Odor Reduction Research, Findings, and Future Direction

Dr. Jay Harmon, Dr. Jacek Koziel, Dr. Steve Hoff

Department of Agricultural and Biosystems Engineering, Iowa State University

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Dr. Jay Harmon
Dr. Steve Hoff
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Dr. Hongwei Xin

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Odor Sources

- Building Ventilation Air
- Outside Manure Storage
- Land Application

Odor Control Impacts

To Be Effective.....

An odor control technology needs to result in at least a 70% reduction of source odor *when needed*

This does not mean 70% reduction, 100% of the time

Research on Odor/Gas Control Techniques

- We are currently concentrating on lowering odor and gas emission from the barn's ventilation air
- Increasing dispersion at the source
- Focusing treatment efforts on specific chemicals responsible for livestock odor

Ultimate Goal: Economically feasible solutions with enough odor reduction to be effective during downwind events

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What Are We Working On?

- Siting model to assist placement of new facilities
- Techniques for "as-needed" odor mitigation
- Topical application to manure
- Biofiltration of ventilation air
- Chemical and sensory assessment of odor
- UV-treatment of ventilation air
- Vegetative environmental buffers (VEBs)
- Quantification of emissions (gas, odor, PM)

What Have We Found?

- Siting is number one priority
- Impractical to treat all exhaust air from animal facilities
- Only a relatively small number of chemicals are responsible for the characteristic livestock odor
- Fine dust is a very effective carrier of odor
- Practical methods exist to treat air on an "as-needed" basis
- Must take into consideration economics of any strategy

Why Can't You University-Types Solve the "Odor Problem"!

Every citizen has a sensor, and each is calibrated differently

Compounds responsible for odor are in the part-per-trillion range

The Key to Remember: <u>Economically –Feasible Odor Control</u>

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Summary of Mitigation Strategies

Dr. Jay Harmon, Professor

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Classification of Effective Odor Mitigation Techniques

- Principles
  - Effective
  - Economical
  - Practical
  - Have limited management demands
  - Limitations are known
  - Not universally applied

Effective Odor Mitigation Techniques: Siting

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Effective Odor Mitigation Techniques: Siting

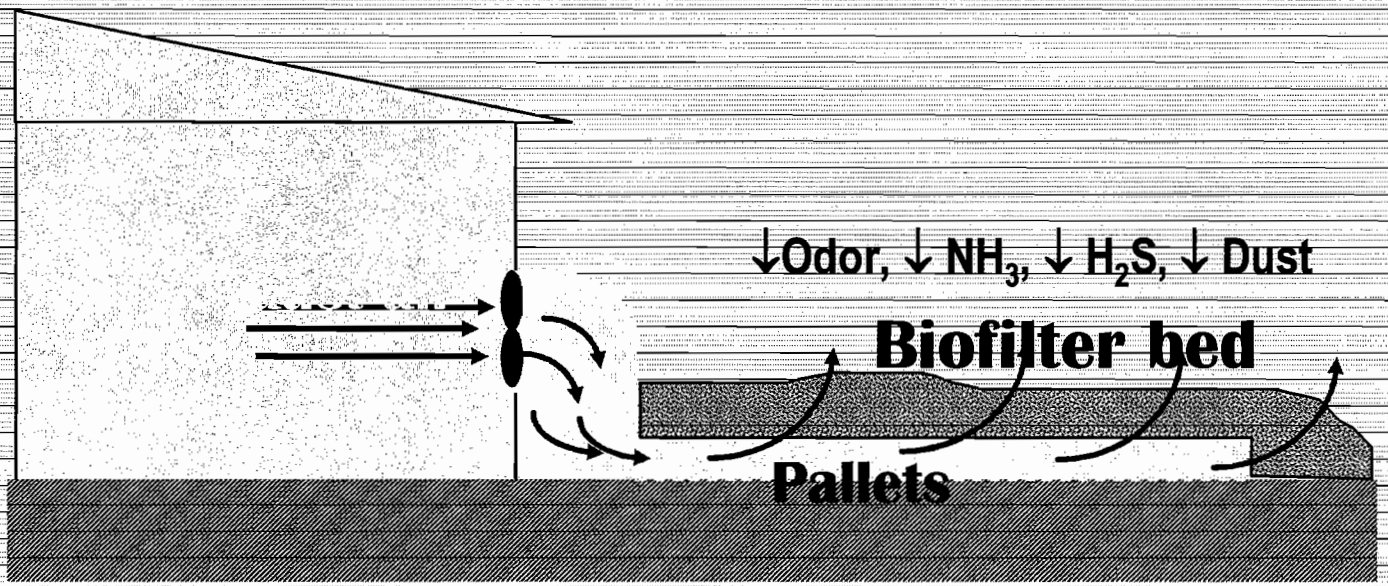
- No strategy is more effective than proper pre-construction site selection
- Scientific Approach – Site dependent
  - All directions are not equal
  - Receptor based
  - Windroses for odor season
  - Atmospheric Stability consideration
  - Determination of Number of Hours of
    - Very Weak Odors (2:1)
    - Identifiable Odors (7:1)

Effective Odor Mitigation Techniques: Siting

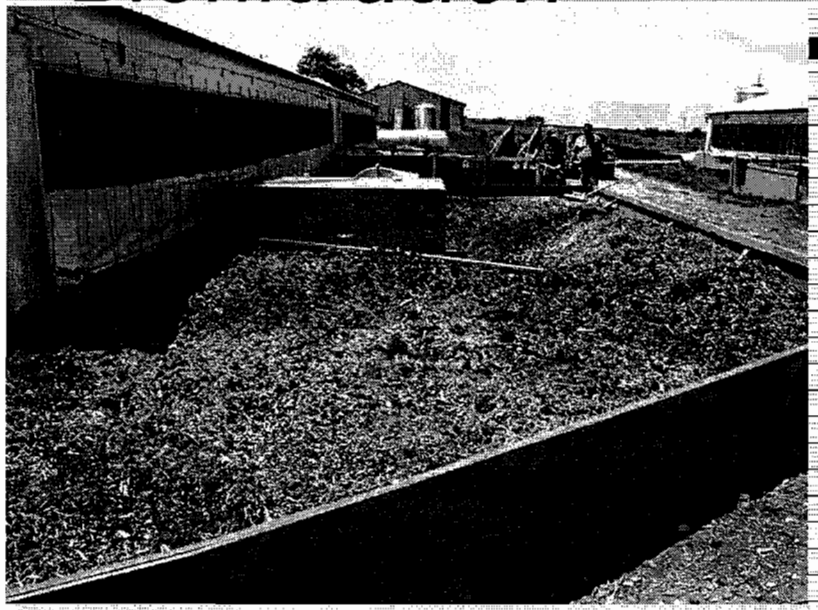
- Limitations of Models
  - Models do not account for the impact of terrain
  - Should be coupled with:
    - Producer education
    - Communication with neighbors
    - Common Sense

Effective Odor Mitigation Techniques: Biofiltration

- Biomaterial filters and acts as a bio-treatment substrate



Effective Odor Mitigation Techniques: Biofiltration



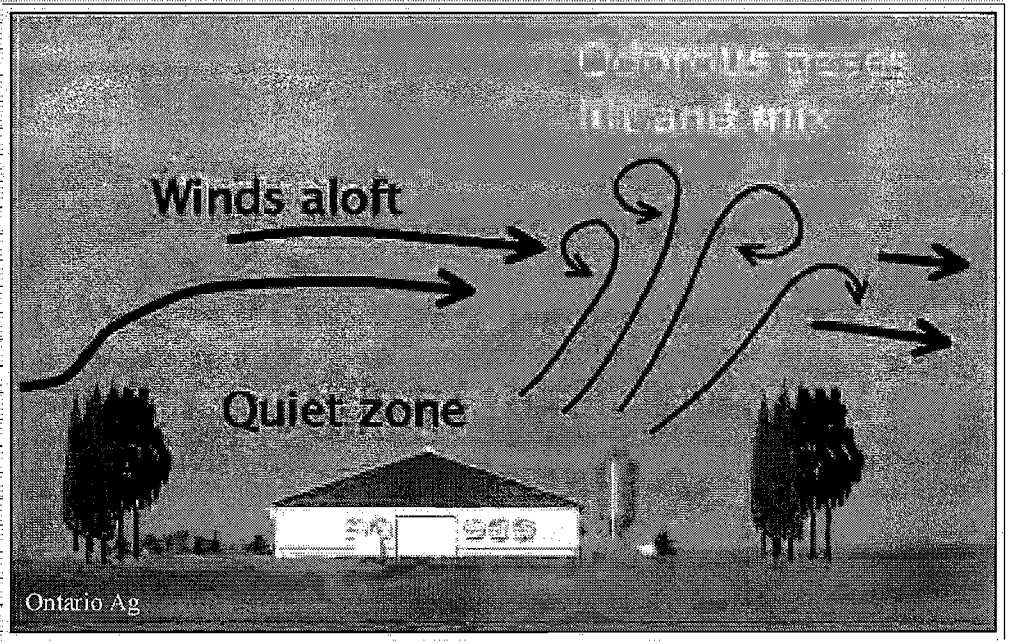
- 60% odor reduction
- Installation $9/pig space (existing fans)
- Energy cost 45 cents/pig finished
- Reduces NH3, H2S, PM also

Effective Odor Mitigation Techniques: Biofiltration

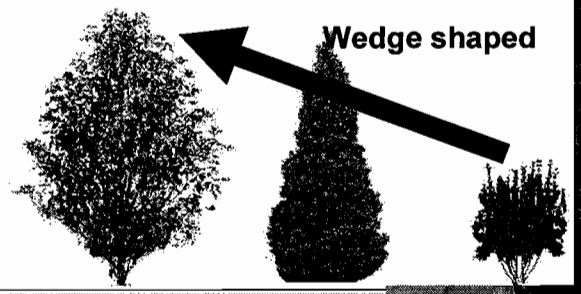
- Limitations
  - Curtain Buildings – partial filtration
  - Proper design to minimize ventilation impact
  - Moisture maintenance critical
  - Large footprint

Effective Odor Mitigation Techniques: Vegetative Environmental Buffers

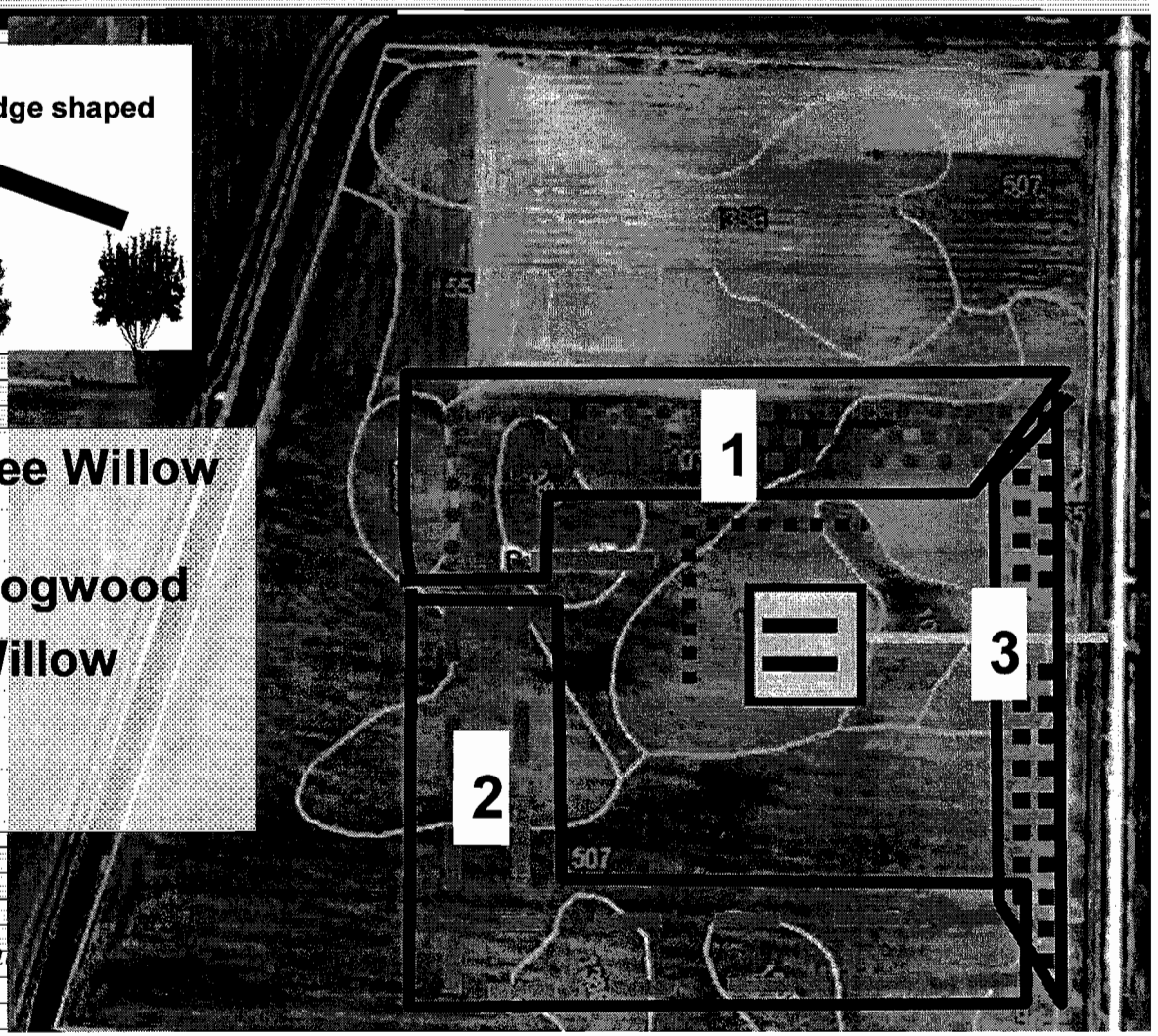
- Vegetative filter
- Promotes mixing and uplift
- Visual Screen
- Difficult to quantify impact



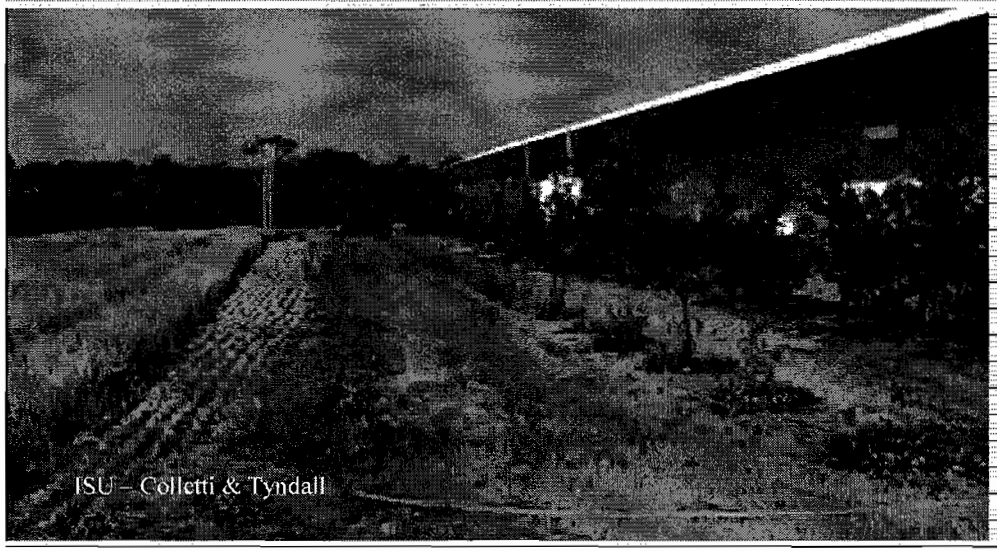
Effective Odor Mitigation Techniques: Vegetative Environmental Buffers



1) Outside row – Austree Willow
   Middle – Red Cedar
   Inside – Red Osier dogwood
2) Outside – Austree Willow
   Inside – Red Cedar
3) Red Osier Dogwood

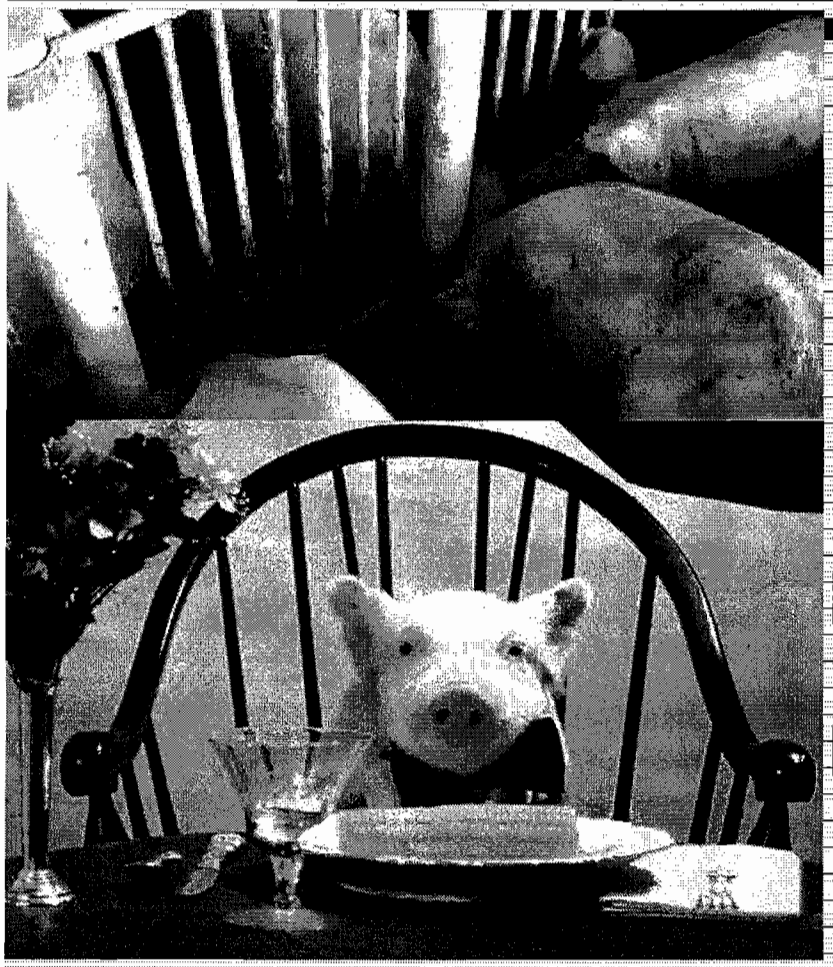


Effective Odor Mitigation Techniques: Vegetative Environmental Buffers



- Up to 15% reduction
- 6 to 10 cents/pig over 20 years
- Years to establish
- Beware natural ventilation applications

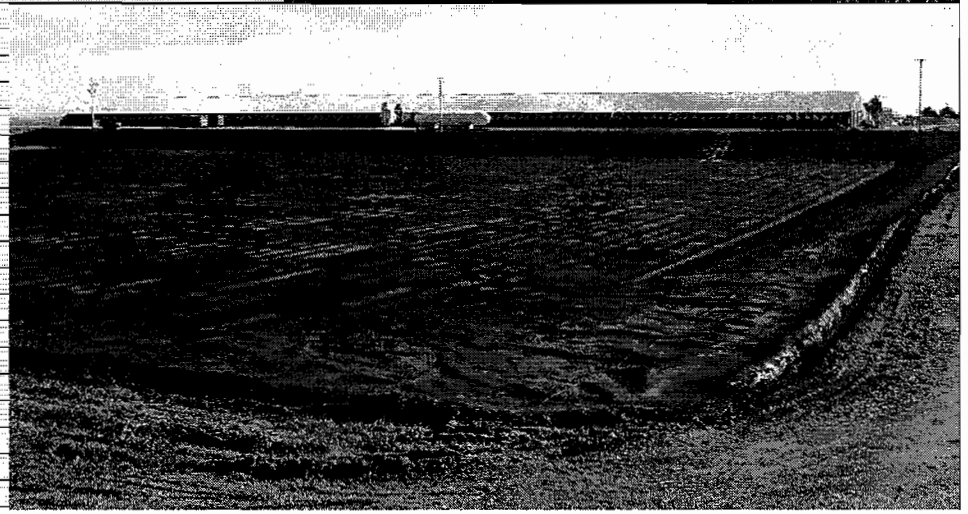
Effective Odor Mitigation Techniques: Dietary Manipulation



- Examples:
  - Crude protein reduced, added crystalline amino acids
  - Limited use of bloodmeal, fishmeal
- Up to 30% reduction
- May improve hedonic tone
- Easy Implementation
  - Stay tuned for developments

Effective Odor Mitigation Techniques: Permeable Covers

- Cover breathes
  - Prevents wind from blowing over surface
  - Material forms a biological substrate



Effective Odor Mitigation Techniques: Permeable Covers

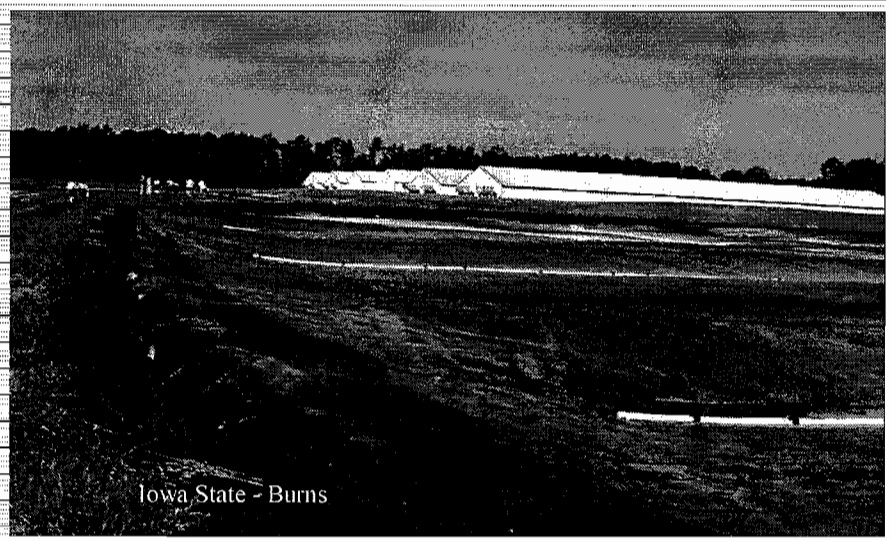
Material	Odor Reduction	Cost per square foot	Life
4″ Straw	40%	$0.10	< 1 yr
6″ Straw	60%	$0.13	< 1 yr
LECA Rock	90%	$1.50	10+ yrs
Geotextile	50%	$0.25	3-5 yrs

Effective Odor Mitigation Techniques: Permeable Covers

- Limitations
  - Biological materials sink
  - Possible pumping problems
  - Distribution can be a challenge on large storage and impractical > 5 acres

Effective Odor Mitigation Techniques: Impermeable Covers

- High-density polyethylene (HDPE) cover
- 90%+ odor reduction
- $2.50/ft^2
- Traps gas, rain, snow that must be handled
- More difficult to remove manure



Effective Odor Mitigation Techniques: Manure Injection

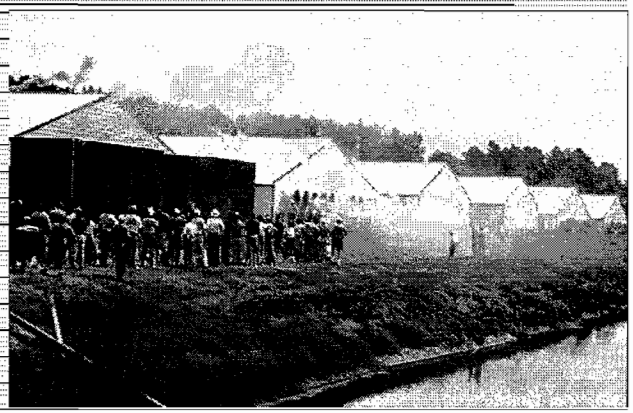
- Odor Reduction > 90%
- Injection toolbars may be retrofit
- Custom cost similar
- Operational additional <0.4 cents/gal
- May be a challenge with no-till

Research Gaps in Odor Mitigation Techniques

- Principles
  - Shows some promise
  - Practical
  - Cost may not be known
  - Some effectiveness may be unknown
  - More work needs to happen before deeming as "effective"

Research Gaps in Odor Mitigation Techniques

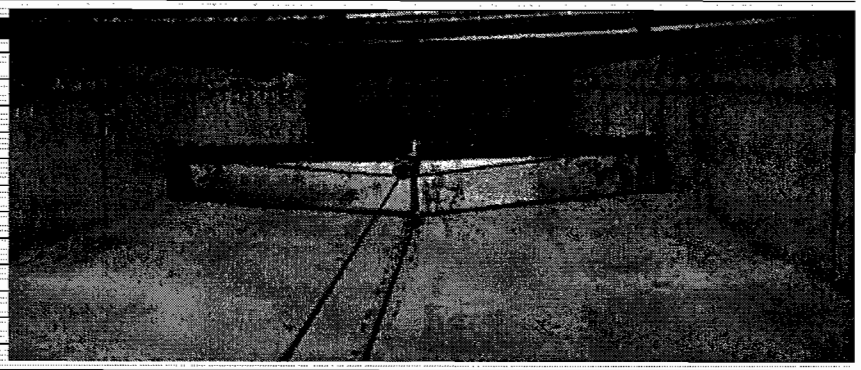
- Barriers (windwall)
  - Remove dust, force air up
  - Low cost
  - Impact downwind?
- Biocurtain w/ ESP
  - Removes dust
  - Quantification/cost?



Research Gaps in Odor Mitigation Techniques

- Diet Manipulation (especially poultry)
  - Ammonia reductions 10 to 40%
  - Odor Reduction?
  - Many other opportunities possible (all species)
- Manure Belt (layers)
  - 80% ammonia reduction
  - 50% higher price
  - Odor Reduction?

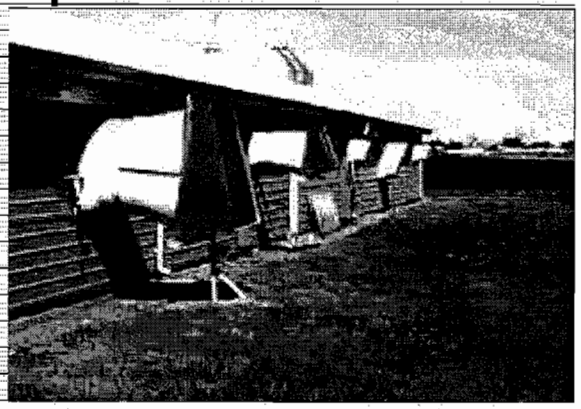
Research Gaps in Odor Mitigation Techniques



- V Manure Scraper
  - Ammonia reduction
  - Costs/Odor?
  - Availability?
- UV Degradation
  - Strong odor reduction in lab scale
  - Implementation/costs?

Research Gaps in Odor Mitigation Techniques

- Bioscrubber
  - Strong odor reduction in Europe
  - Impact on ventilation?
  - Costs?/Winter practicality?
- Topical applications
  - Example: zeolite (poultry)
  - Lab trials show odor reductions
  - Implementation/costs?



Odor Mitigation Techniques

- Must be:
  - Effective
  - Economical
  - Practical
  - Have limited management demands
  - Limitations are known
  - Not universally applied

Chemical and Sensory Analysis of Odor

Dr. Jacek Koziel, Associate Professor

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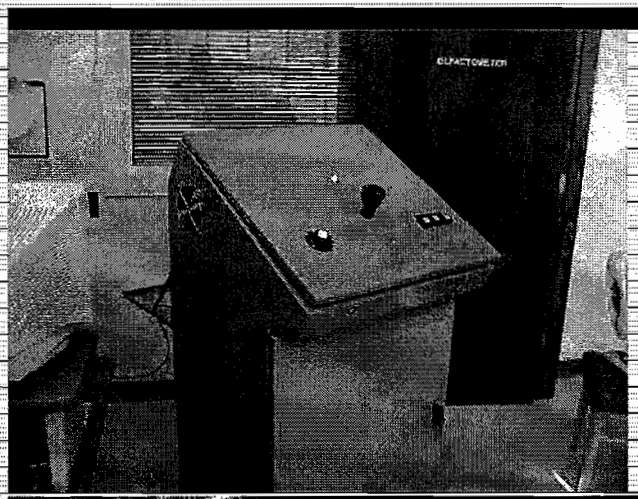
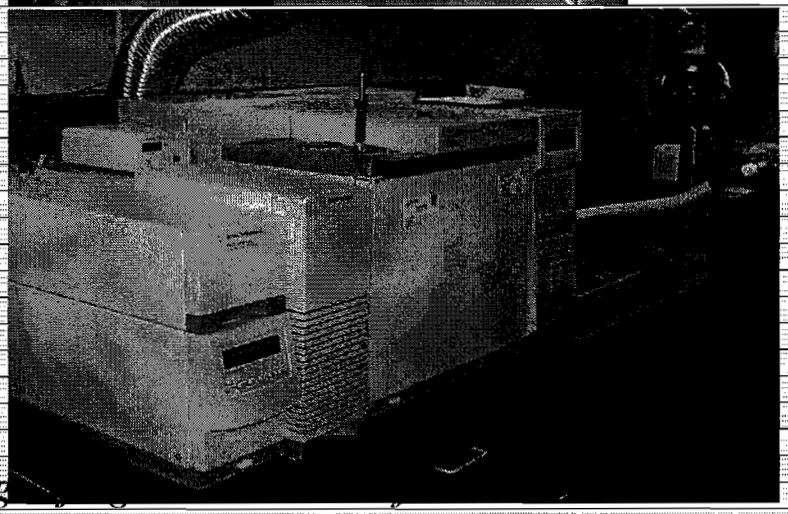
Analytical Tools for Assessing Odor



St. Croix Sensory's AC'SCENT International Olfactometer (measures composite odor using trained panelists)



Microanalytics's GC-MS-O (Simultaneous measurement of chemical composition and odor)

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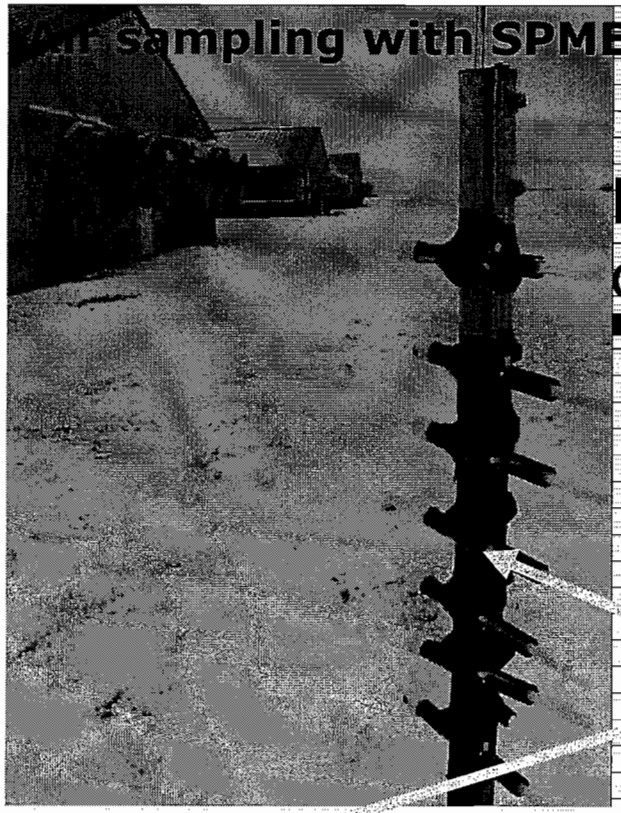
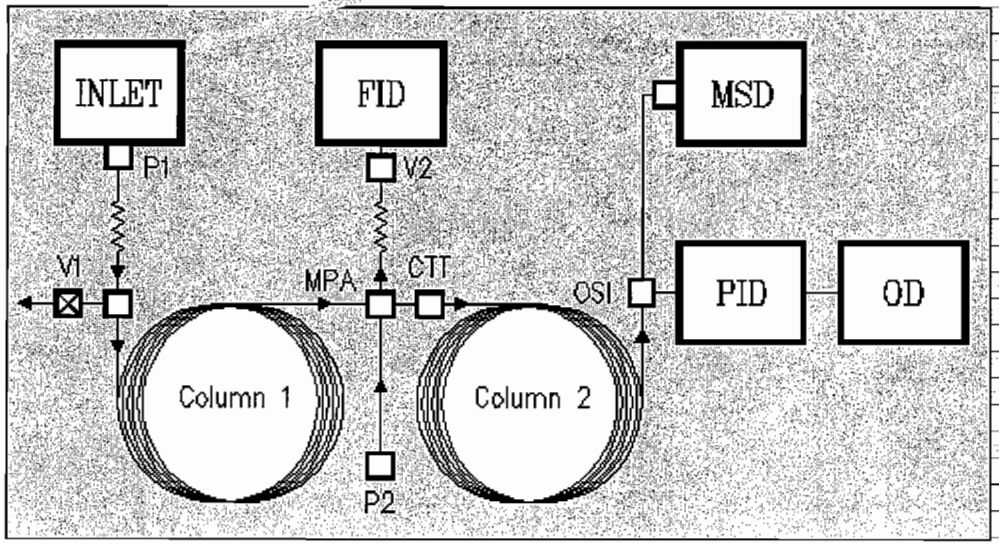
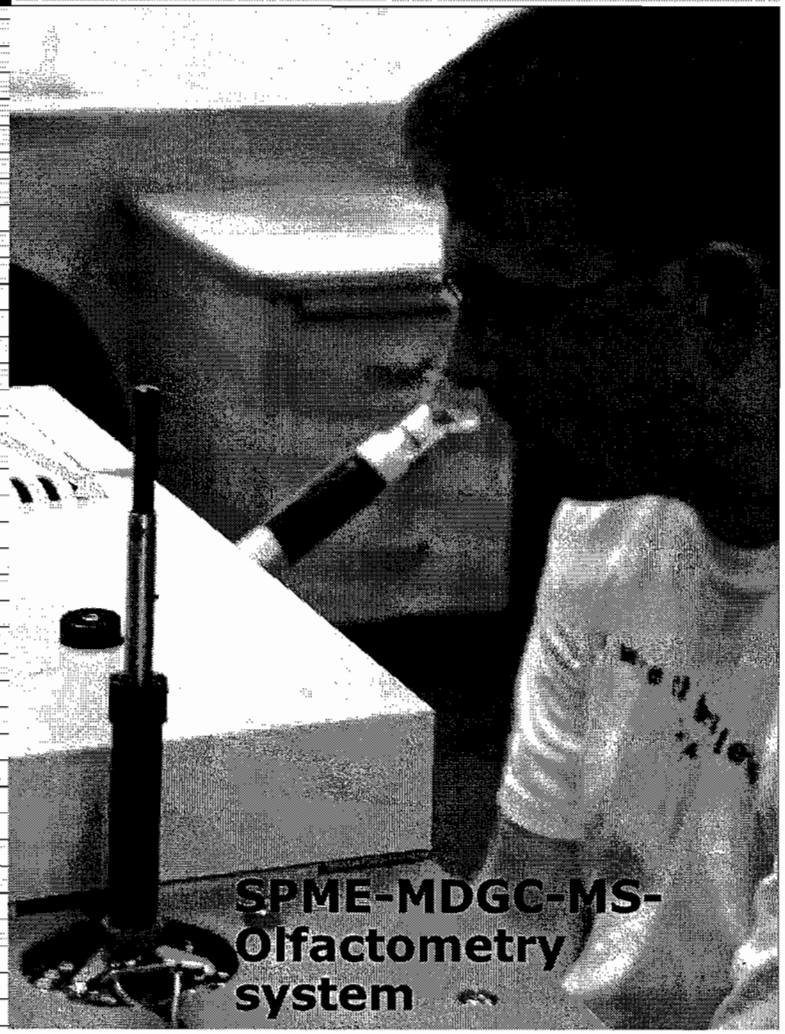


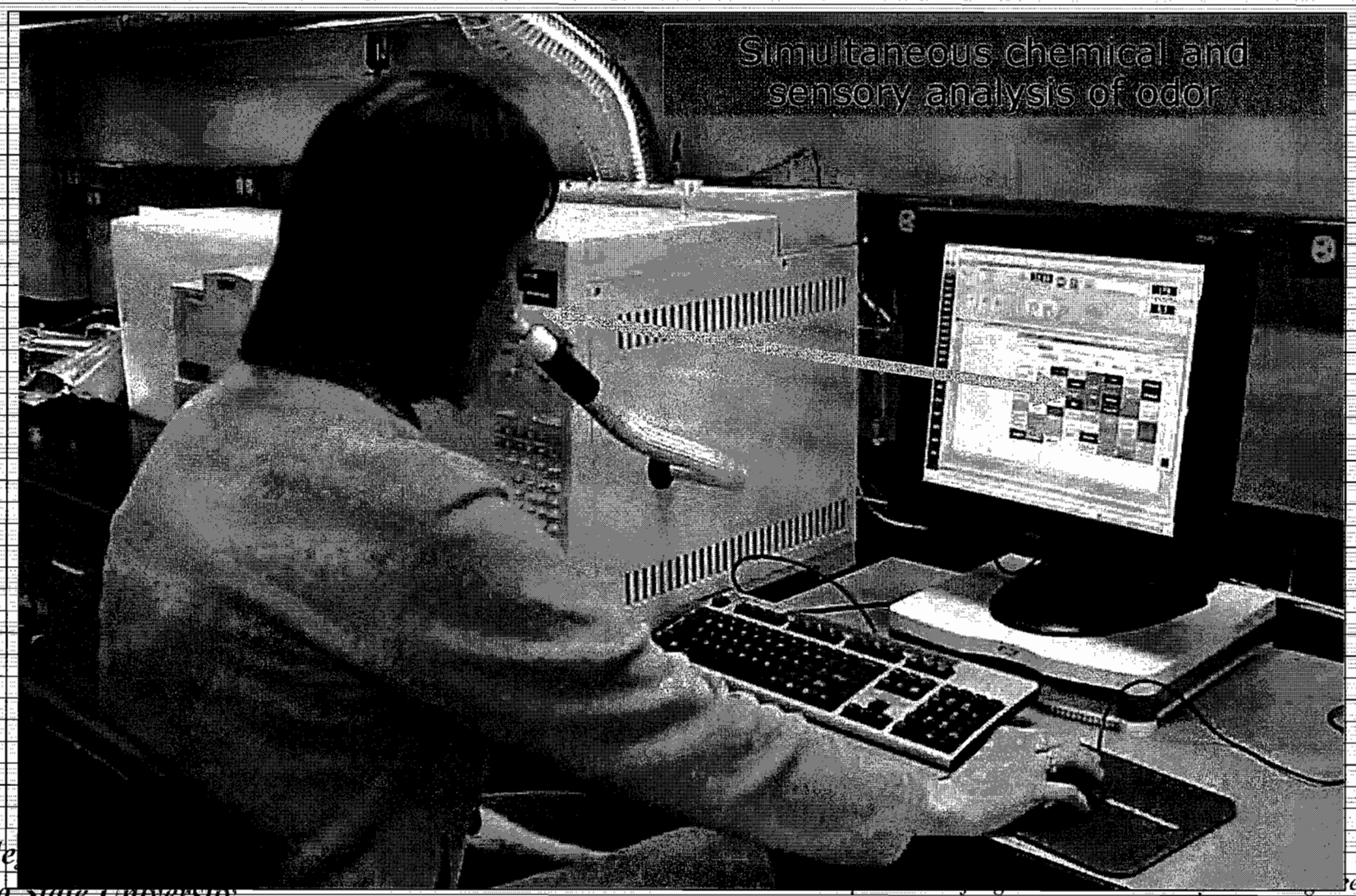
Methodology: simultaneous chemical and odor analyses

SPME





Prioritizing and matching chemicals in air samples with specific compounds causing 'characteristic' livestock odor



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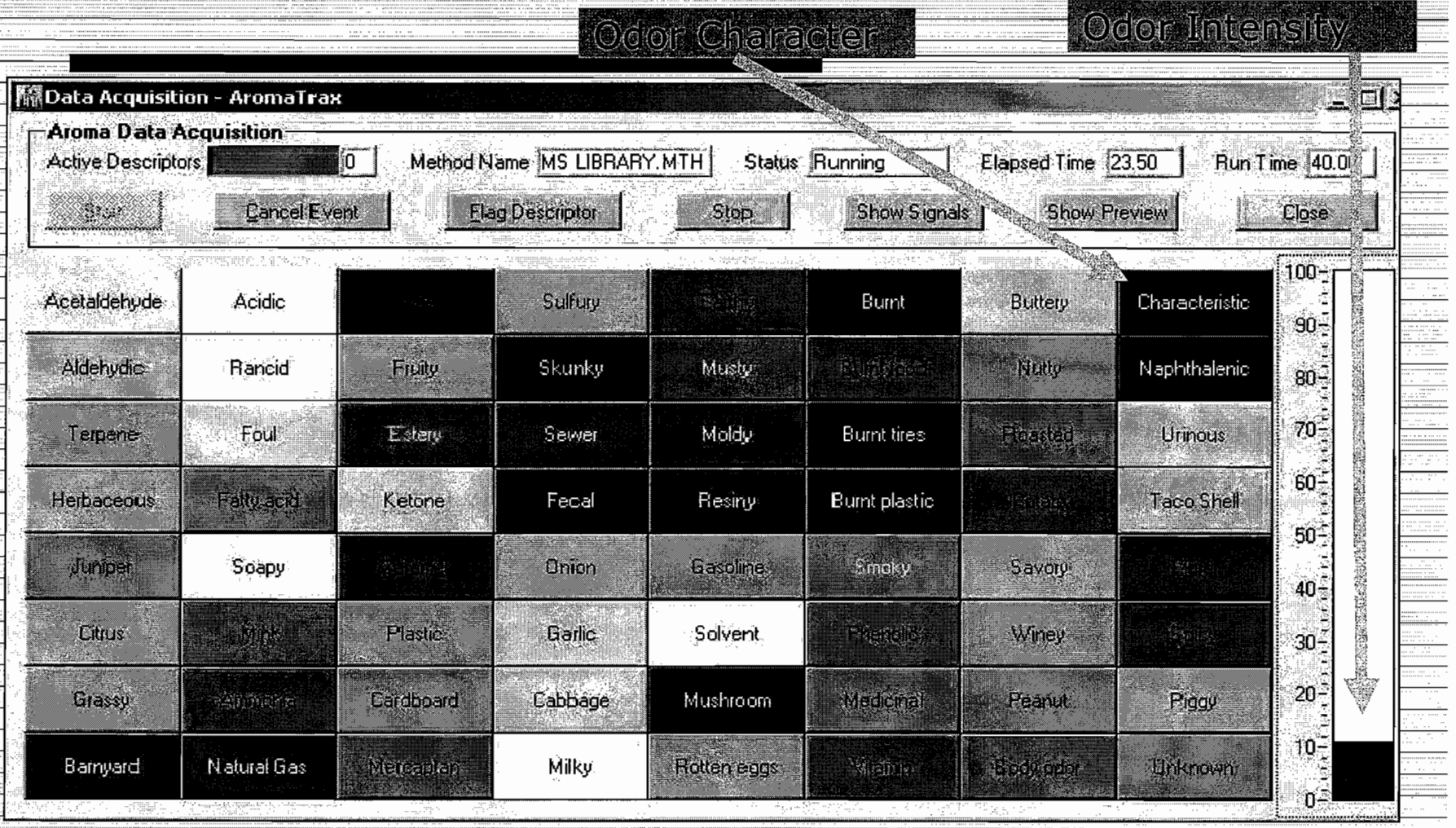
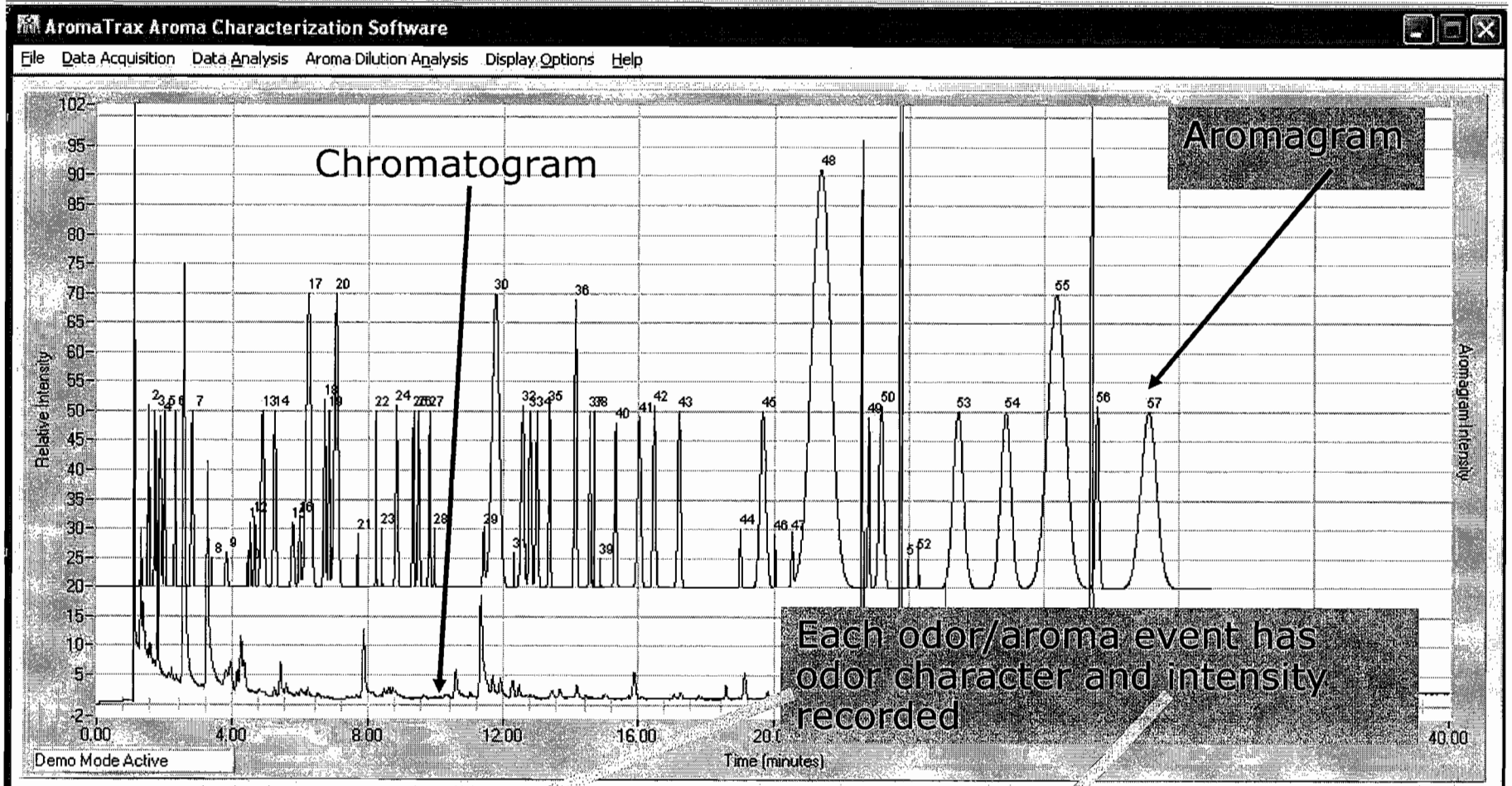
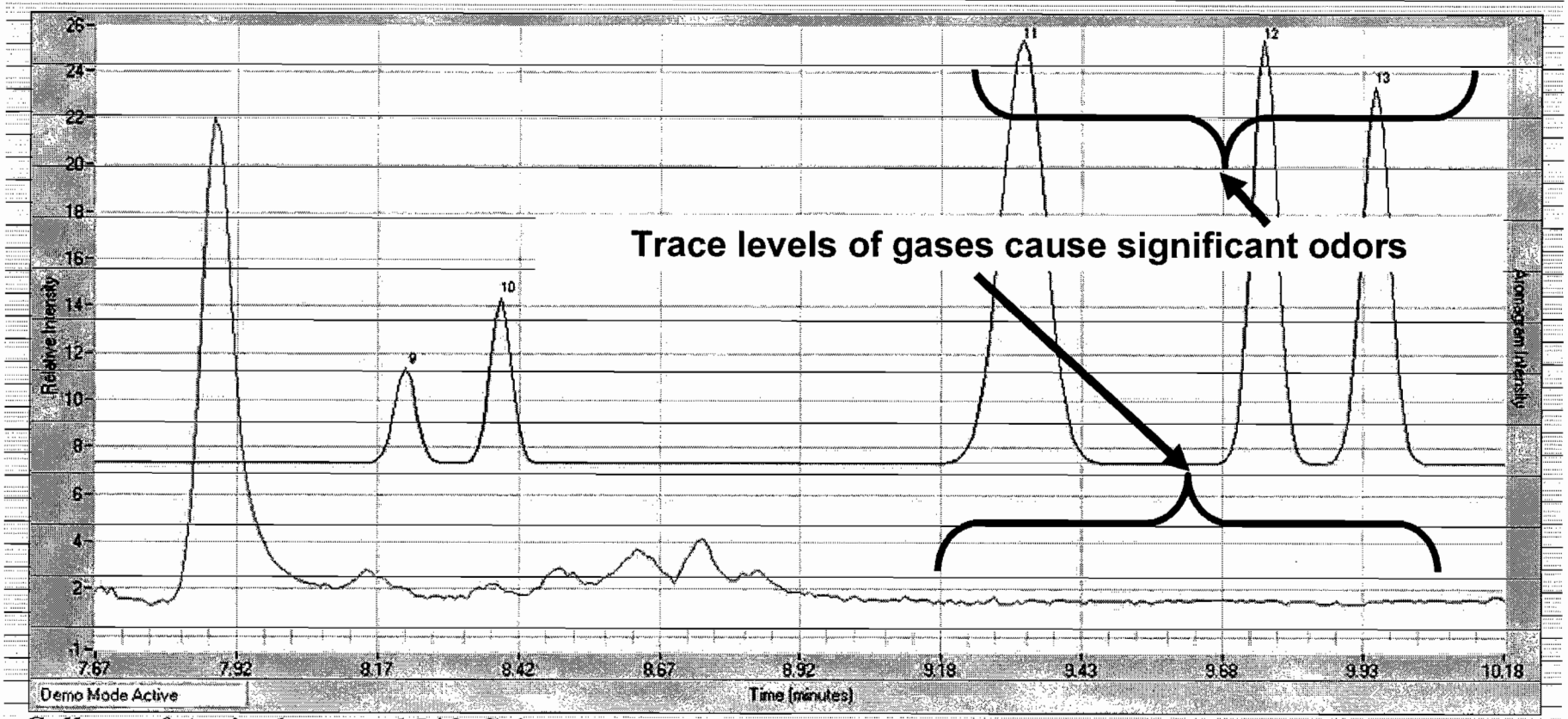
Finding chemicals causing 'characteristic' livestock odors




AromaTrax Aroma Characterization Software
File
Data Acquisition
Data Analysis
Aroma Dilution Analysis
Display Options
Help
Chromatogram
Aromagram
Each odor/aroma event has odor character and intensity recorded
Relative Intensity
Aromagram Intensity
Time (minutes)
0.00
4.00
8.00
12.00
16.00
40.00
Demo Mode Active
Raw Data File DATA.MS
Aroma Events 57
Results Data File SMP016.RS2
Event Number
Descriptor
Start Time (min)
Event Width
Intensity
Area
1 Sewer 1.28 0.08 10 79
2 Fecal Sewer Sweet 1.48 0.09 31 278
3 Sewer Onion Sulfury 1.67 0.10 30 299

Simultaneous chemical and olfactometry analysis of livestock odor



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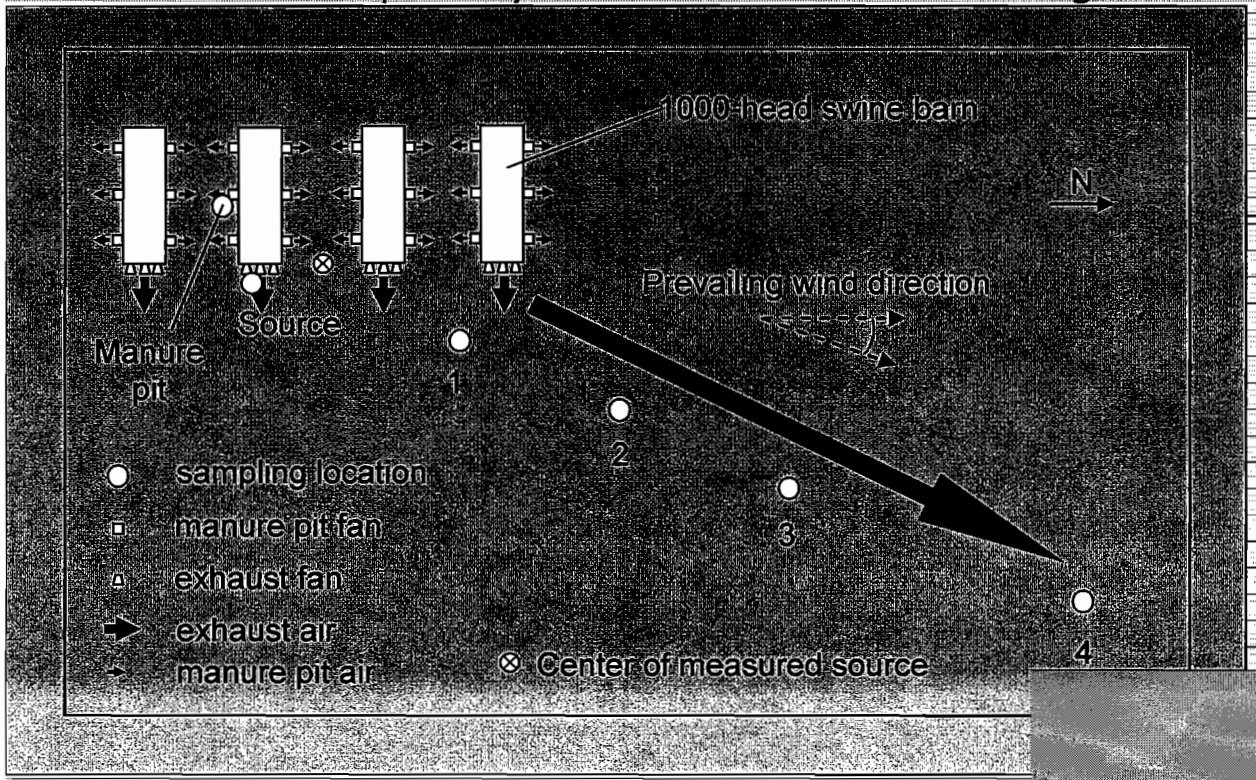
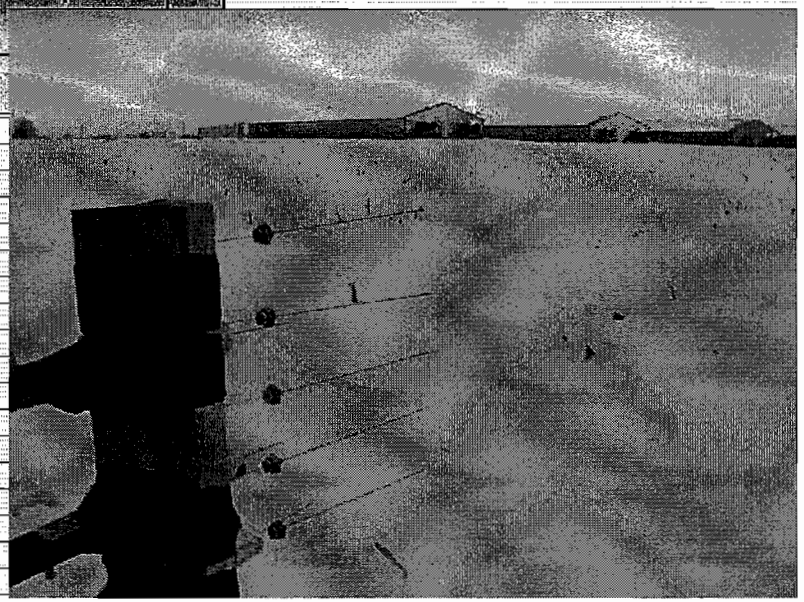
Identification of priority swine odorants of the highest impact downwind





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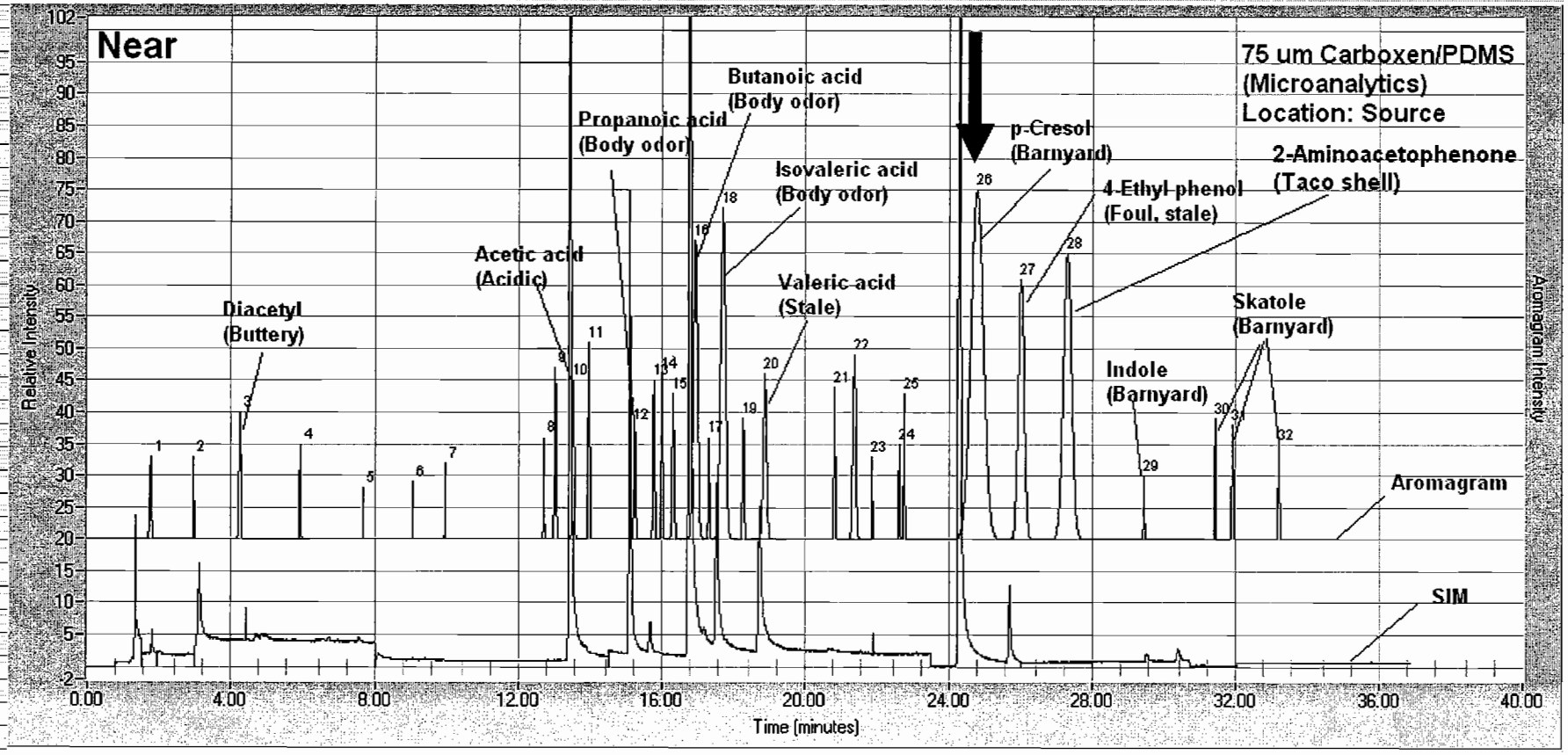
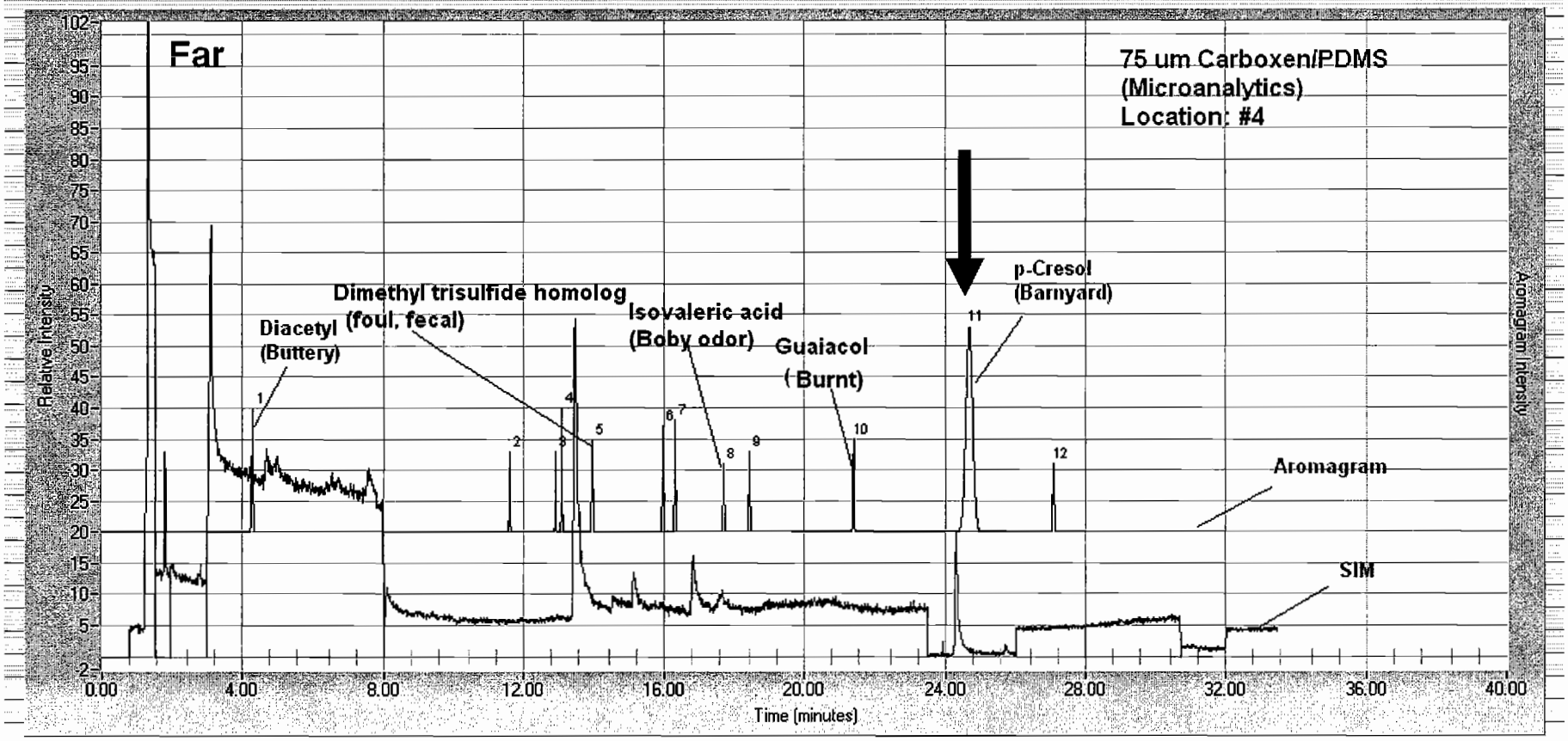
Identification of priority swine odorants of the highest impact downwind



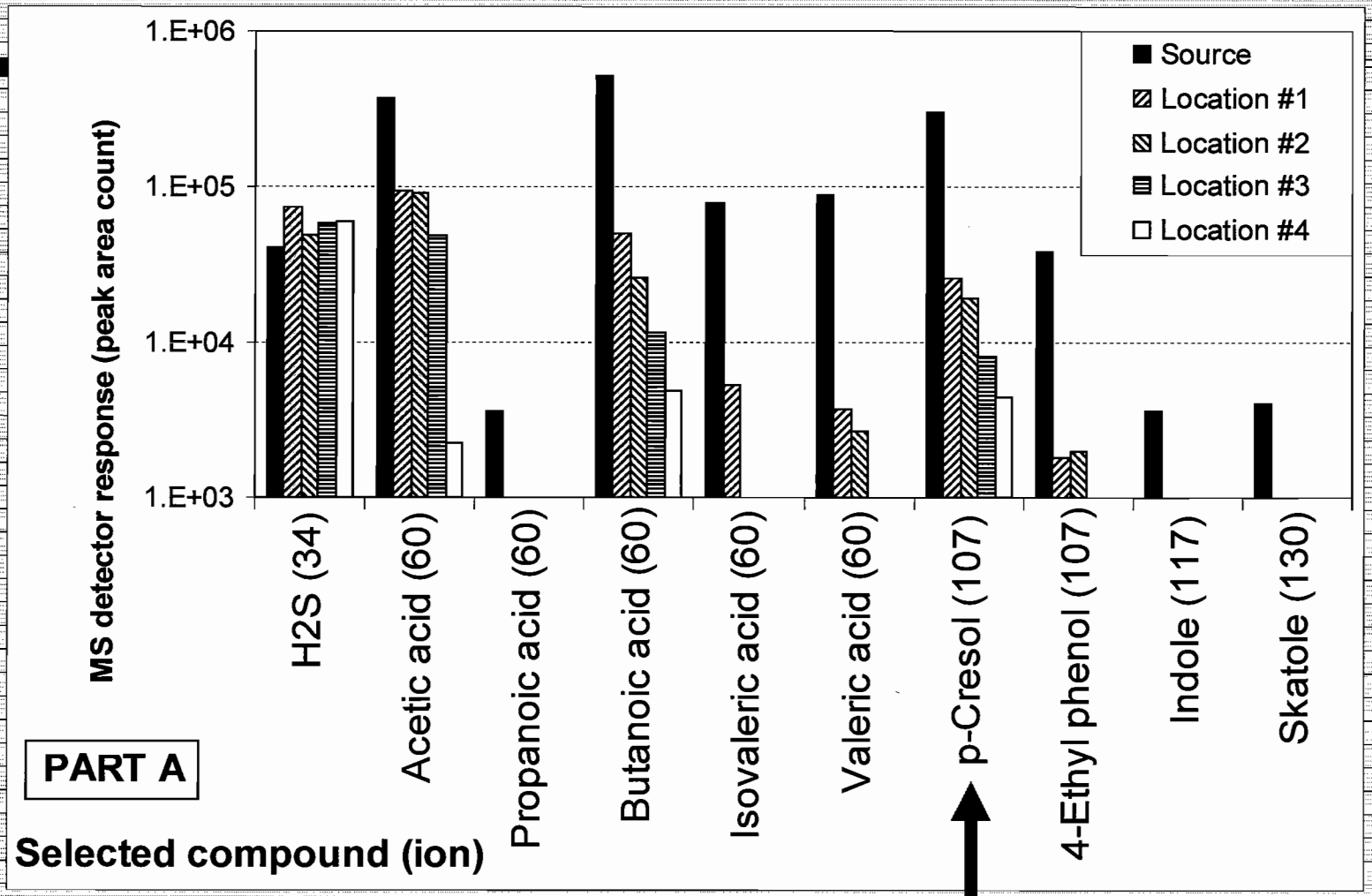
Near source:
20 min exposure of SPME fiber

Identification of priority swine odorants of the highest impact downwind

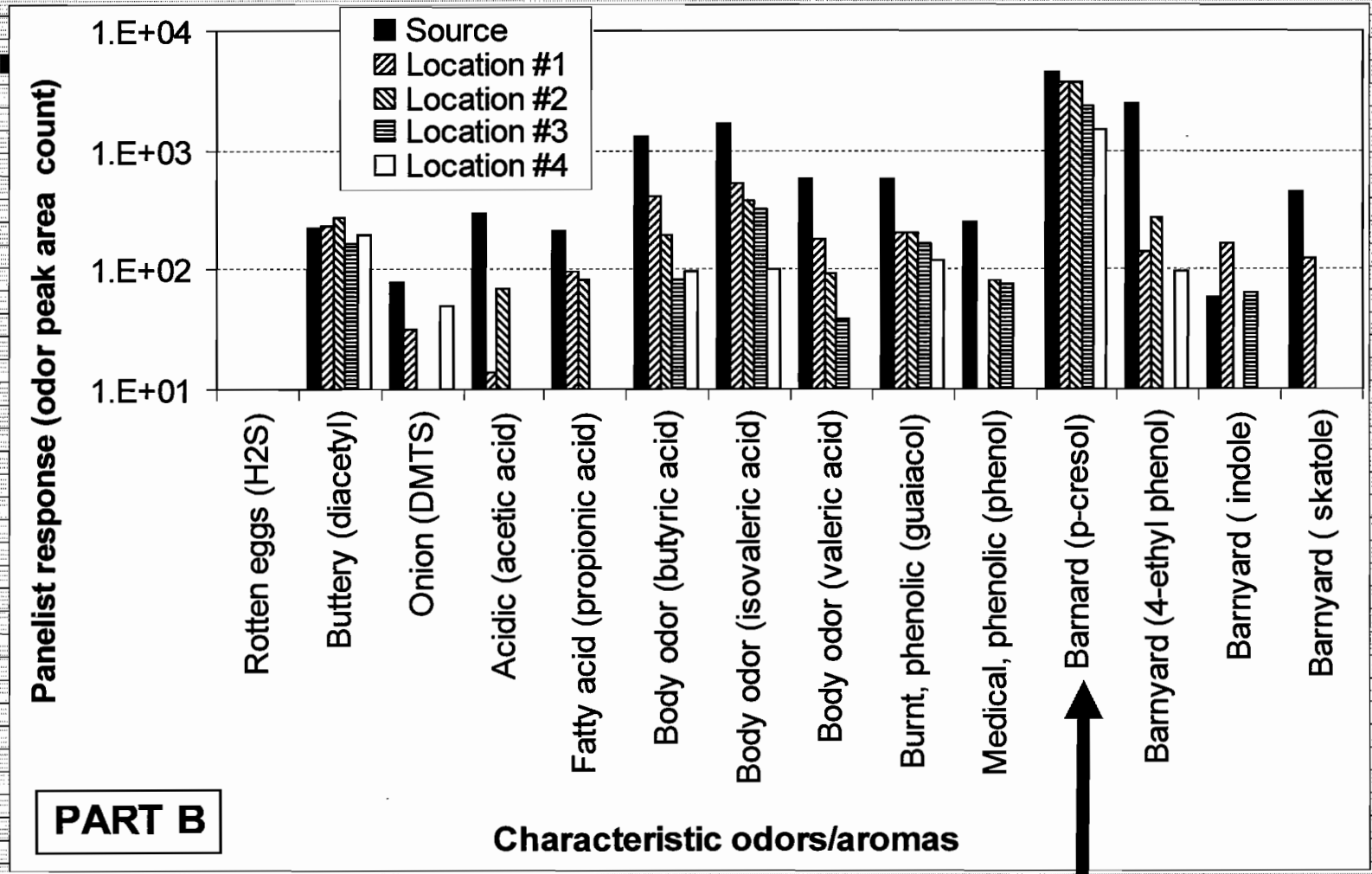


Far from the source:
20 min exposure of SPME fiber to ambient air

Identification of priority swine odorants of the highest impact downwind: chromatogram

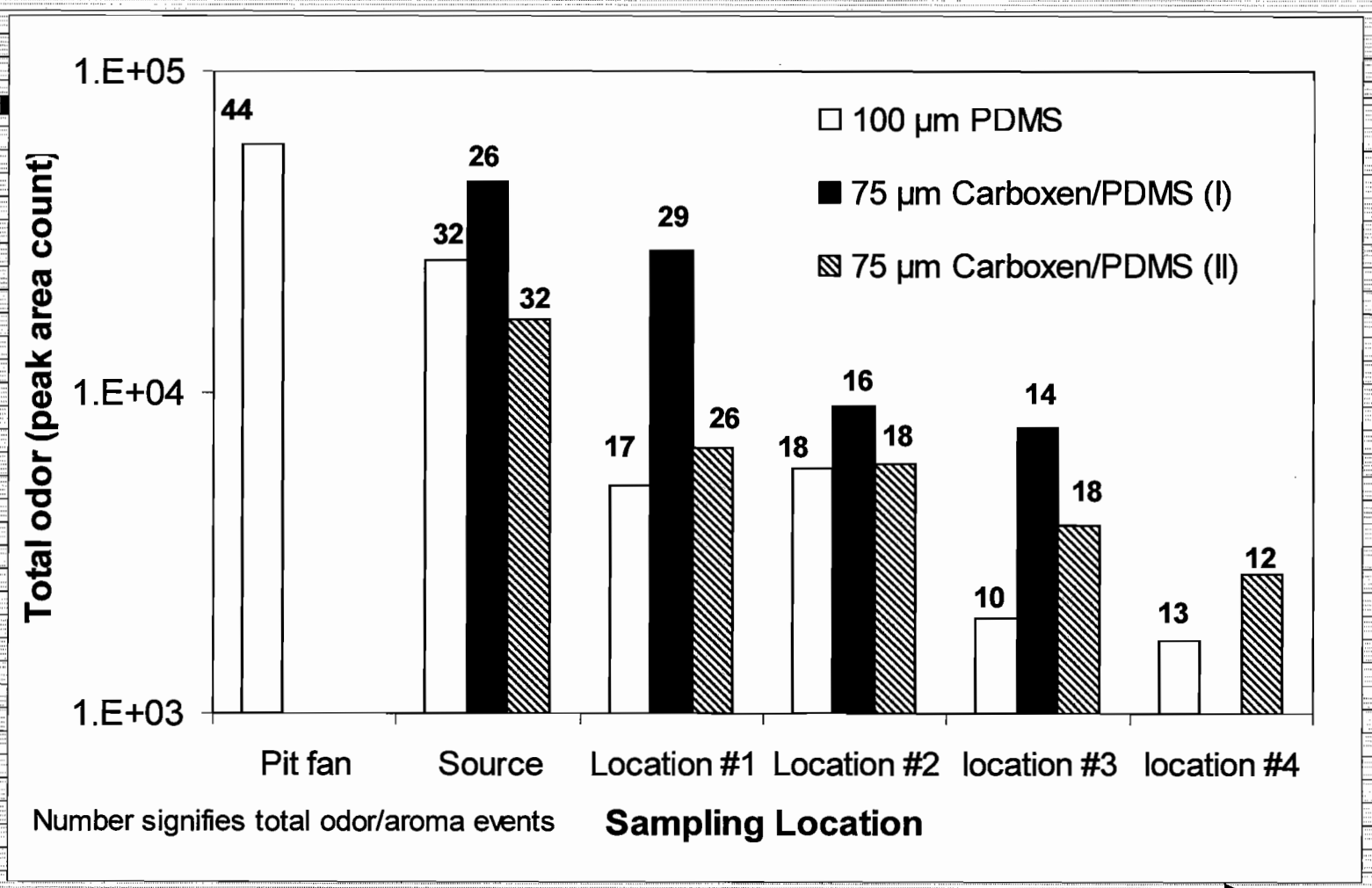


Identification of priority swine odorants of the highest impact downwind: aromagram



PART B

Effects of SPME fiber type and distance from the source



Distance from the source

More Detail Descriptions

- Biofiltration Research
- UV Treatment of Odors
- Siting Considerations

Biofiltration Research

Dr. Steve Hoff, Professor

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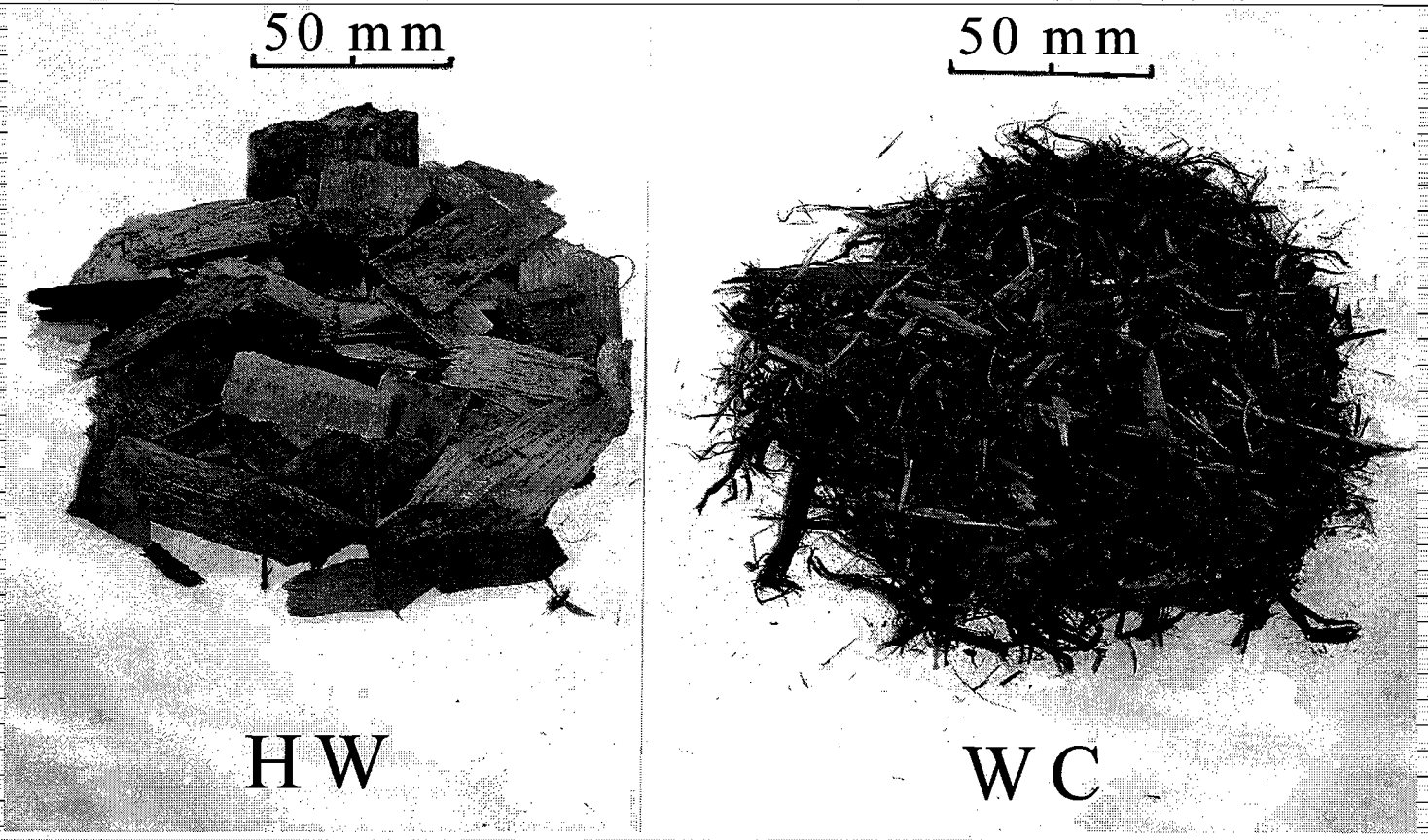
Wood Chips Tested

Hardwood (HW) and Western Cedar (WC)



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Completed Biofilter

wood chips only

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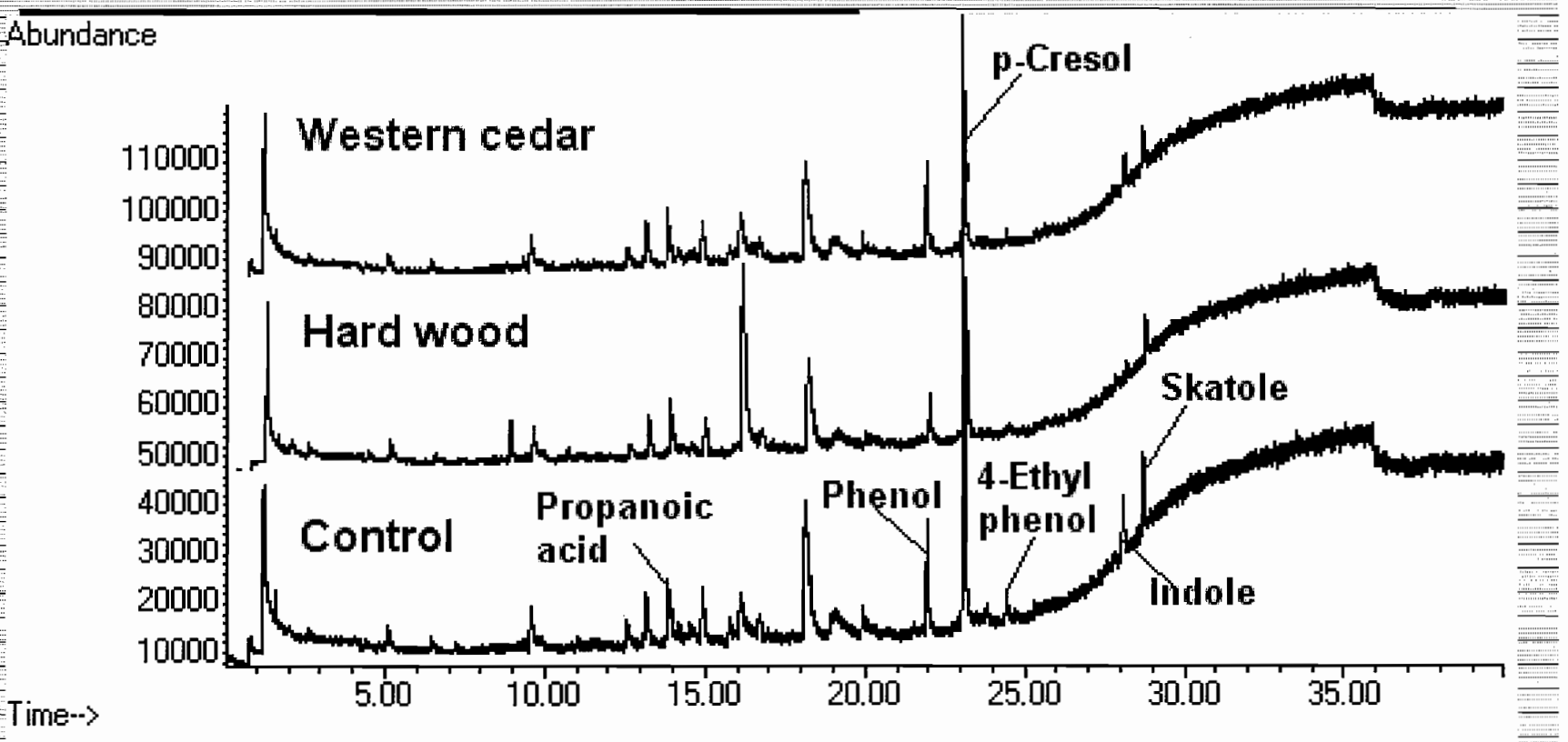
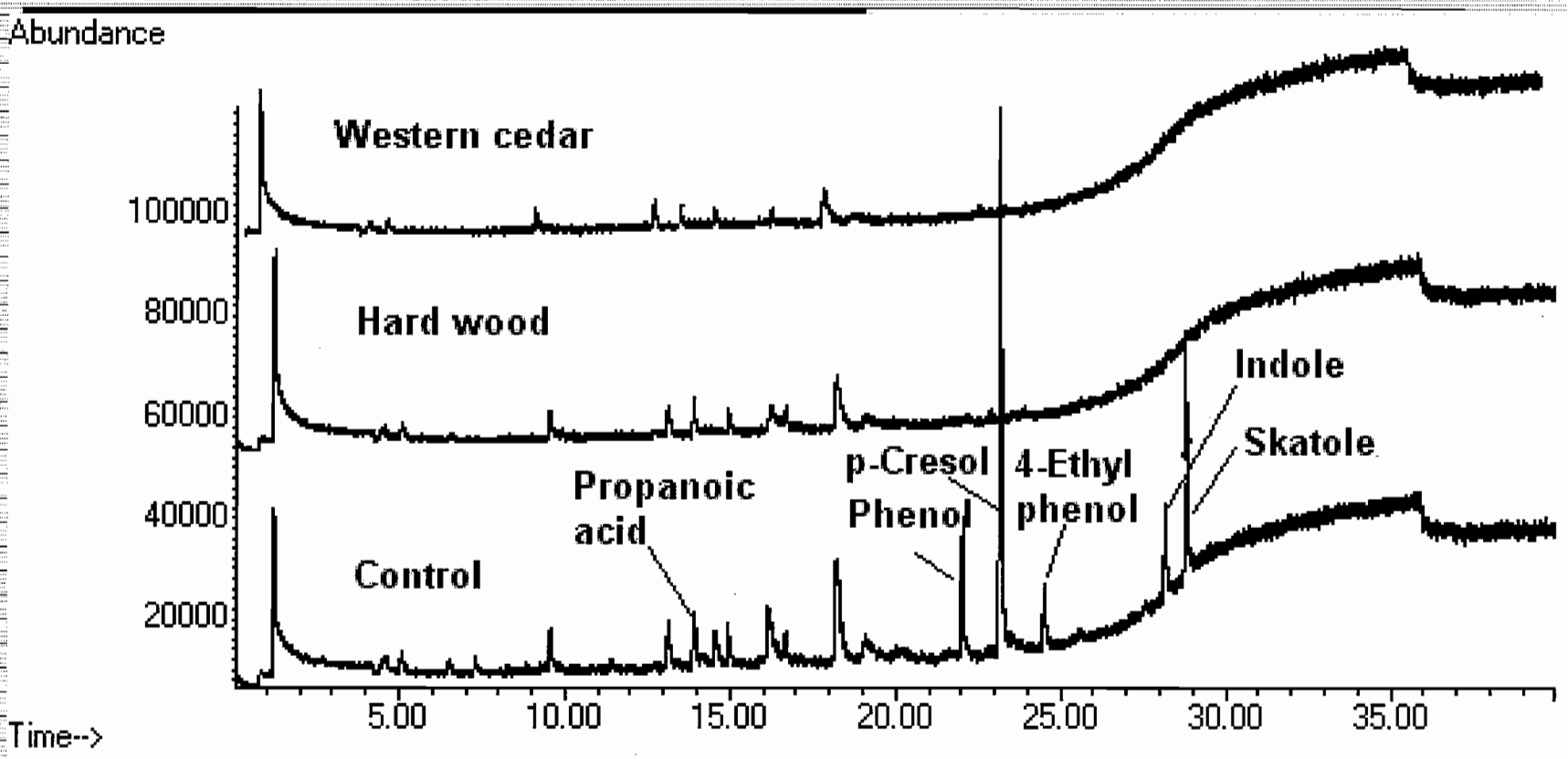
GC-MS Results for a Poorly Operating Biofilter

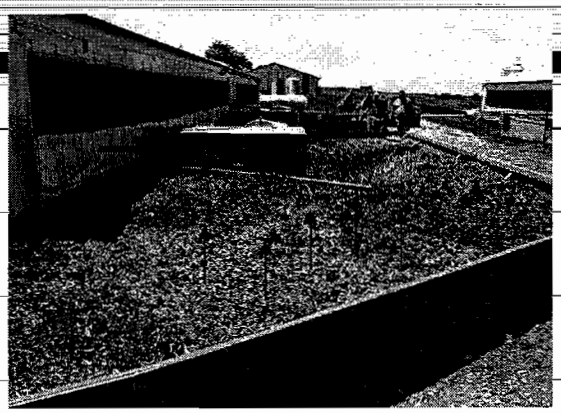


GC-MS Results for a Properly Operating Biofilter



p-Cresol Shown to be One of the Most Prevalent Compounds Found at Distances Downwind (Koziel et al, 2006)

BF Exhaust vs Pit Exhaust Air



Results of Research

	Biofiltered Room	Control Room
Odor Concentration (OU/ft^3)	199±154	529±394
	62% Decrease	
NH_3 Concentration (ppm)	2.6±3.0	9.5±3.3
	73% Decrease	

As-Needed Odor and Gas Control

- Downwind odor events are generally short-term due to a narrow exposure angle
- Odor events most prevalent at night during very stable atmospheres
- Why not control for odors if and when needed?

Stable vs Unstable Atmospheres

Odors tend to "hang" near the earth surface

Stable atmosphere (night, early evening, early morning)

Odors rise vertically near the source

Unstable atmosphere (daytime high solar conditions)

downwind distance

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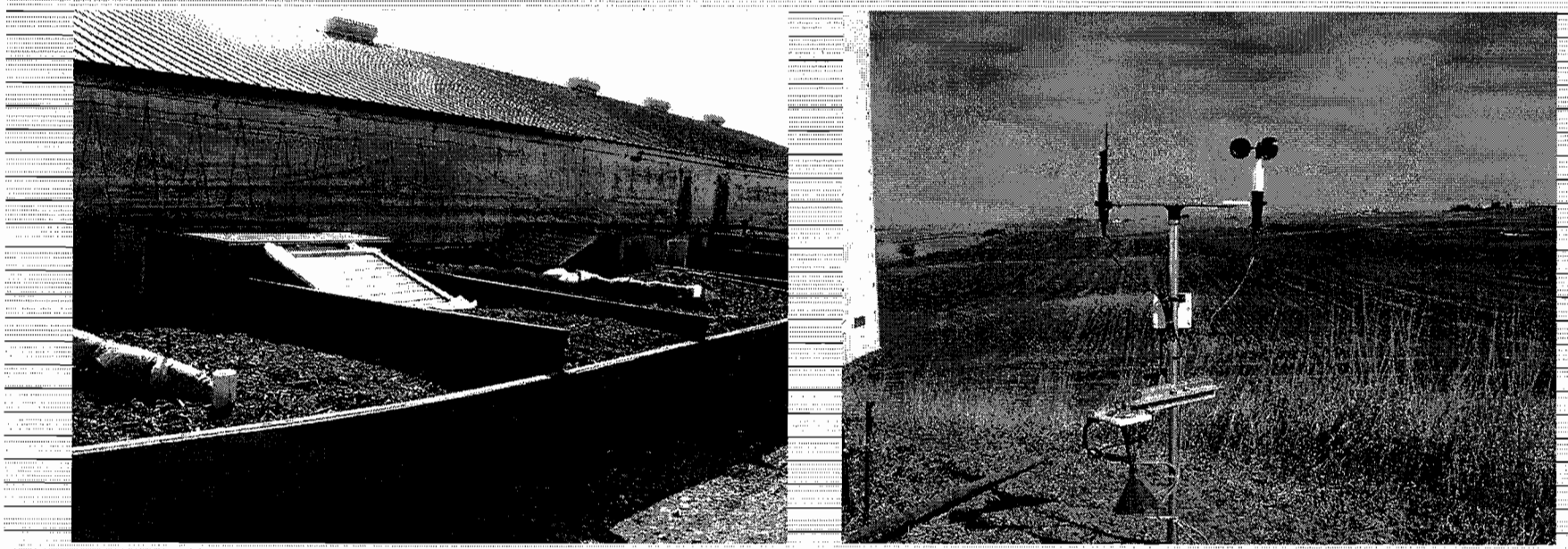
Example from On-Farm Research

- We have placed three "fictitious" neighbors in the northern hemisphere of our on-farm research site
- Our research shows.....The actual time that wind originates from the source to any of the three neighbors during stable atmospheres is no more than 6.7% of the time

As-Needed Odor Control



Completed Biofilter With ByPass Control

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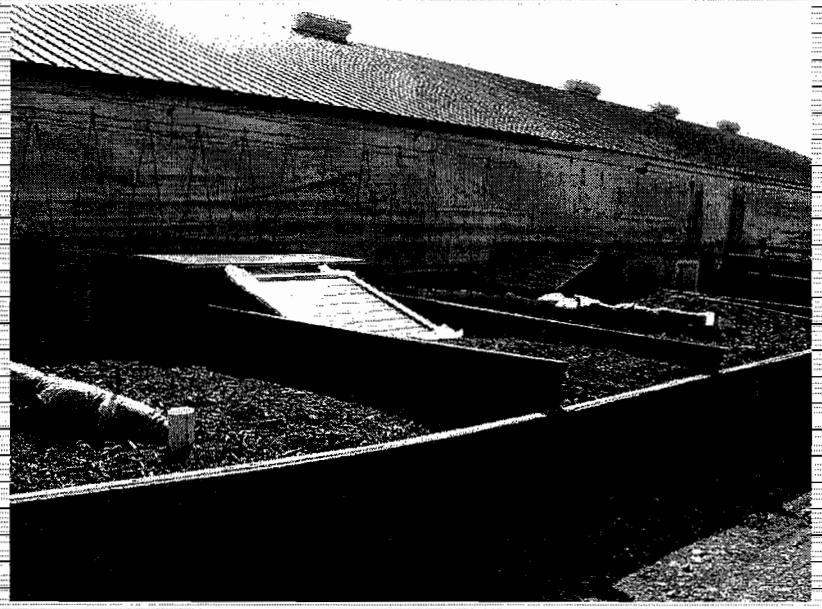
Future Work



- Need to test tunnel barns
- Need to test effect on animals over longer periods

UV Treatment of Odor-causing Compounds

Dr. Jacek Koziel, Associate Professor

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UV Treatment of Odor-Causing Compounds

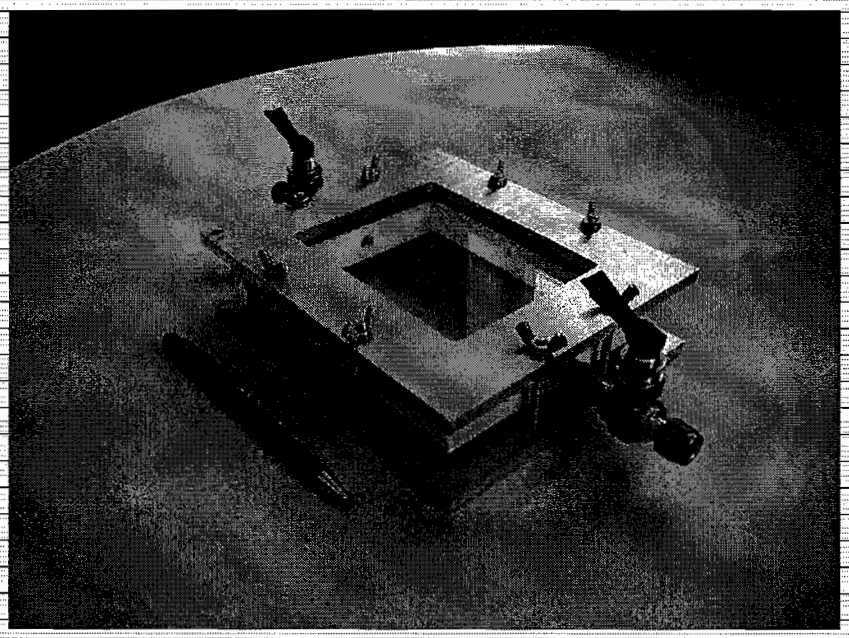
- Odor in ventilation air + UV light = less odorous air
- Focus on treatment of gases causing the 'characteristic' livestock odor

UV Treatment of Ventilation Air

- Laboratory scale results are excellent (i.e., very high odor removal rates)
- Immediate startup time (on-off)
- Short treatment time
- Added benefit of UV – inactivation of airborne pathogens, other gases of regulatory significance
- Low energy input
- Possibly applicable to existing and new systems

UV Treatment of Surrogate Livestock Odor

- Chamber used for UV treatment of odorous air (with photocatalysis)



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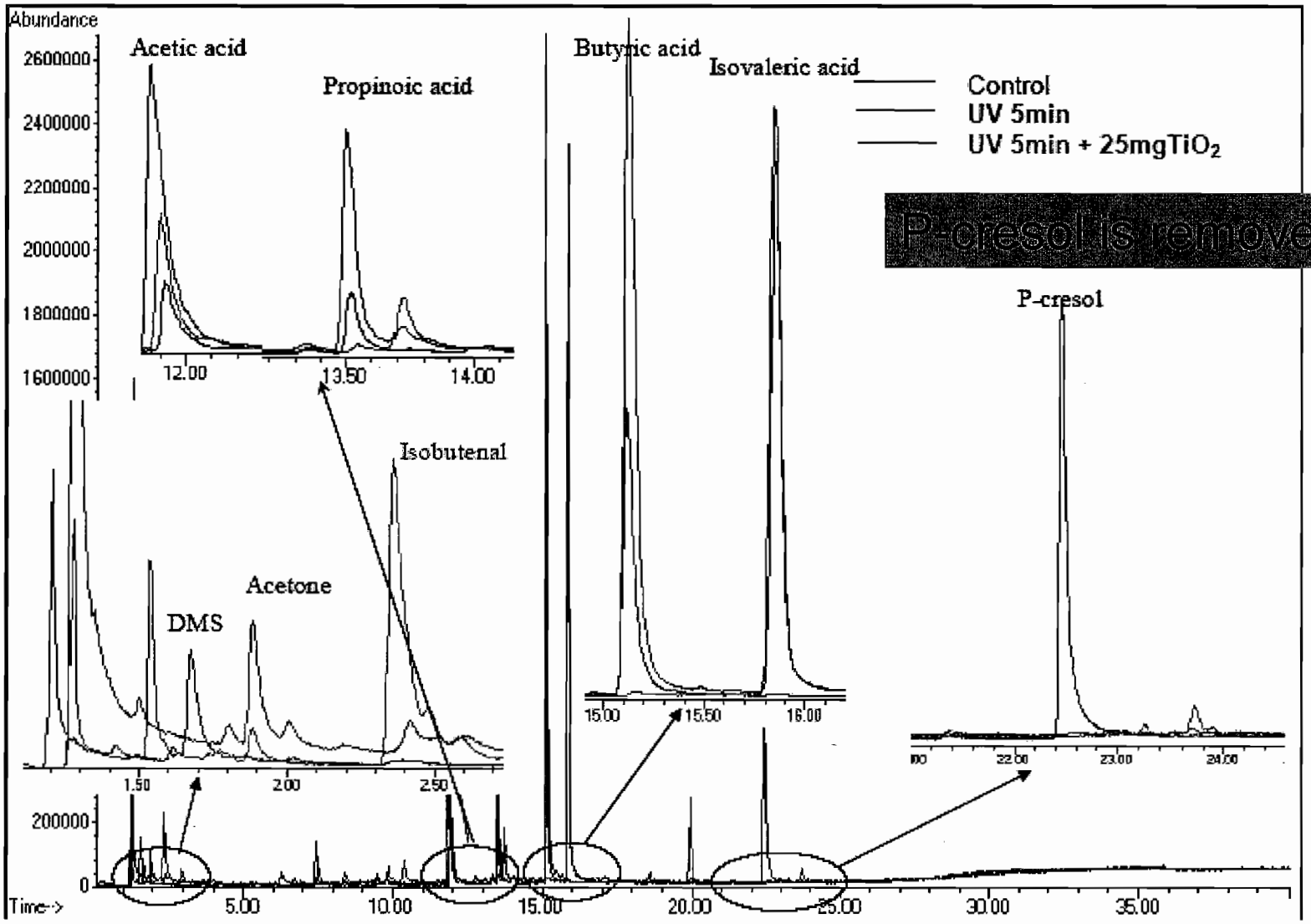
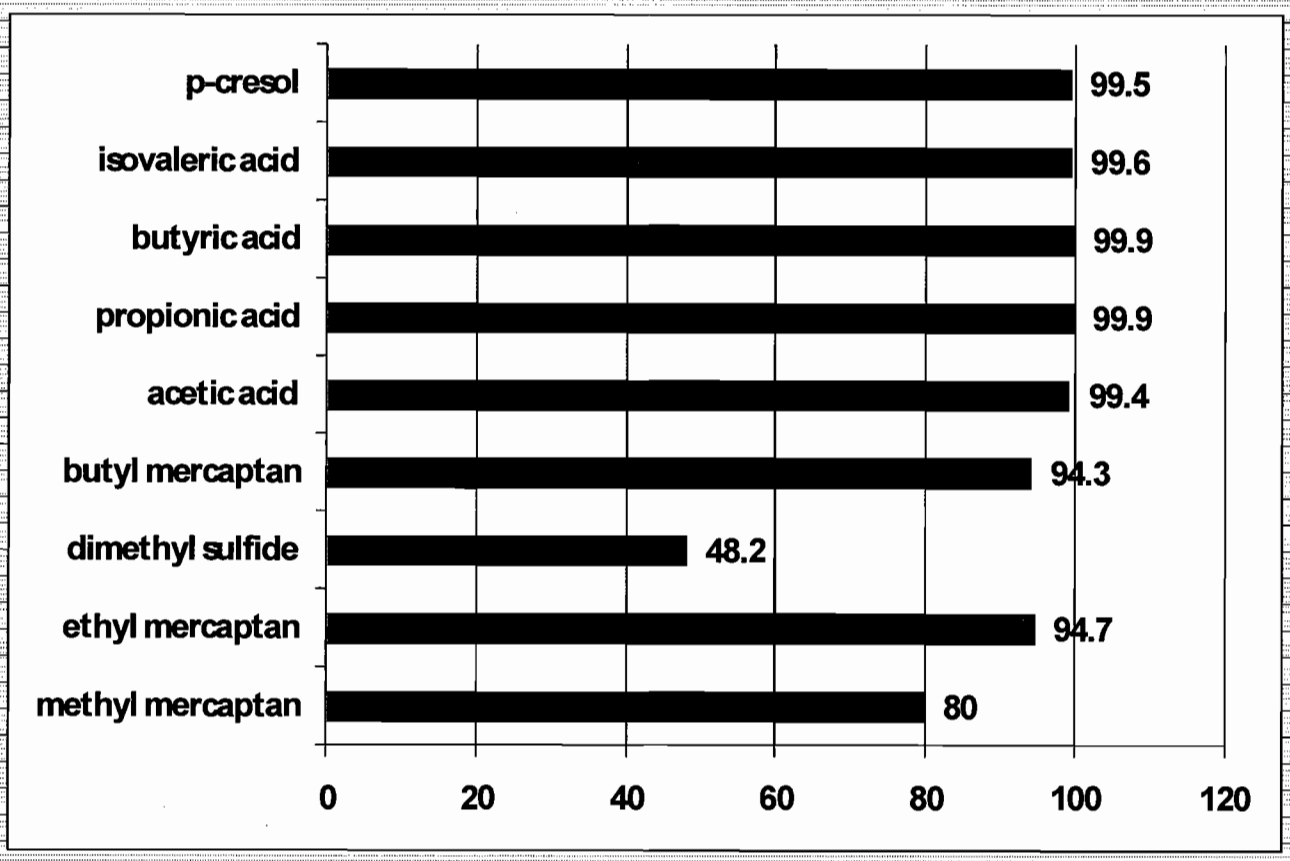
UV Treatment: Results to date (1)



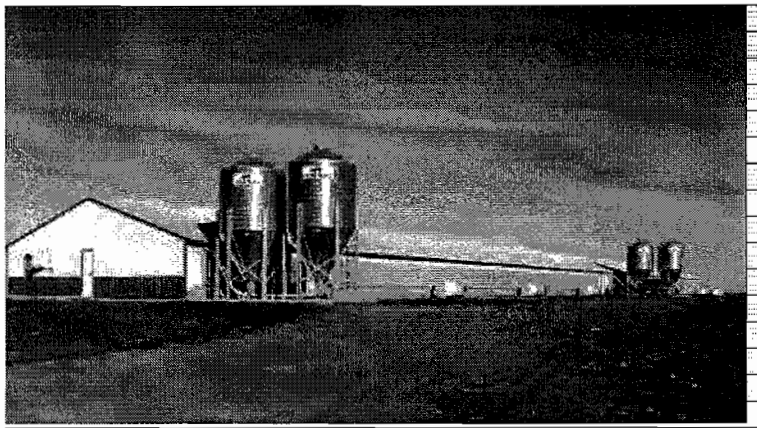
UV Treatment: Results to date (2)

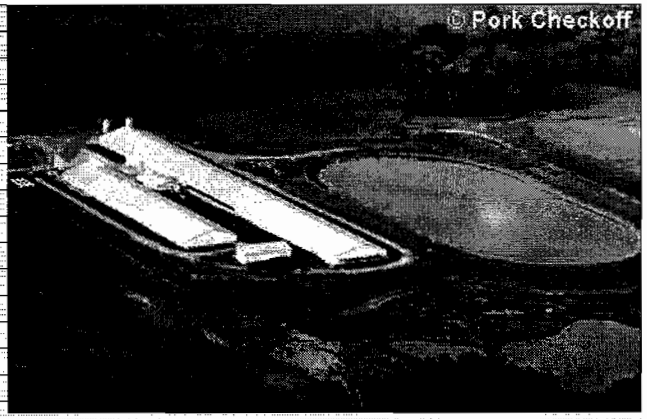
VOC removal efficiency (%) for 1 sec irradiation



UV Treatment: Future work

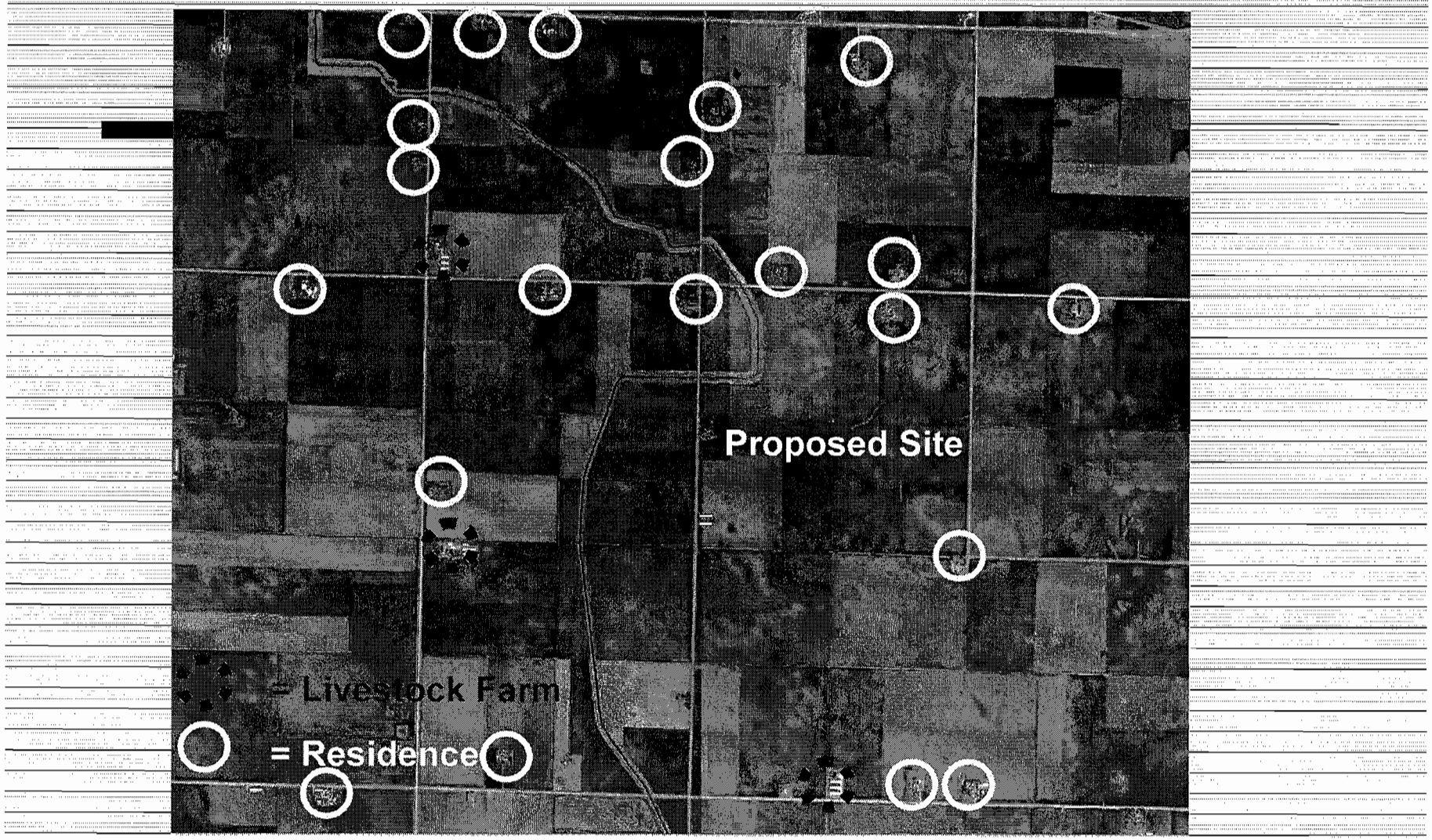
- Scale up to pilot- and commercial scale
- 3 years
- Seeking funding





Siting of Swine Facilities Using a Community Assessment Model (CAM)

Siting Decisions

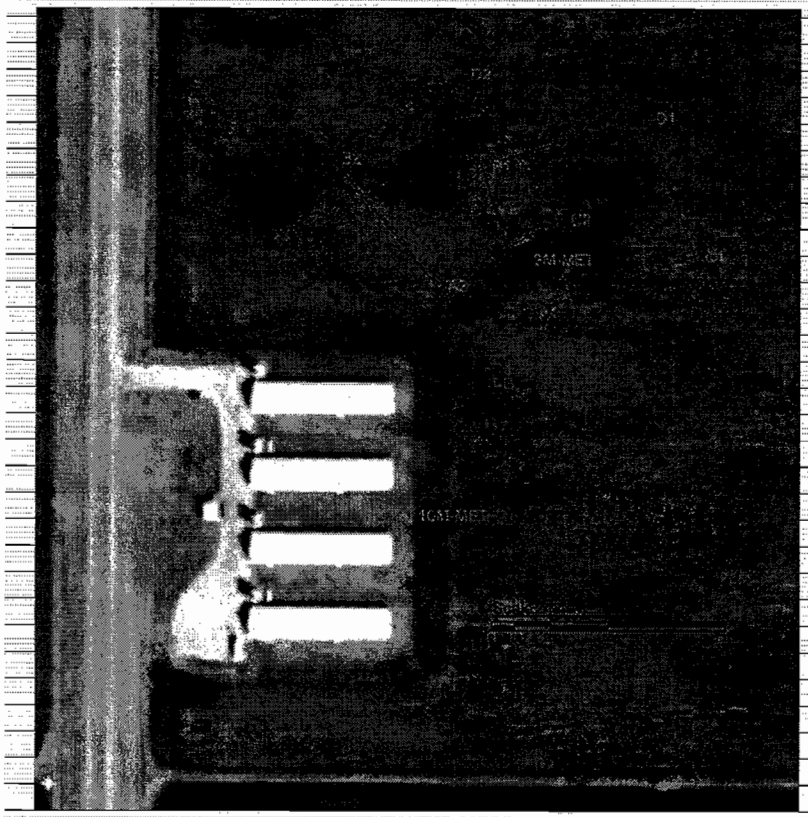


Facility Siting Work

- Develop a tool that can be used to assess the odor impact of a proposed animal facility on receptors in a community
- The Result: Community Assessment Model For Odor Dispersion (CAM)

Field Data Results Compared to Modeled Dispersion

We Have Verified Modeled Predictions Using a 4-Barn Deep-Pit Finishing Site in Central Iowa.



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Siting Decisions

Factors to Consider

Historical Weather Patterns

% time in various directions and the relation to neighbors

Current Sources

What sources currently exist and how do these relate to the proposed source and existing neighbors?

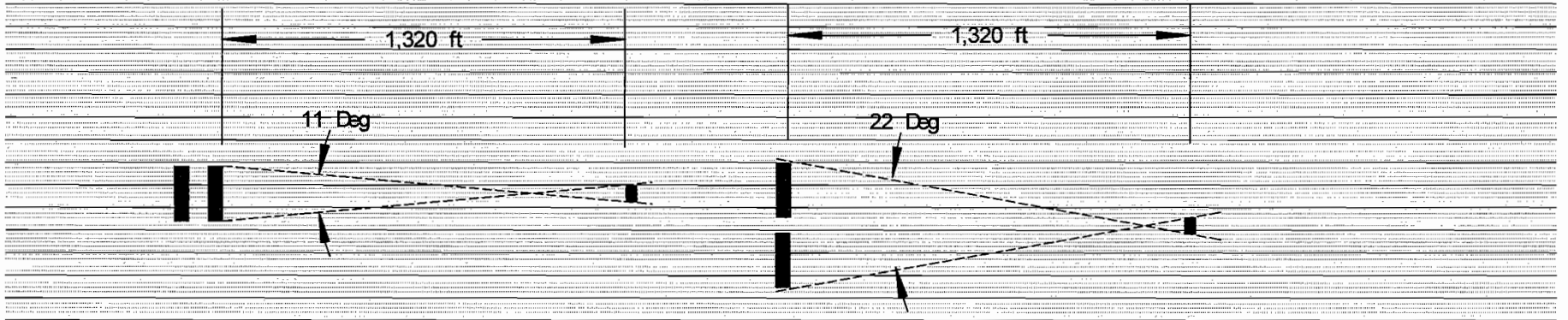
Distances are not Equal in all Directions

In Iowa, predominant summer winds from S, SSE.

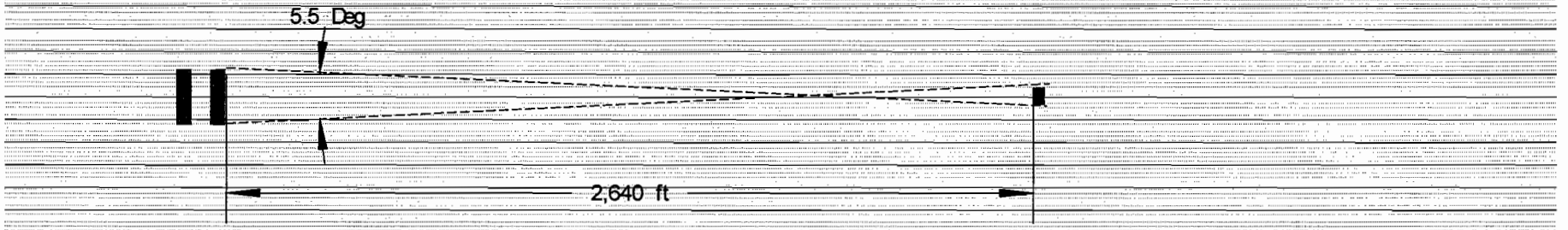
A facility to the south of a neighbor at a given distance has a greater odor impact as one to the north at the same distance.

Odor Transport

Effect of Distance and Size



Exposure Angles



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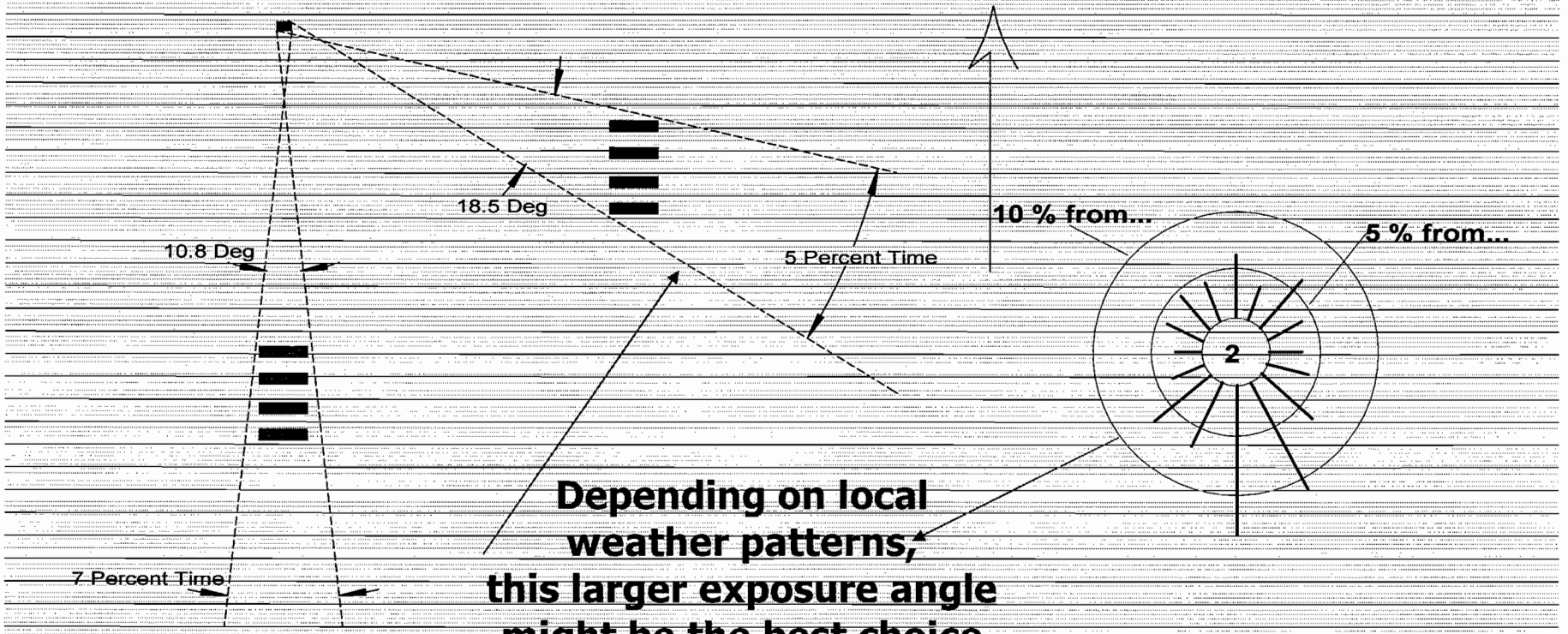
Distance, Orientation, and Local Weather

Summer, Central Iowa



Depending on local weather patterns, this larger exposure angle might be the best choice

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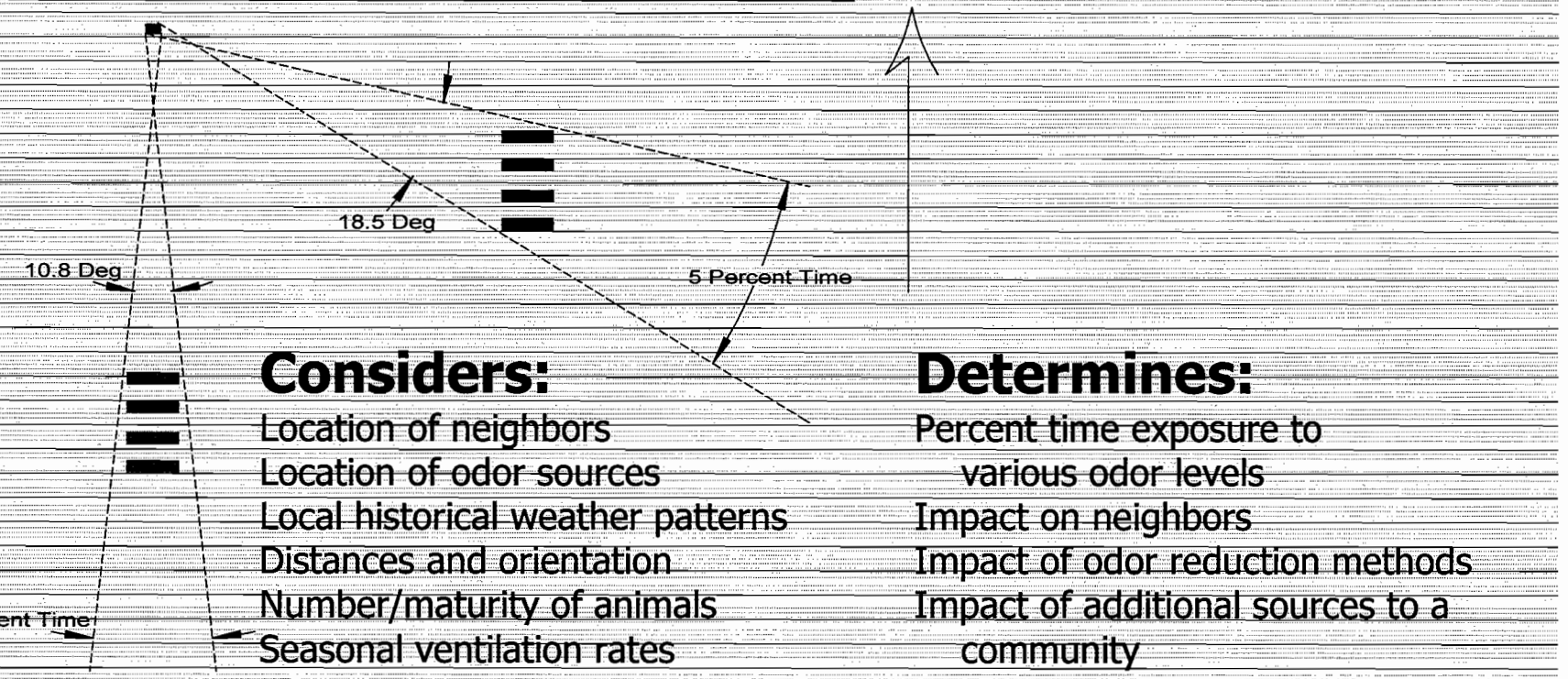
Community-Based Odor Assessment Model

Developed, Field Tested, Now Being Requested in Practice



Considers:

- Location of neighbors
- Location of odor sources
- Local historical weather patterns
- Distances and orientation
- Number/maturity of animals
- Seasonal ventilation rates

Determines:

- Percent time exposure to various odor levels
- Impact on neighbors
- Impact of odor reduction methods
- Impact of additional sources to a community

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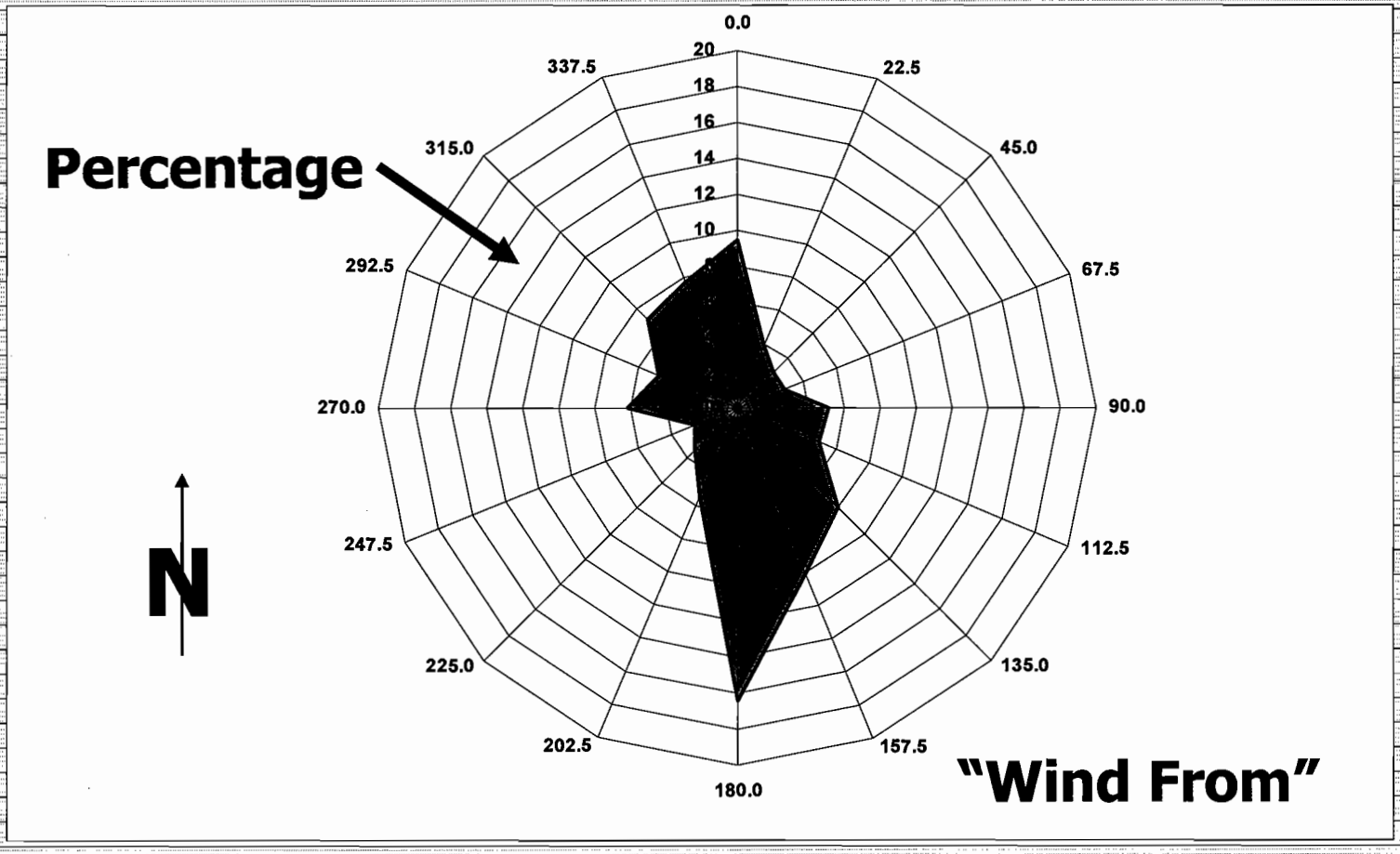
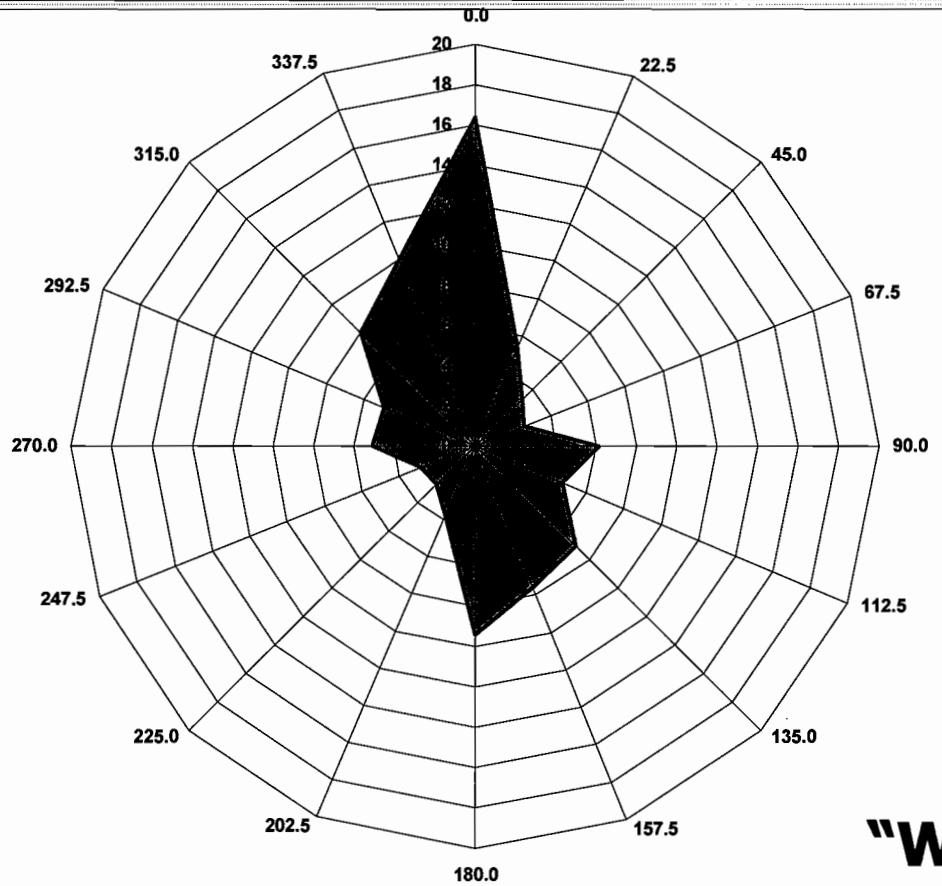
Wind Rose Pattern: Algona, IA

March-October, Historical Average



Downwind Rose Pattern: Algona, IA

March-October, Historical Average



"Wind To"

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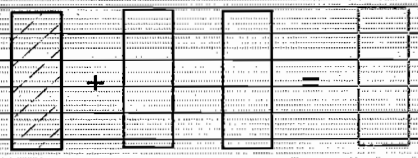
Odor Levels Used in CAM

Weak Odor (2:1 level)
It takes 2 Parts Fresh Air Mixed with 1 Part
Odorous Air to Make the Odor Nearly Undetectable



Identifiable Odors (7:1 level)
It takes 7 Parts Fresh Air Mixed with 1 Part
Odorous Air to Make the Odor Nearly Undetectable

Nasal Ranger®
in Action

Using 7:1 Odor Level is Common for Assessment

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Putting Odor Levels, Facility Size, and Localized Weather Patterns Together….

We have put together Odor Roses for 12-locations in Iowa by combining facility size, neighbor location, distance, and modeled odor concentrations

Here is what we get……

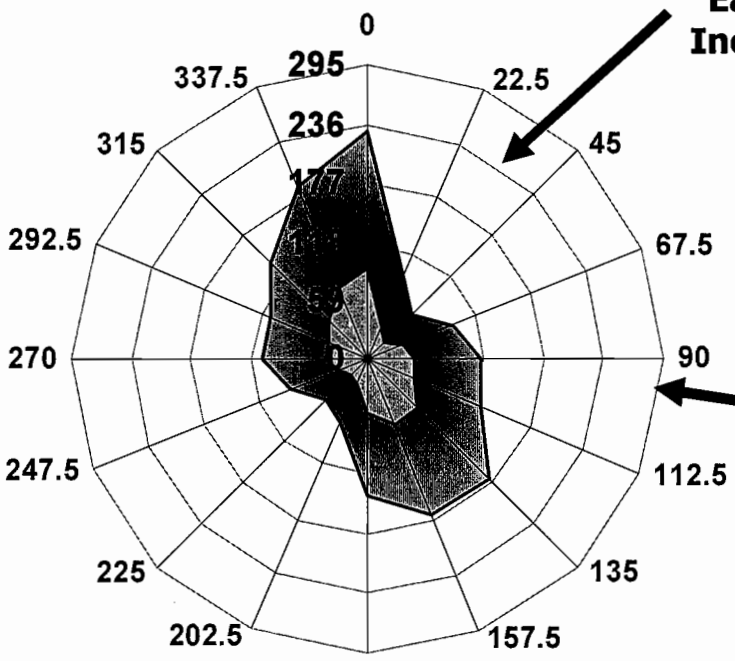
How to Read: If I am a neighbor 1,250 ft from a 4,8000-hd DPSF, and I am NW of the site, I can expect to experience 4% 2:1 or higher odors and 3% 7:1 or higher odors.

Algona Odor Rose

Algona Odor Hours

1,250 ft Separation

- 2:1 Odors
- 7:1 Odors



Each Ring Represents a 1% Increase in March-to-October Hours (59 hrs=1%, etc)

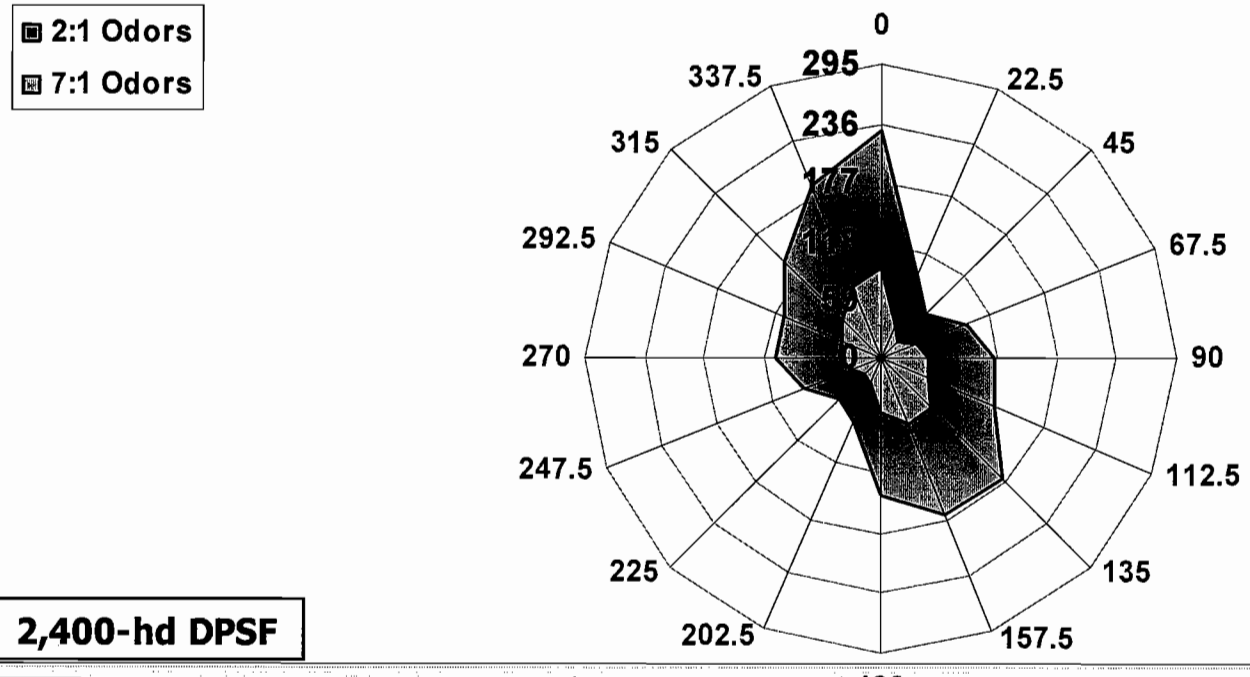
5% Exposure

2,400-hd DPSF

Algona Odor Rose: 1,250 ft Distance

Algona Odor Hours

1,250 ft Separation



2,400-hd DPSF

Algona Odor Rose: 1,750 ft Distance

Algona Odor Hours

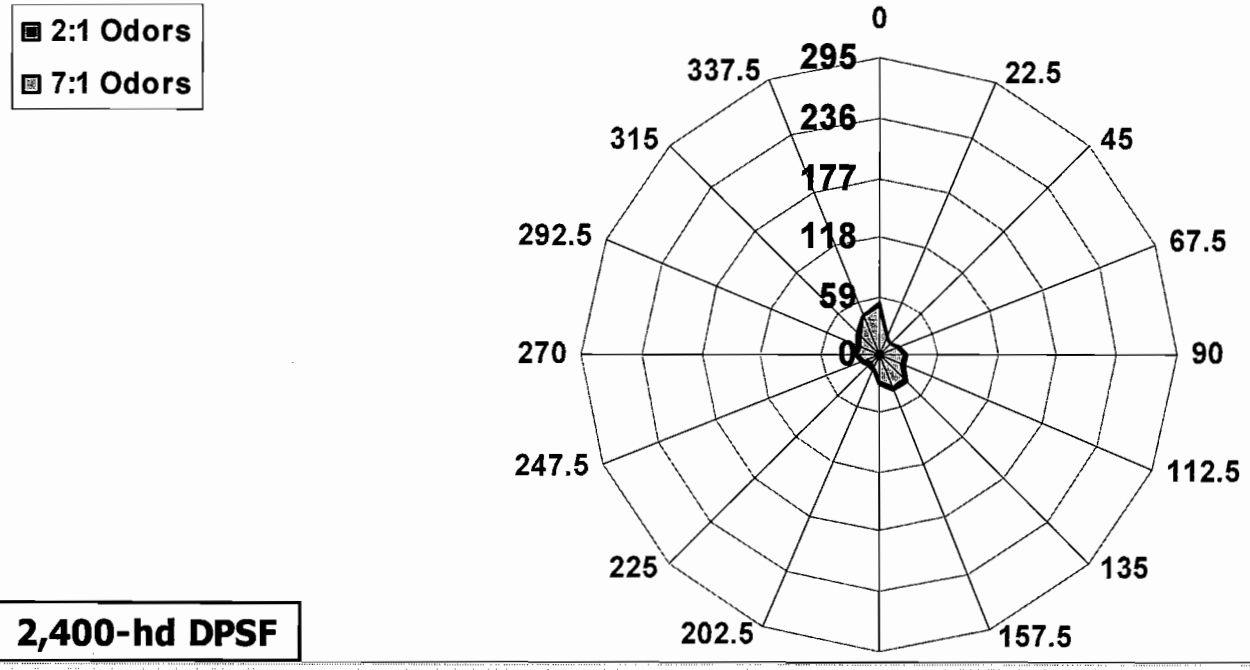
1,750 ft Separation

2,400-hd DPSF

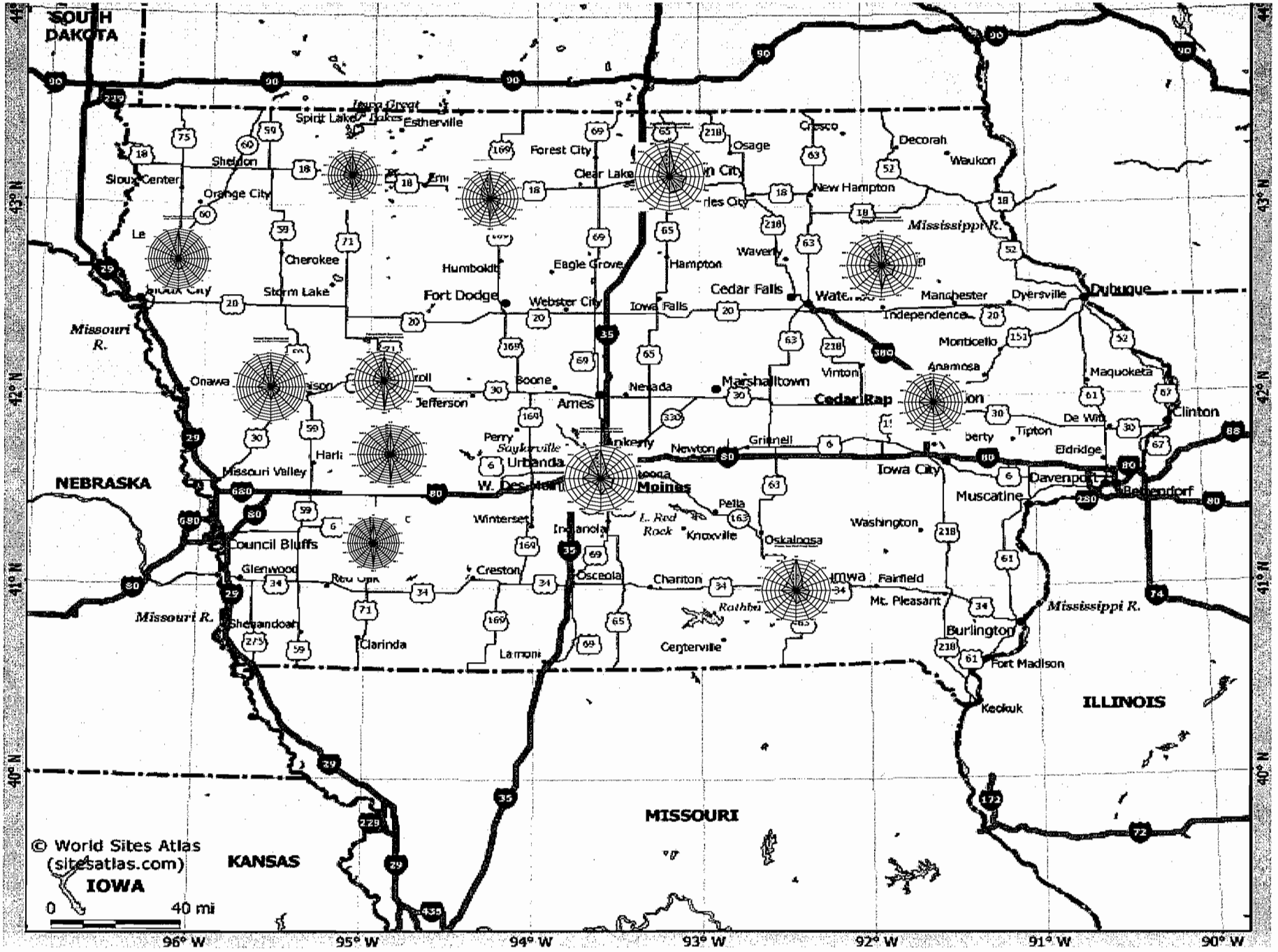
Algona Odor Rose: 2,250 ft Distance

Algona Odor Hours

2,250 ft Separation



2,400-hd DPSF


SOUTH DAKOTA
NEBRASKA
KANSAS
MISSOURI
ILLINOIS
IOWA
Spirit Lake
Estherville
Sheldon
Sioux Center
Orange City
Le Mars
Sioux City
Storm Lake
Cherokee
Humboldt
Fort Dodge
Webster City
Eagle Grove
Forest City
Clear Lake
Hampton
Osage
Crosco
Decorah
Waukon
New Hampton
Mississippi R.
Waverly
Cedar Falls
Waterloo
Manchester
Dyersville
Dubuque
Independence
Iowa Falls
Missouri R.
Onawa
Jefferson
Boone
Ames
Nevada
Marshalltown
Monticello
Anamosa
Maquoketa
Clinton
Cedar Rap
Vinton
Tipton
De Witt
Eldridge
Grinnell
Newton
Iowa City
Davenport
Muscatine
Bettendorf
Harlan
Missouri Valley
Council Bluffs
Glenwood
Shenandoah
Clarinda
Creston
Osceola
Chariton
Centerville
Lamoni
Winterset
Indianola
Des Moines
Pella
Knoxville
Oskaloosa
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Fairfield
Mt. Pleasant
Burlington
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Red Rock L.
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Wind Roses

Click on a city to view data from that area.

For an explanation of the graphs, click here.

Using CAM in Practice

- By Word-of-Mouth, we have been asked to use CAM for helping producers make decisions on siting of new facilities in Iowa.
- We caution producers that CAM is not EPA-approved.
- Nevertheless, producers have been very receptive to our decisions predicted by CAM.

Partnership in Iowa for Siting

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Decision Criteria Used

Siting requests with CAM Evaluated as:

- **Limit proposed source load for neighbors to 1% 2:1 odors (58 hrs) and ½% 7:1 odors (29 hrs).**
- **Limit proposed + existing source load for neighbors to 2% 2:1 odors (115 hrs) and 1% 7:1 odors (58 hrs).**
- **Siting choice judged against all four criteria.**

Hour amounts based on March-thru-October hours

CAM Example Run

Proposed 2,400-hd Deep-Pit Finisher

Case 1

2400-hd Deep-Pit Swine Finisher
Central Iowa

Example Demonstrates Use of Model with One Source and Multiple Receptors and fine-tuning of the source location

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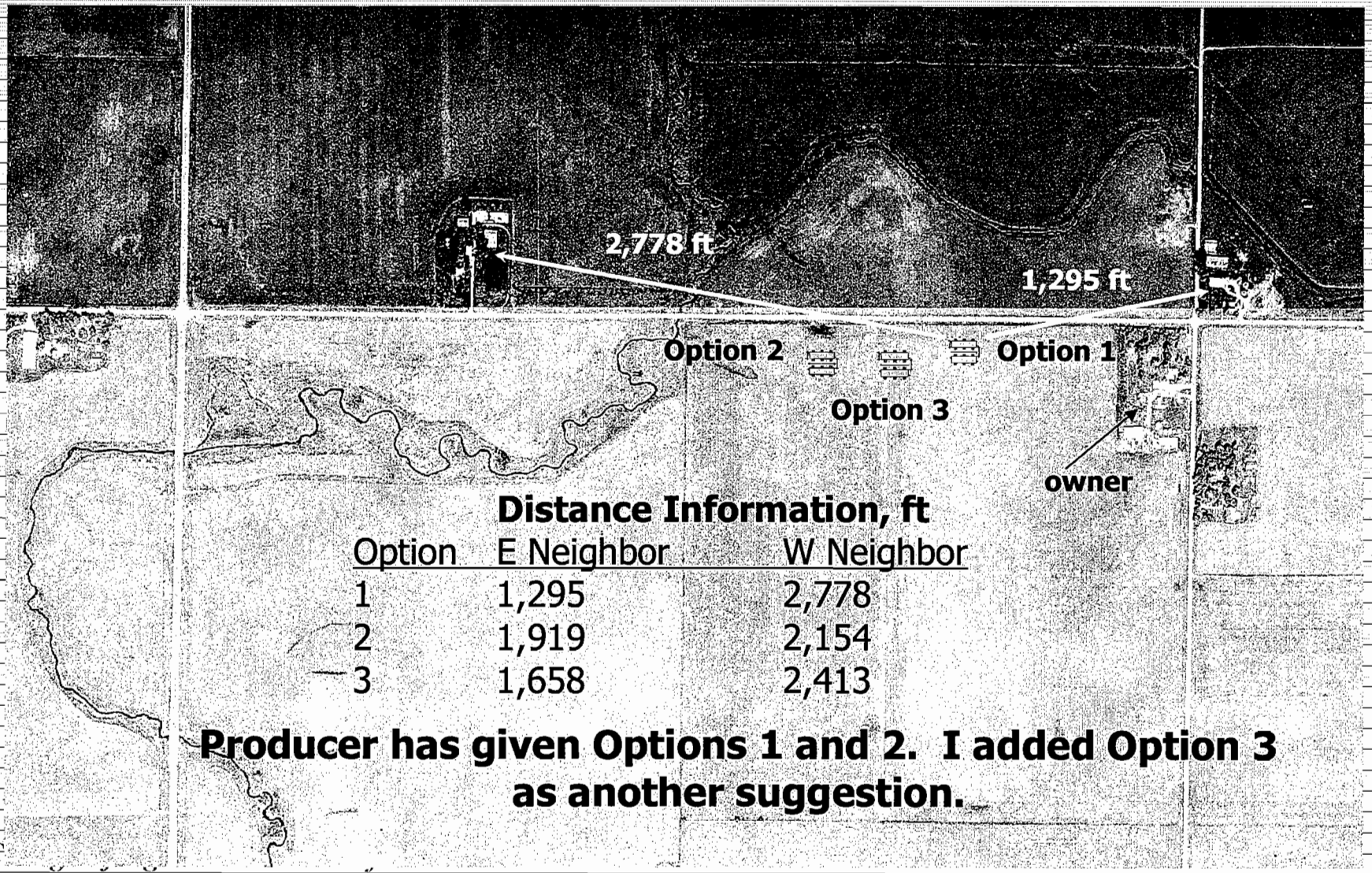
Case 1 Siting Example

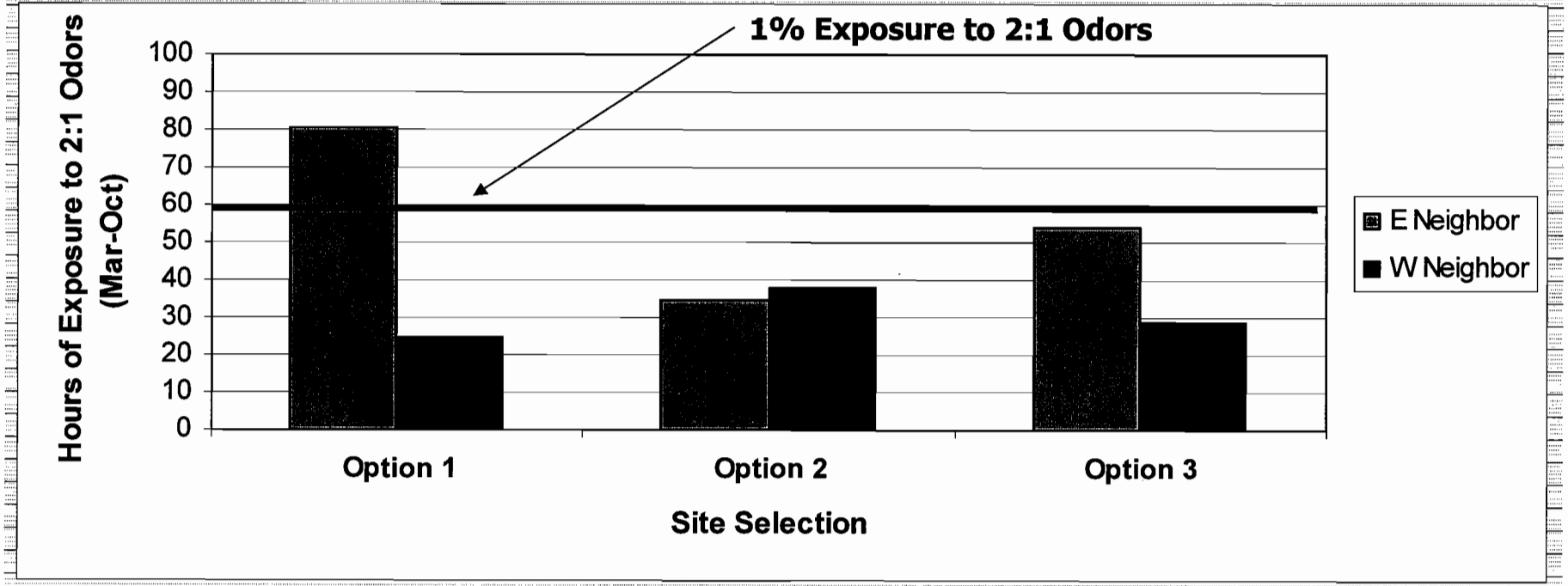


Distance Information, ft

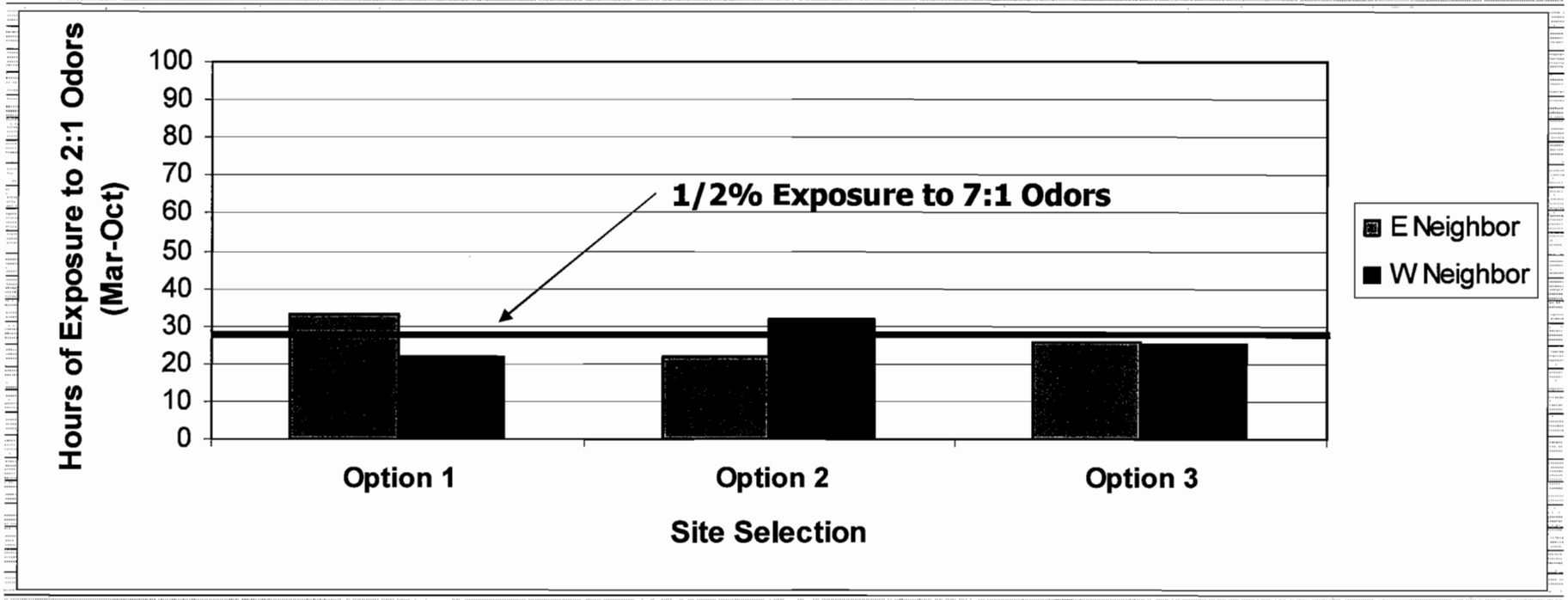
Option	E Neighbor	W Neighbor
1	1,295	2,778
2	1,919	2,154
3	1,658	2,413

Producer has given Options 1 and 2. I added Option 3 as another suggestion.

Case 1: Exposure to 2:1 Odors



Case 1: Exposure to 7:1 Odors



CAM Example Run

Proposed 2,400-hd Deep-Pit Finisher

Case 2

Actual Siting Request
2400-hd Deep-Pit Swine Finisher
NW Iowa
Example Demonstrates Use of Model with Multiple Sources and Multiple Receptors

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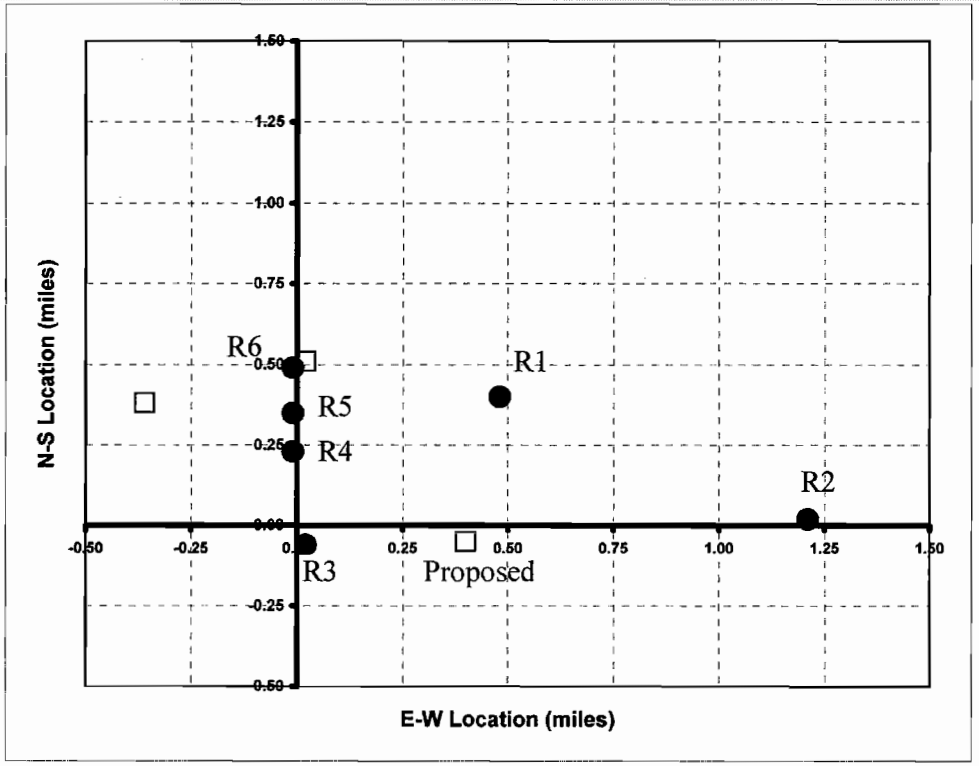
Case 2: CAM Output

Source No.	Source ID	x (mi)	y (mi)
1	P2400PW	0.40	-0.05
2	E1000G	-0.36	0.38
3	E1200N	0.02	0.51

Receptor No.	Receptor ID	x (mi)	y (mi)
1	R1	0.48	0.40
2	R2	1.21	0.02
3	R3	0.02	-0.06
4	R4	-0.01	0.23
5	R5	-0.01	0.35
6	R6	-0.01	0.49



Case 2: Option 1

Summary Analysis for: **Example - Option 1**

Modeled on: xx/xx/xx

Receptor No. (ID)	Odor Category	Total Hours of Exposure (Mar to Oct) From Sour			Proposed Site(s) Hrs.	Total Community Hrs.	Criteria One: Proposed Site Only		Criteria Two: All Sources		Receptor No. (ID)
		P2400WF	E1000BG	E1200N			Less Than 1% 2:1 Odors From Proposed?	Less Than 0.5% 7:1 Odors From Proposed?	Less Than 2% 2:1 Odors All Sources?	Less Than 1% 7:1 Odors All Sources?	
1	2:1	71	12	14	71	96	No		Yes		1
R1	7:1	40	11	2	40	53		No		Yes	R1
	15:1	38	5	0	38	43					
2	2:1	11	8	0	11	19	Yes		Yes		2
R2	7:1	8	1	0	8	9		Yes		Yes	R2
	15:1	3	0	0	3	3					
3	2:1	65	61	10	65	136	No		No		3
R3	7:1	30	31	0	30	61		No		No	R3
	15:1	28	17	0	28	45					
4	2:1	40	76	29	40	146	Yes		No		4
R4	7:1	22	36	18	22	76		Yes		No	R4
	15:1	17	36	6	17	59					
5	2:1	35	85	88	35	208	Yes		No		5
R5	7:1	19	55	46	19	121		Yes		No	R5
	15:1	13	38	35	13	85					
6	2:1	27	62	333	27	421	Yes		No		6
R6	7:1	22	34	333	22	388		Yes		No	R6
	15:1	10	27	333	10	370					

Proposed Option 1 exceeded levels for 2 receptors

Case 2: Option 2

Summary Analysis for: **Example - Option 2**

Modeled on: **xxlxxlxx**

Receptor No. (ID)	Odor Category	Total Hours of Exposure (Mar to Oct) From Sourc P2400WF	E1000BG	E1200N	Proposed Site(s) Hrs.	Total Community Hrs.	Criteria One: Proposed Site Only — Less Than 1% 2:1 Odors From Proposed?	Less Than 0.5% 7:1 Odors From Proposed?	Criteria Two: All Sources — Less Than 2% 2:1 Odors All Sources?	Less Than 1% 7:1 Odors All Sources?	Receptor No. (ID)
1	2:1	46	12	14	46	72	Yes		Yes		1
R1	7:1	26	11	2	26	39		Yes		Yes	R1
	15:1	18	5	0	18	23					
2	2:1	44	8	0	44	53	Yes		Yes		2
R2	7:1	23	1	0	23	24		Yes		Yes	R2
	15:1	21	0	0	21	21					
3	2:1	14	61	10	14	85	Yes		Yes		3
R3	7:1	10	31	0	10	41		Yes		Yes	R3
	15:1	6	17	0	6	23					
4	2:1	13	76	29	13	119	Yes		No		4
R4	7:1	8	36	18	8	62		Yes		No	R4
	15:1	3	36	6	3	45					
5	2:1	12	85	88	12	186	Yes		No		5
R5	7:1	8	55	46	8	110		Yes		No	R5
	15:1	2	38	35	2	75					
6	2:1	11	62	333	11	405	Yes		No		6
R6	7:1	5	34	333	5	371		Yes		No	R6
	15:1	2	27	333	2	361					

Proposed Option 2 does not exceed levels for any receptors

Three receptors have elevated exposure from all sources.

Case 2: Spatial Planning Using CAM

Summary Given Producer

Site Possibility	<1% 2:1 Odors?	<1/2% 7:1 Odors?
Option 1	No	No
Option 2	Yes	Yes

Did any of the proposed locations cause >2% 2:1 odors or > 1% 7:1 odors in the community from the existing situation?

Yes

Closing Remarks on Siting

We need an organized method for assessing odor impact to the community.

The big unknowns:

- **An existing + proposed source load to receptors should be limited to a total of _____ hrs at an odor level of _____.**
- **An individual source load to receptors should be limited to _____ hrs at an odor level of _____.**

Final Thoughts

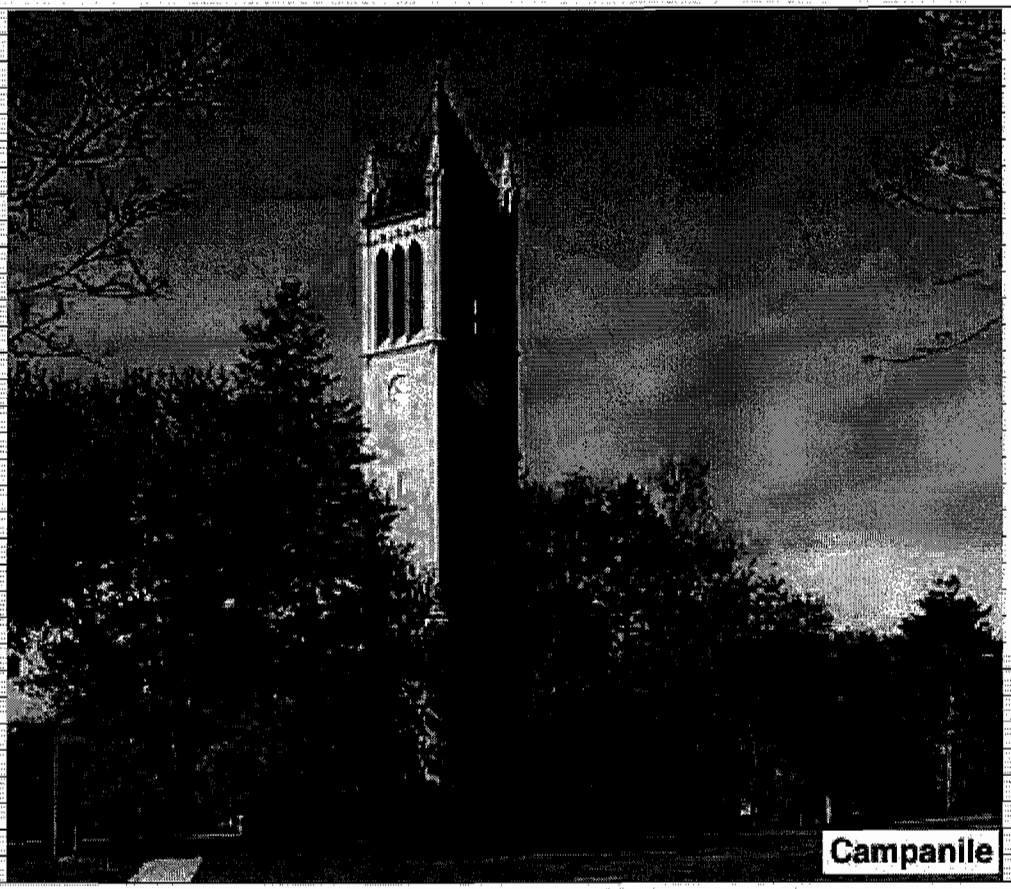
- **First Off…..There is absolutely no substitute for proper site selection. This is the number one odor control technology we know of. Good siting choices do not need mitigation.**

- **Second…..Effective odor control will be a suite of options. Example is *"as-needed" partial biofiltration + diet modification + VEBs + ……..=70% or more odor reduction***

- **Third…..Any mitigation strategy adopted MUST have a proven economic assessment associated with it.**

- **Finally…..Incorporating a mitigation strategy should be associated with a distance credit proportional to the level of odor control, as proven with research.**

Thank You



Campanile

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