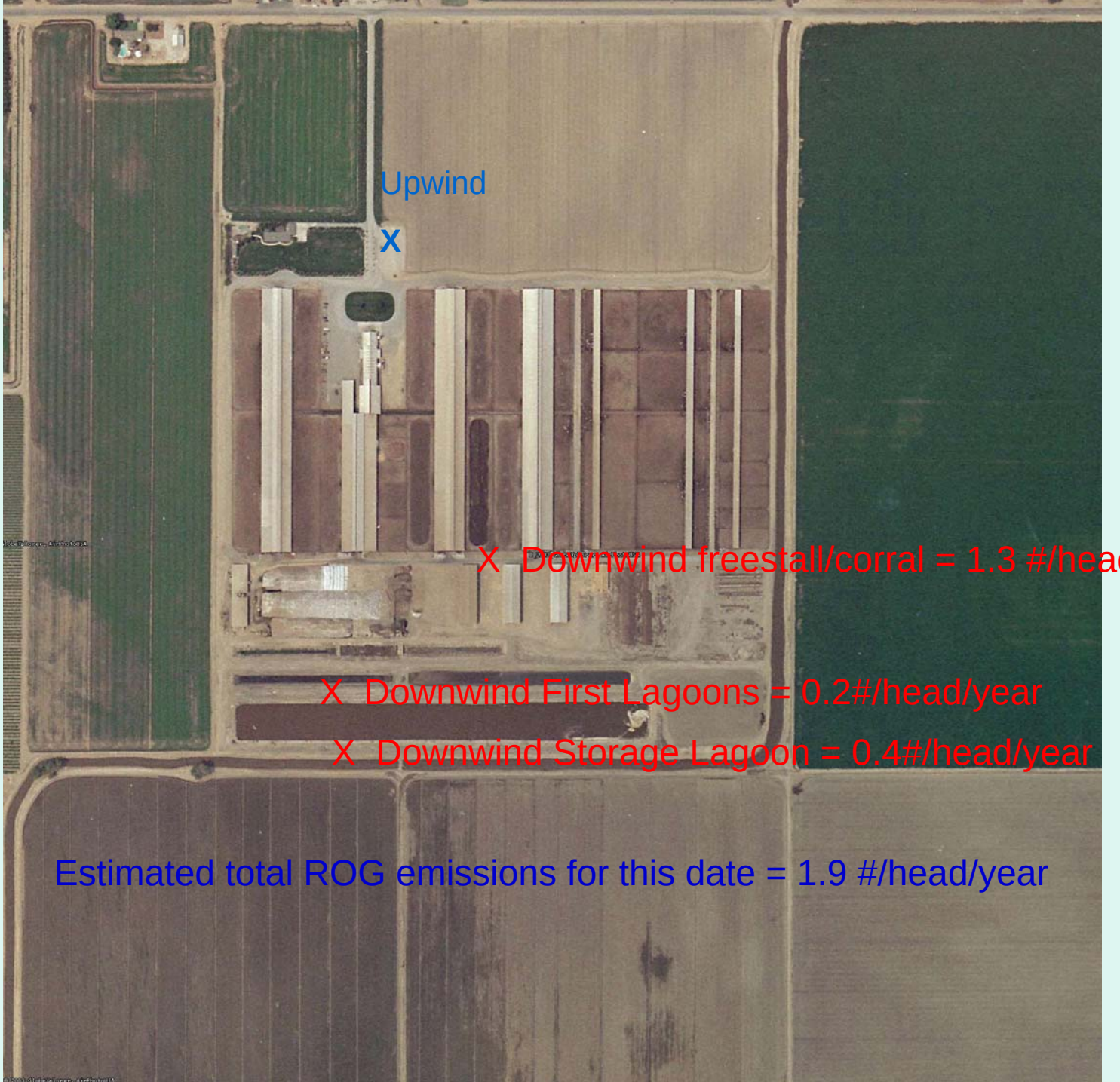
Sum = 1.9



Comments:

Summer wind direction and speed were typical for this location. Wind speed in the early afternoon was less than at other locations but the direction was sufficiently consistent for modeling.

Summing the emission rates is probably valid for this instance because the sampling points are in a sequence from upwind to downwind.

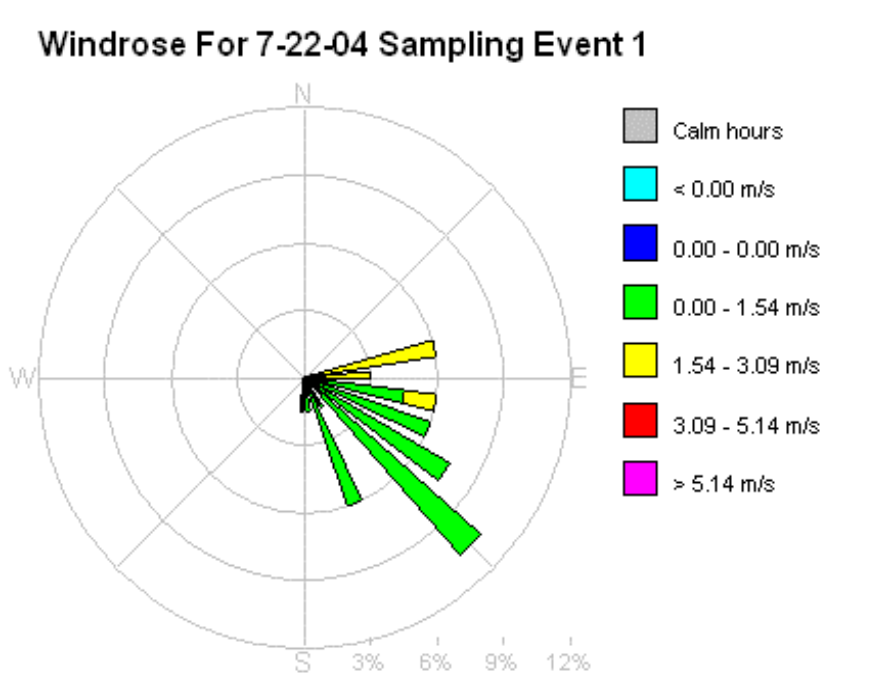

Upwind
X
X Downwind freestall/corral = 1.3 #/head/year
X Downwind First Lagoons = 0.2#/head/year
X Downwind Storage Lagoon = 0.4#/head/year
Estimated total ROG emissions for this date = 1.9 #/head/year

Kings County Dairy

7-22-04 test 1 1100 to 1330

Summer Dairy 2	Measured TO-15 Concentration	Net TO-15 Concentration	Emission Rate
	μg/m³	μg/m³	#/hd/yr
Freestall	64.3	12.4	0.9
Initial Lagoon	219.3	161.5	1.7
Storage Lagoon	69.7	19.3	1.1

Sum = 3.7



Comments:

Summer wind direction and speed were typical for this location. Wind speed in the late morning was less than at other locations. There was more variability in the direction so modeled emissions are less accurate than other sampling episodes.

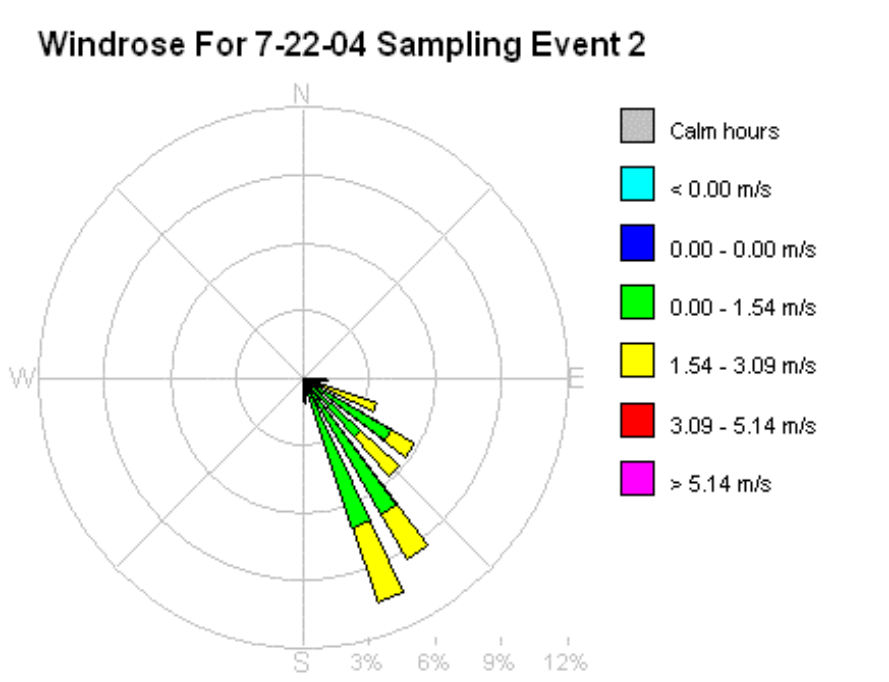
Summing the emission rates is probably valid for this instance because the sampling points are in a sequence from upwind to downwind.

Kings County Dairy

7-22-04 test 2 1330 to 1600

Summer Dairy 2	Measured TO-15 Concentration	Net TO-15 Concentration	Emission Rate
	μg/m³	μg/m³	#/hd/yr
Freestall	78.7	24.6	1.5
Initial Lagoon	85.5	36.8	0.3
Storage Lagoon	61.8	21.5	0.9

Sum = 2.7



Comments:

Summer wind direction and speed were typical for this location. Wind speed in the early afternoon was less than at other locations but the direction was sufficiently consistent for modeling.

Summing the emission rates is probably valid for this instance because the sampling points are in a sequence from upwind to downwind.

Kings County Dairy - Modeled emissions of methane and ROG (TNMHC) from free stalls and exercise areas. This was the first data collection for this project and the analysis was done by Dr. Rassmussen at the Oregon Graduate Research Institute.

Sampling Periods			Free Stall / Exercise Areas Sampled DW4 Concentrations				Modeled Concentrations 0.5 0.5		
Date	Start	End	CH4 $\mu g/m^3$	TNMHC $\mu g/m^3$	Net CH4 $\mu g/m^3$	Net TNMHC	Free Stall $\mu g/m^3$	Exerc. $\mu g/m^3$	Modeled Conc
21-Oct-02	1248	1440	2444.3	173.2	883.9	128.7	154.0	72.3	113.2
21-Oct-02	1522	1722	3913.5	234.3	2485.1	182.9	174.3	114.0	144.2
21-Oct-02	1737	1940	11969.7	402.9	8526.6	263.2	693.1	552.1	622.6
21-Oct-02	2005	2155	9601.2	227.2	7770.8	151.5	734.1	513.7	623.9

Sampling Periods			Methane Emissions						
Date	Start	End	Measure/Modeled	$\mu g/m^2$-s Freestall	$\mu g/m^2$-s Exerc.	kg/day	kg/1000hd-day	kg/hd/yr	lb./hd/yr
21-Oct-02	1248	1440	7.8	39.1	39.1	295.2	147.6	53.9	118.5
21-Oct-02	1522	1722	17.2	86.2	86.2	651.6	325.8	118.9	261.6
21-Oct-02	1737	1940	13.7	68.5	68.5	517.6	258.8	94.5	207.8
21-Oct-02	2005	2155	12.5	62.3	62.3	470.7	235.4	85.9	189.0

Sampling Periods			Reactive Organic Gas Emissions Measured as Total Non-methane Hydrocarbons (TNMHC)						
Date	Start	End	Measure/Modeled	$\mu g/m^2$-s Freestall	$\mu g/m^2$-s Loaf	kg/day	kg/1000hd-day	kg/hd/yr	lb./hd/yr
21-Oct-02	1248	1440	1.1	5.7	5.7	43.0	21.5	7.8	17.3
21-Oct-02	1522	1722	1.3	6.3	6.3	48.0	24.0	8.8	19.3
21-Oct-02	1737	1940	0.4	2.1	2.1	16.0	8.0	2.9	6.4
21-Oct-02	2005	2155	0.2	1.2	1.2	9.2	4.6	1.7	3.7

Data and modeled emissions shown in this slide are examples of a single episode of data collection at a single dairy. These data are presented to illustrate the sampling and modeling procedures and **cannot be used to estimate emissions from dairy operations**.

Kings County Dairy - **Modeled emissions of methane and ROG (TNMHC) from the lagoon. This was the first data collection for this project and the analysis was done by Dr. Rassmussen at the Oregon Graduate Research Institute.**

Date	Start	End	Test Period	Measured Concs		Net CH4	Net TNMHC	Modeled Concentrations		
				CH4 μg/m^3	TNMHC μg/m^3			Free Stall μg/m^3	Loaf μg/m^3	Lagoons
21-Oct-02	1248	1440	1	3532.4	63.5	1972.0	19.0	15.9	28.4	126.8
21-Oct-02	1522	1722	2	4311.9	98.6	2883.6	47.2	16.7	28.7	153.9
21-Oct-02	2005	2155	4	21937.5	251.3	20107.1	175.6	63.3	126.5	631.8

Date	Start	End	Test Period	Methane					
				Housing (mg/m3)	Modeled Net Lagoon (mg/m3)	Measure/ Modeled	kg/1000hd-day	kg/hd/yr	Lagoon lb./hd/yr
21-Oct-02	1248	1440	1	173.3	1798.7	14.2	132.3	48.3	106.2
21-Oct-02	1522	1722	2	390.7	2492.9	16.2	151.1	55.1	121.3
21-Oct-02	2005	2155	4	1181.9	18925.2	30.0	279.4	102.0	224.4

Date	Start	End	Test Period	TNMHC				
				Housing (μg/m^3)	Modeled Net Lagoon (μg/m^3)	Measure/ Modeled	Lagoon kg/hd/yr	Lagoon lb./hd/yr
21-Oct-02	1248	1440	1	25.2	-6.2	0.0	-0.2	-0.4
21-Oct-02	1522	1722	2	28.8	18.4	0.1	0.4	0.9
21-Oct-02	2005	2155	4	23.0	152.6	0.2	0.8	1.8

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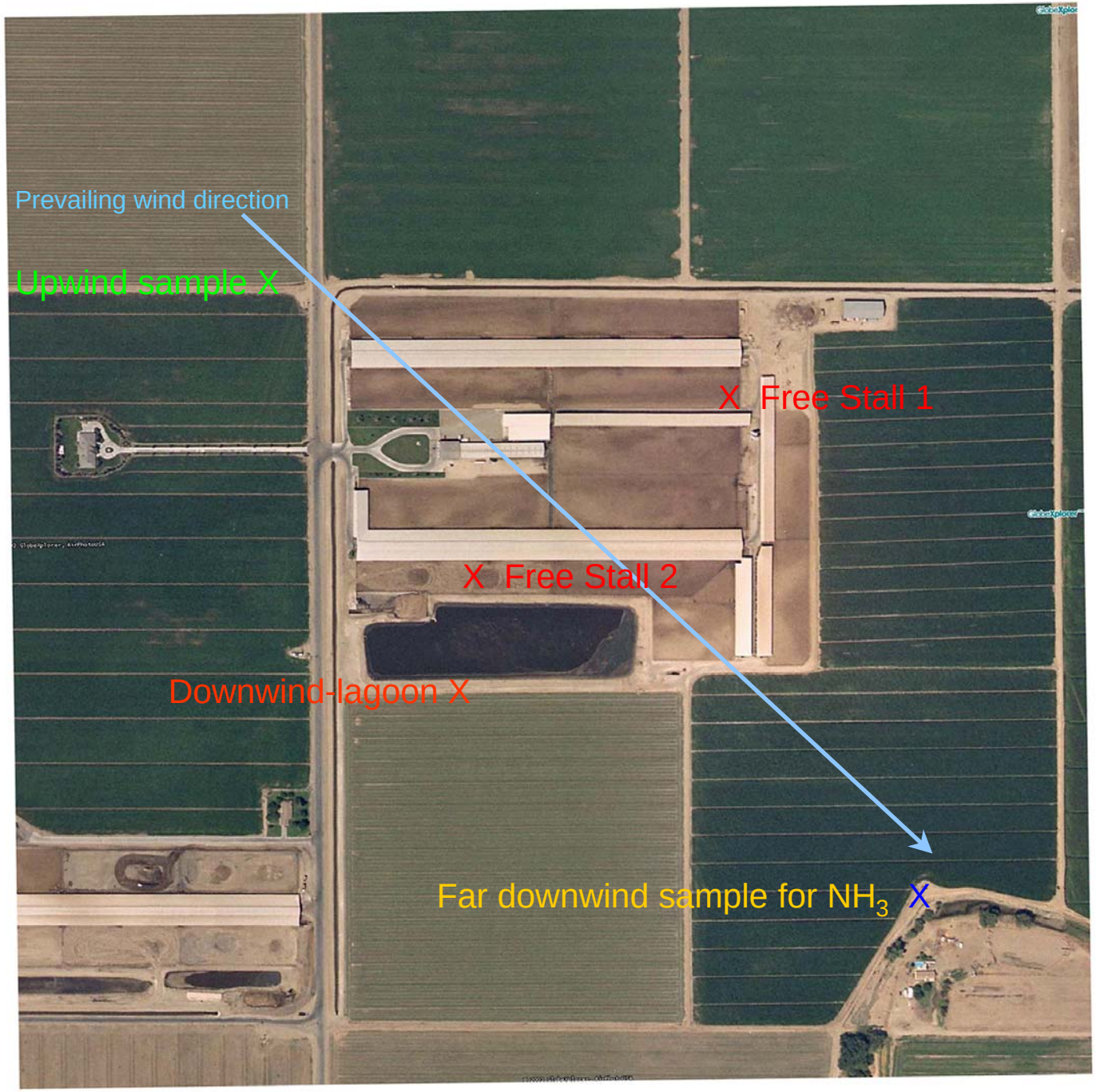


Merced County Dairy.

Approximately 3000 milking cows and 500 dry cows.

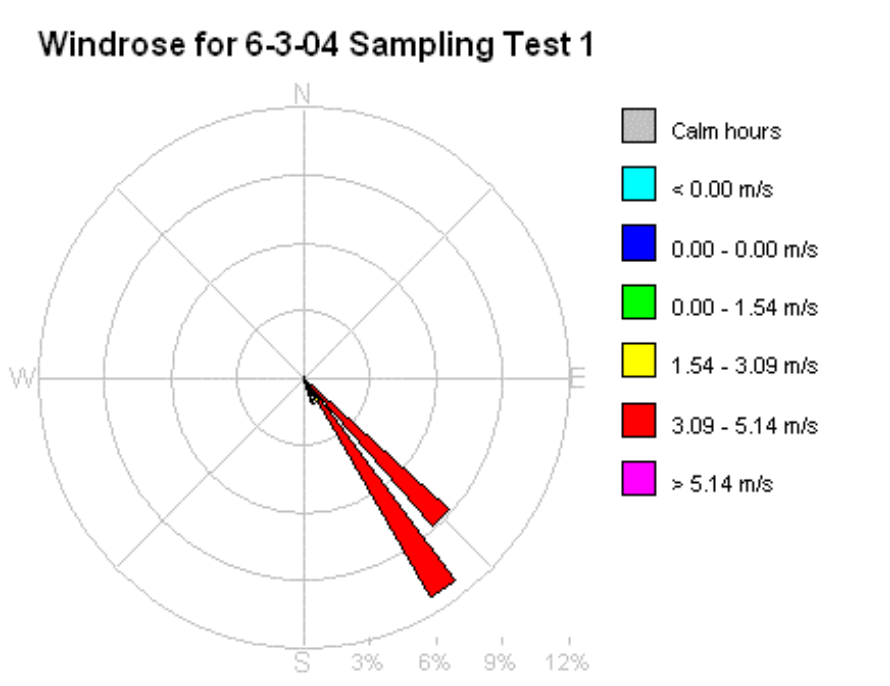
A single, large lagoon.

No feed storage at the dairy.

Merced County Dairy

6-3-04 test 1 945 to 1230

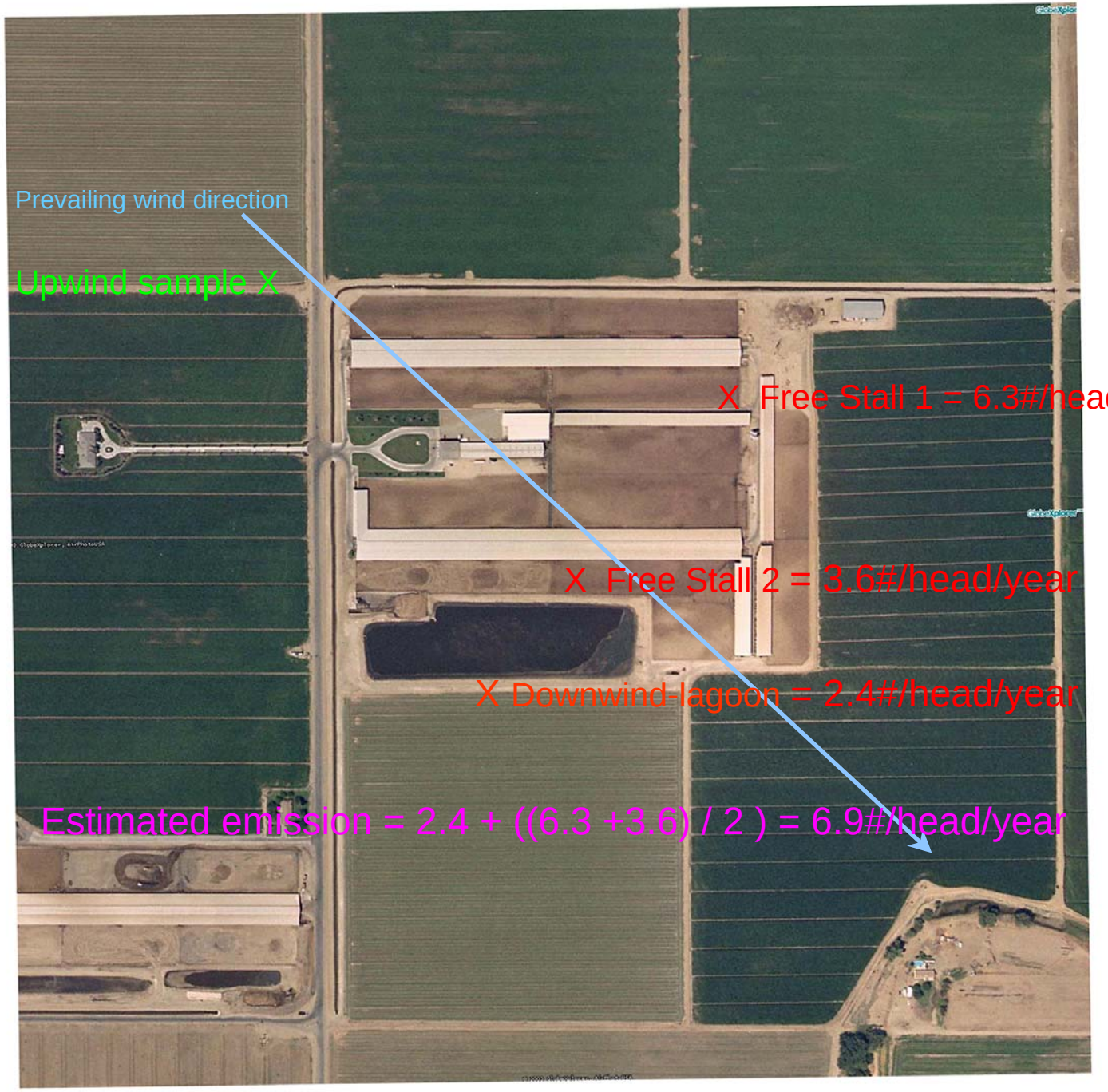
Summer Dairy 1	Measured TO-15 Concentration	Net TO-15 Concentration	Emission Rate
	µg/m³	µg/m³	#/hd/yr
Lagoon	79.2	16.2	2.4
Freestall 1	101.1	21.3	6.3
Freestall 2	73.5	14.4	3.6



Comments:

Summer wind conditions provided for almost a 3 hour sampling period in the late morning. Wind direction and speed were very consistent.

These emission rates cannot be summed to estimate a total facility emission as can be done for the Kings County Dairy because the two “Freestall” sampling points are not sequential. They are separate samples of two similar areas of the dairy. Averaging the two values might be appropriate but adding them is not.



Merced County Dairy.

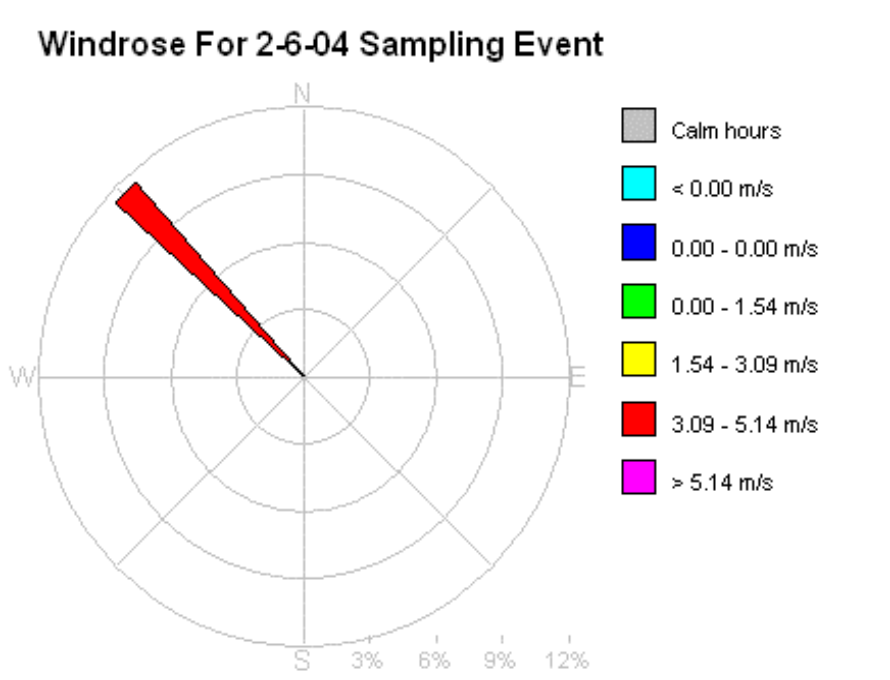
Sampled:

June 4, 2004

Merced County Dairy

2/6/2004 1100 to 1105

Winter Dairy 1	Measured TO-15 Concentration	Net TO-15 Concentration	Emission Rate
	μg/m³	μg/m³	#/hd/yr
Lagoon	139.6	39.4	1.5
Freestall 1	118.6	17.1	4.2
Freestall 2	109.7	20.1	3.8



Comments:

Winter wind conditions precluded the usual 2 hour sampling period with the wind from the NW. This was a 5 minute sample with the wind from the SE.

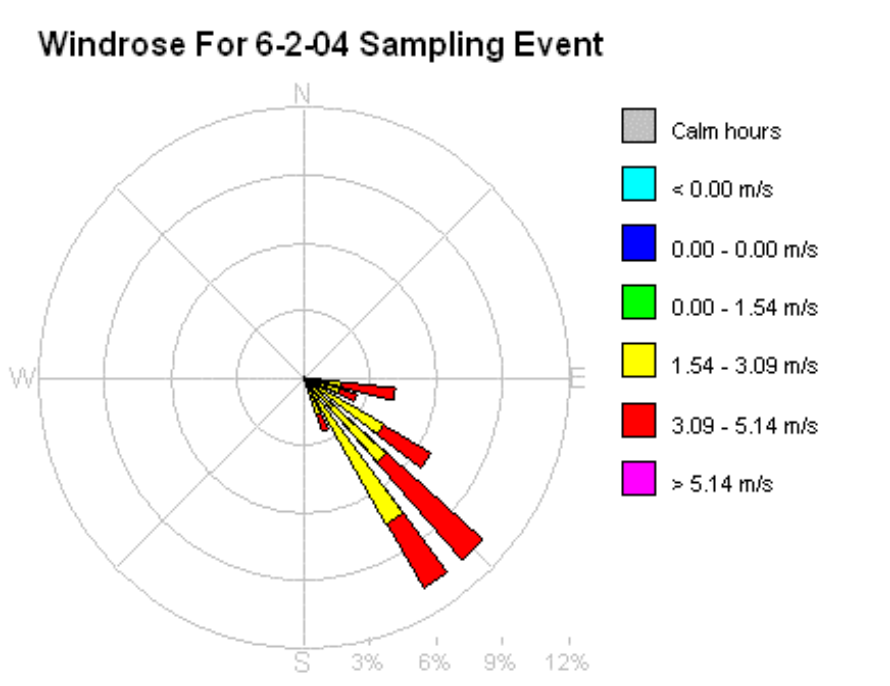
These emission rates cannot be summed to estimate a total facility emission as can be done for the Kings County Dairy because the two “Freestall” sampling points are not sequential. They are separate samples of two similar areas of the dairy. Averaging the two values might be appropriate but adding them is not.

Merced County Dairy

6/2/2004 1100 to 1440

Summer Dairy 1	Measured TO-15 Concentration	Net TO-15 Concentration	Emission Rate
	µg/m³	µg/m³	#/hd/yr
Lagoon	67.9	63.1	2.4
Freestall 1	56.7	52.6	14.6
Freestall 2	736.2	729	168.3

Values in Red include concentrations of specific gasses that have not been positively identified or quantified.



Comments:

Summer wind conditions provided a long, 3.7 hour, mid-day sampling period.

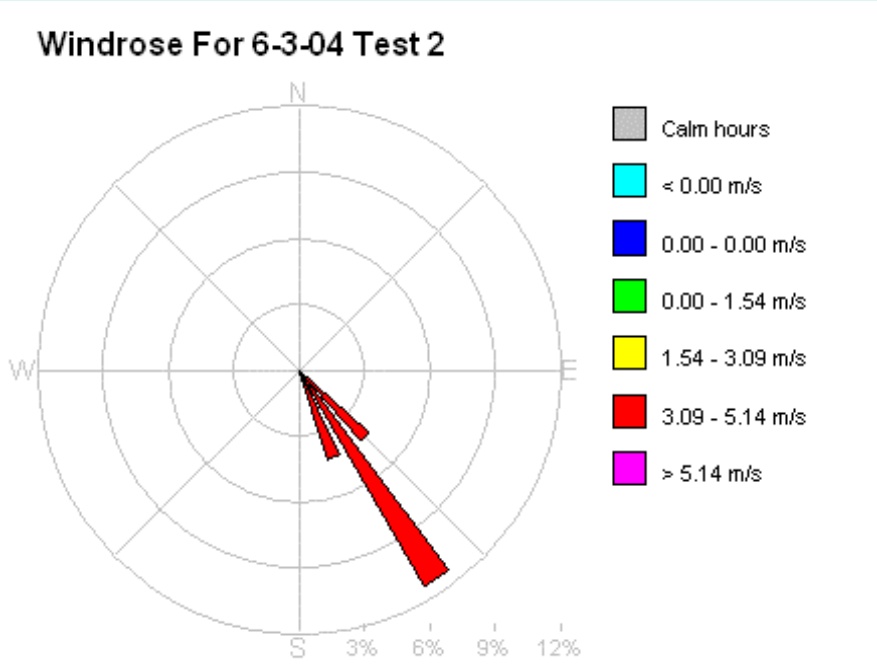
Large concentrations of a few gasses not found in other samples will require further investigation to determine their origin. Emissions modeled with this data should not be considered valid until the analytical results have been verified or corrected.

Merced County Dairy

6-3-04 test 2 1300 to 1500

Summer Dairy 1	Measured TO-15 Concentration	Net TO-15 Concentration	Emission Rate
	µg/m³	µg/m³	#/hd/yr
Lagoon	431.5	345.5	17.7
Freestall 1	90.3	67.5	19.1
Freestall 2	111.0	86.2	20.5

Values in Red include concentrations of specific gasses that have not been positively identified or quantified.



Comments:

Summer wind conditions provided a normal 2 hour sampling period in the late morning. Wind speed and direction were very consistent.

Large concentrations of a few gasses not found in other samples will require further investigation to determine their origin. Emissions modeled with this data should not be considered valid until the analytical results have been verified or corrected.

	6/2/2004			6-3-04 Test 1			6-3-04 Test 2			7/21/2004			7-22-04 Test 1			7-22-04 Test 2			2/6/2004		
	FS1	FS2	LGN	FS1	FS2	LGN	FS1	FS2	LGN	FS1	LGN	LGN2	FS1	LGN	LGN2	FS1	LGN	LGN2	Lgn	FS1	FS2
Compound	#/hd/yr	#/hd/yr	#/hd/yr	#/hd/yr	#/hd/yr	#/hd/yr	#/hd/yr	#/hd/yr	#/hd/yr	#/hd/yr	#/hd/yr	#/hd/yr	#/hd/yr	#/hd/yr	#/hd/yr	#/hd/yr	#/hd/yr	#/hd/yr	#/hd/yr	#/hd/yr	#/hd/yr
propylene	0.0	0.0	0.0	0.0	0.7	0.2	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	(0.4)	0.0
Dichlorodifluoromethane	0.0	1.3	0.2	(0.6)	(0.8)	0.1	1.7	1.6	0.2	0.1	(0.0)	0.0	0.0	0.0	0.0	0.1	0.0	0.0	(0.0)	0.1	(0.9)
chloromethane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.6	0.0	(0.3)	(0.0)	(0.3)	0.0	0.0	0.0	0.0	0.0	0.0	(0.1)	2.9	0.2
Dichlorotetrafluoroethane	0.0	0.8	0.0	0.0	0.0	0.7	0.0	0.9	0.1	0.0	0.0	0.0	0.0	0.0	0.0	(0.2)	(0.0)	(0.2)	0.0	0.0	(0.5)
vinyl chloride	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1,3-Butadiene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1
Methane,bromo-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ethanol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
chloroethane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trichloromonofluoromethane	0.0	0.6	0.1	(0.0)	0.2	(0.2)	0.7	0.7	0.1	0.0	(0.0)	0.0	0.0	0.0	0.0	(0.0)	0.0	0.0	(0.0)	0.0	(0.4)
acetone	0.0	3.4	0.4	2.1	(3.8)	(2.3)	10.8	5.0	0.7	0.4	(0.1)	(0.3)	0.0	0.1	0.7	(0.3)	0.0	0.2	(0.0)	0.4	(0.1)
isopropylalcohol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ethene,1,1-dichloro-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ethane,1,1,2-trichloro-1,2,2-trifluoro-	0.7	0.6	0.1	(0.1)	0.0	0.0	0.7	0.7	0.1	0.0	0.0	0.0	0.0	0.0	(0.0)	0.0	0.0	0.0	0.0	(0.0)	0.0
Carbondisulfide	0.0	0.2	0.0	(0.0)	(0.0)	0.0	0.2	0.2	0.0	0.0	(0.0)	0.0	0.0	0.0	0.0	0.0	(0.0)	0.0	0.0	0.0	(0.1)
methylenechloride	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(0.0)	(0.1)	0.1
trans1,2-dichloroethylene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
tert-butylmethylether(MTBE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
n-hexane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ethane,1,1-dichloro-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
vinylacetate	0.0	0.0	0.3	1.8	0.0	(0.6)	(2.4)	(0.4)	0.0	(0.4)	(0.0)	(0.3)	0.0	0.0	(0.0)	0.5	(0.0)	0.3	0.2	(0.1)	0.9
MEK$$2-butanone	3.0	0.0	0.4	(0.5)	1.8	0.6	1.5	1.3	1.0	0.1	0.0	0.0	0.0	0.0	(0.0)	0.0	0.0	(0.1)	0.2	(0.2)	1.4
cis-1,2-dichloroethene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ethylacetate	1.3	0.6	0.0	1.1	0.0	(0.3)	0.1	0.6	0.2	0.4	0.0	(0.0)	0.1	0.0	0.1	0.6	(0.0)	(0.0)	0.0	0.1	0.1
Chloroform	0.2	0.2	0.0	(0.1)	(0.0)	(0.0)	(0.1)	(0.0)	0.0	(0.0)	(0.0)	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
tetrahydrofuran	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	(0.1)	0.0
Ethane,1,1,1-trichloro-	0.5	0.4	0.1	(0.1)	(0.1)	(0.0)	0.5	0.5	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Ethane,1,2-dichloro-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Benzene	0.3	0.3	0.0	(0.0)	(0.1)	(0.0)	0.3	0.3	0.1	0.0	0.0	0.0	0.0	0.0	(0.0)	0.0	0.0	(0.0)	(0.0)	0.0	0.0
carbontetrachloride	0.9	0.8	0.1	(0.1)	(0.1)	(0.0)	0.9	0.9	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(0.0)	0.0	0.0	0.0
Cyclohexane	0.3	0.0	0.0	0.0	(0.1)	(0.0)	(0.1)	(0.2)	0.0	0.1	(0.0)	(0.0)	0.1	(0.0)	0.1	0.0	0.0	(0.0)	0.0	(0.2)	0.0
n-heptane	0.3	0.4	0.0	(0.1)	(0.1)	(0.1)	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	(0.0)	0.1	0.0	(0.0)	0.0	(0.0)	0.0
Trichloroethylene	0.4	0.0	0.1	(0.5)	(0.4)	(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Propane,1,2-dichloro-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1,4-dioxane	0.0	9.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Methane,bromodichloro-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MethylIsobutylKetone	1.4	0.0	0.2	(0.3)	(0.2)	(0.1)	1.4	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(0.1)	(0.3)	0.0	(1.3)	(0.8)
1-Propene,cis-1,3-dichloro-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1-Propene,trans-1,3-dichloro-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Toluene	0.4	0.8	0.0	0.1	(0.1)	0.0	0.3	0.3	0.1	0.0	0.1	0.2	0.0	0.2	0.2	0.0	0.2	0.2	(0.0)	0.0	0.0
Ethane,1,1,2-trichloro-	0.0	0.0	0.0	0.0	0.4	(0.1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
methyln-butylketone$$2-hexanone	2.0	1.6	0.3	(0.4)	(0.4)	(0.1)	(0.4)	(0.3)	0.0	0.0	0.0	(0.0)	0.0	0.0	(0.0)	(0.0)	0.0	(0.1)	0.0	(0.0)	(0.1)
Methane,dibromochloro-	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tetrachloroethylene	0.0	0.0	0.0	(0.1)	(0.1)	(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ethane,1,2-dibromo-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Benzene,chloro-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ethylbenzene	0.3	0.3	0.0	(0.0)	(0.1)	(0.0)	(0.1)	(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	(0.0)	0.0	0.0	(0.0)	(0.0)	0.0	0.0
m&p-xylene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Styrene	0.0	1.5	0.0	(0.3)	(0.3)	(0.1)	(1.9)	(1.6)	0.0	0.0	0.0	0.0	0.5	0.1	(0.0)	0.0	0.0	(0.3)	(0.2)	0.2	0.0
o-xylene	0.0	5.5	0.0	0.0	0.3	(0.1)	(1.5)	(1.2)	0.1	0.0	0.0	0.0	0.0	0.0	(0.0)	0.0	0.0	0.0	0.0	0.0	0.0
Methane,tribromo-	0.0	49.1	0.0	1.0	0.0	0.3	(3.0)	(3.3)	3.5	0.0	0.0	0.0	0.0	0.2	(0.1)	0.0	0.0	0.0	0.0	0.0	0.0
Ethane,1,1,2,2-tetrachloro-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Benzene,1-ethyl-4-methyl-	0.4	0.3	0.1	(0.0)	(0.1)	(0.0)	(0.5)	(0.4)	0.0	(0.0)	0.0	(0.0)	0.0	0.0	(0.0)	0.0	0.0	0.0	0.0	0.0	0.0
Benzene,1,3,5-trimethyl-	0.0	0.3	0.1	0.1	(0.1)	(0.1)	(0.6)	(0.8)	0.0	(0.0)	0.0	(0.0)	0.0	0.0	(0.0)	0.1	0.0	0.0	0.0	0.0	0.1
Benzene,1,2,4-trimethyl-	0.4	0.3	0.0	(0.1)	(0.1)	(0.0)	(0.1)	(0.4)	0.0	0.0	0.0	0.0	0.0	0.0	(0.0)	0.0	0.0	(0.0)	0.0	0.0	0.0
Benzene,1,3-dichloro-	0.5	2.7	0.0	(0.1)	(0.1)	(0.0)	(0.3)	(0.1)	0.2	0.0	(0.0)	(0.1)	0.0	0.0	(0.0)	0.0	(0.0)	(0.1)	(0.0)	0.0	(0.0)
Benzene,1-chloro-3-methyl-	0.8	0.0	0.0	(0.1)	(0.9)	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Benzene,1,4-dichloro-	0.4	2.6	0.0	(0.1)	(0.1)	(0.0)	(0.2)	(0.1)	0.2	0.0	(0.0)	(0.1)	0.0	0.0	(0.0)	0.0	(0.0)	(0.1)	(0.0)	(0.0)	(0.0)
Benzene,1,2-dichloro-	0.2	81.1	0.0	0.1	(0.3)	0.2	(10.0)	(8.3)	10.3	0.0	0.0	(0.0)	0.0	0.8	(0.4)	(0.0)	(0.0)	(0.1)	0.0	0.0	(0.0)
Benzene,1,2,4-trichloro-	0.0	2.8	0.0	0.0	0.0	0.0	(0.9)	(0.8)	0.1	0.0	0.0	0.0	0.0	0.0	(0.0)	0.0	0.0	0.0	0.0	0.0	0.0
1,3-Butadiene,1,1,2,3,4,4-hexachloro-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	14.6	168.3	2.4	6.3	3.6	2.4	19.1	20.5	17.7	1.3	0.2	0.4	0.9	1.7	1.1	1.5	0.3	0.9	1.5	4.2	3.1

Individual TO-15 compound emissions (#/head/year) for Kings and Merced Dairies

Uncertainty Factors

- **Primary questionable factor is the analytical problem.**
- No analytical standard for ozone precursors from dairy operations exists. The EPA TO-15 standard was used because it is commonly employed for air quality analysis.
- TNMHC analysis from GC-FID is an over-estimation since many gasses included in it are not ROG's and it is difficult to detect gasses that contaminate the sample during the analytical process.
- Recently, we found an EPA standard gas for PAM analysis that appears to be closer to an ozone precursor standard and could be used in analysis of samples from dairies and other animal operations.
- This problem is the most important research priority for further work in determining the ozone precursor emissions from animal operations.

Uncertainty Factors

- **Secondary questionable factors include**:
- Requirement for consistent wind direction and speed for modeling of results.
- Wide range of management levels at dairies.
- Sampling problems related to the analytical difficulties.
- Seasonal variability
- Influence of upwind and surrounding agricultural operations.

Very Preliminary Conclusions

- The animal holding areas (free-stalls and exercise corrals) are a larger source of ROG than the lagoons by a factor of 2 - 4.
- The seasonal variability may not be as large as expected.
- The Kings dairy that was managed more intensively had lower ROG emissions from both the animal areas that were flushed and scraped more frequently and the sequential lagoon system.

QUESTIONS?

Monitoring and Modeling of ROG at California Dairies

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