Ammonia and Hydrogen Sulfide Emissions from Beef Cattle Feedlots

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Sponsors:

U.S. Department of Agriculture

Texas A&M University

Texas Cattle Feeders Association

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2000-2004 - Texas Agricultural Experiment Station

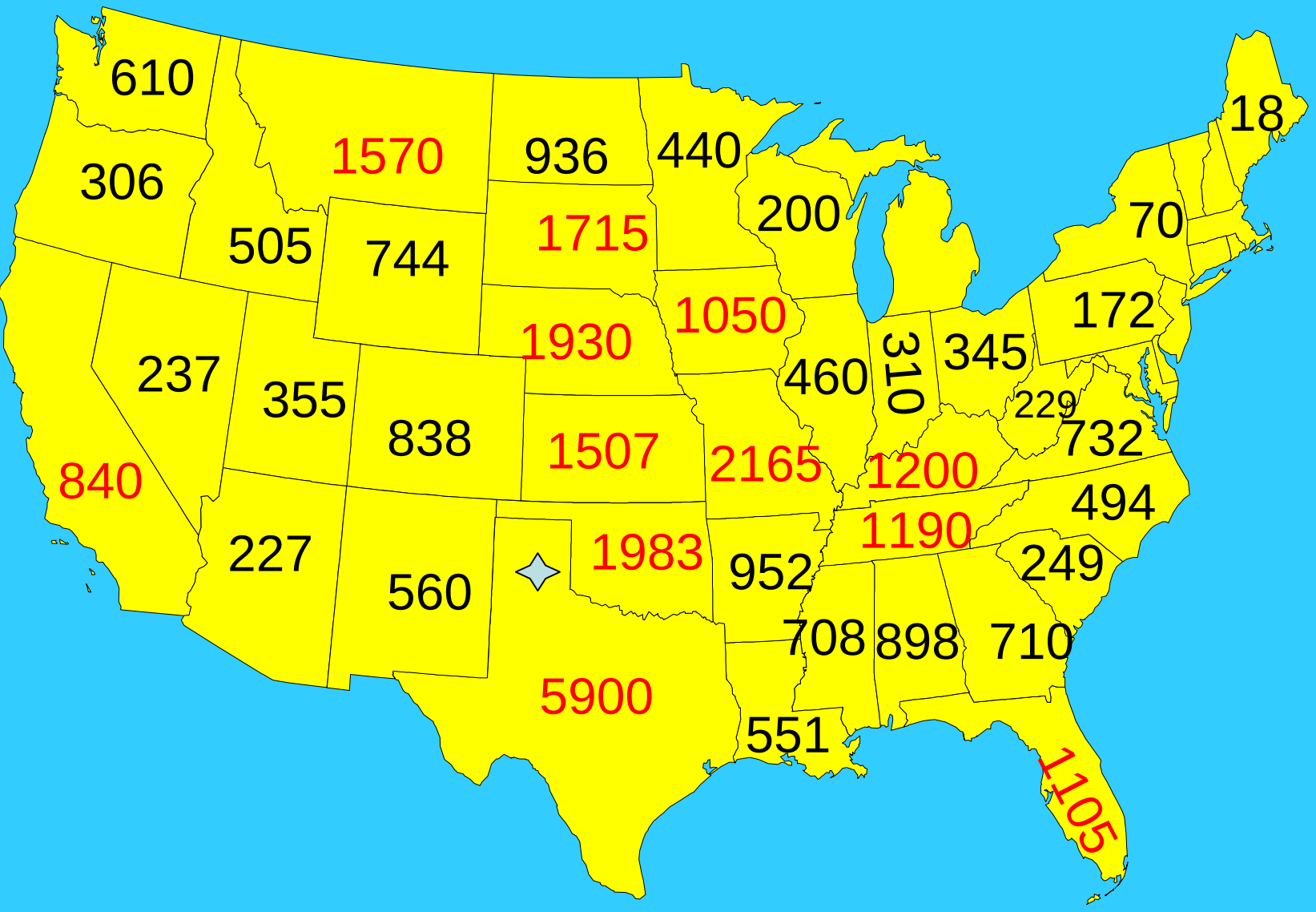
beef cattle – NH_3, H_2S, VOCs, odor

swine – PM-10, TSP, NH_3, H_2S, VOCs and odor

NH_3 and H_2S and air quality in USA

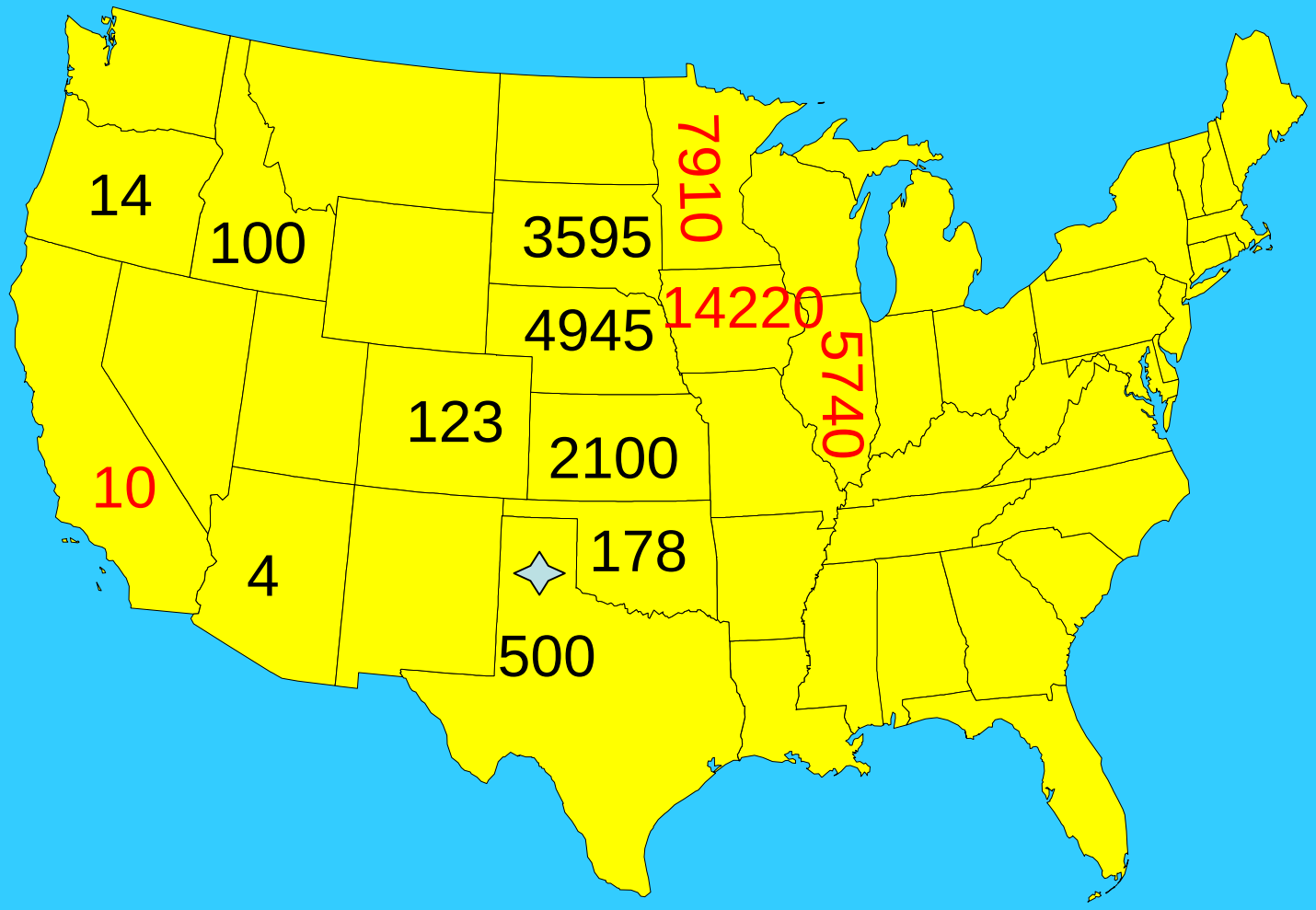
- NH_3
  - 2.30 mln tons/year emitted to atmosphere (2003)
  - Livestock is the largest source
  - Formation of PM-2.5 (regulated pollutant)
  - Odorant
  - Deposition to surface waters and possible nitrate contamination of ground water
  - No emission factors for beef cattle feedlots
  - CERCLA reporting of releases > 100 lb (45kg) / day
- H_2S
  - Poisonous
  - Used to be on hazardous air pollutant list (U.S. EPA)
  - Strong odorant
  - No emission factor for beef cattle feedyards

Beef cattle population (x 1000)



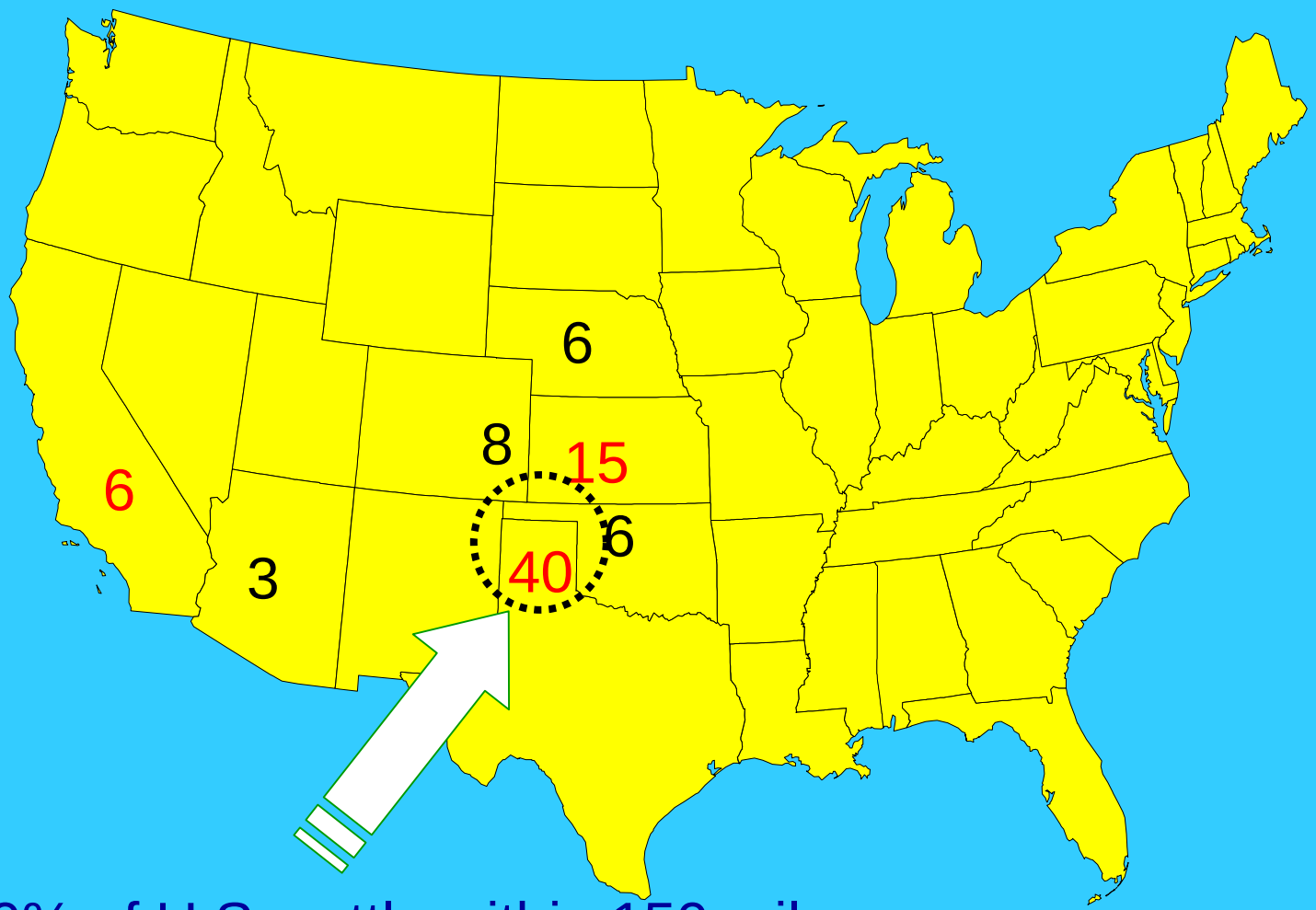
Source: Dr. L. Wayne Greene (Texas A&M University)

Number of small feedlots (<1000-head capacity)



Source: Dr. L. Wayne Greene (Texas A&M University)

Number of large feedlots (>32,000-head capacity)



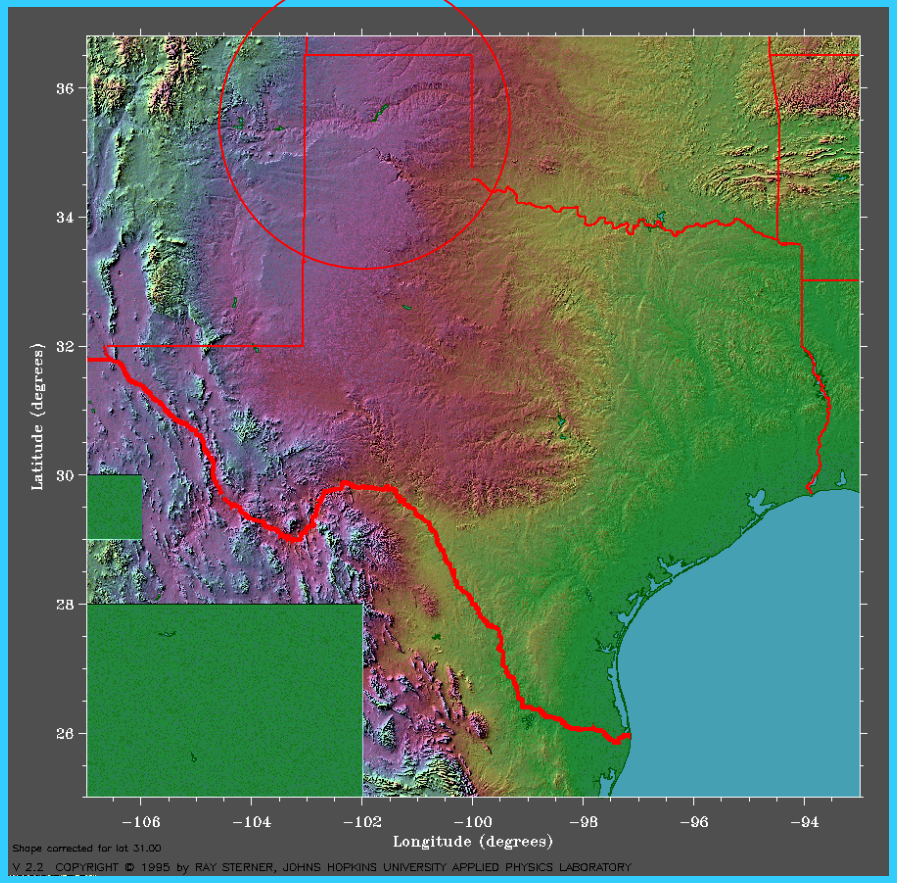
~30% of U.S. cattle within 150 miles of Amarillo, TX = 7 to 8 million

Source: Dr. L. Wayne Greene (Texas A&M University)

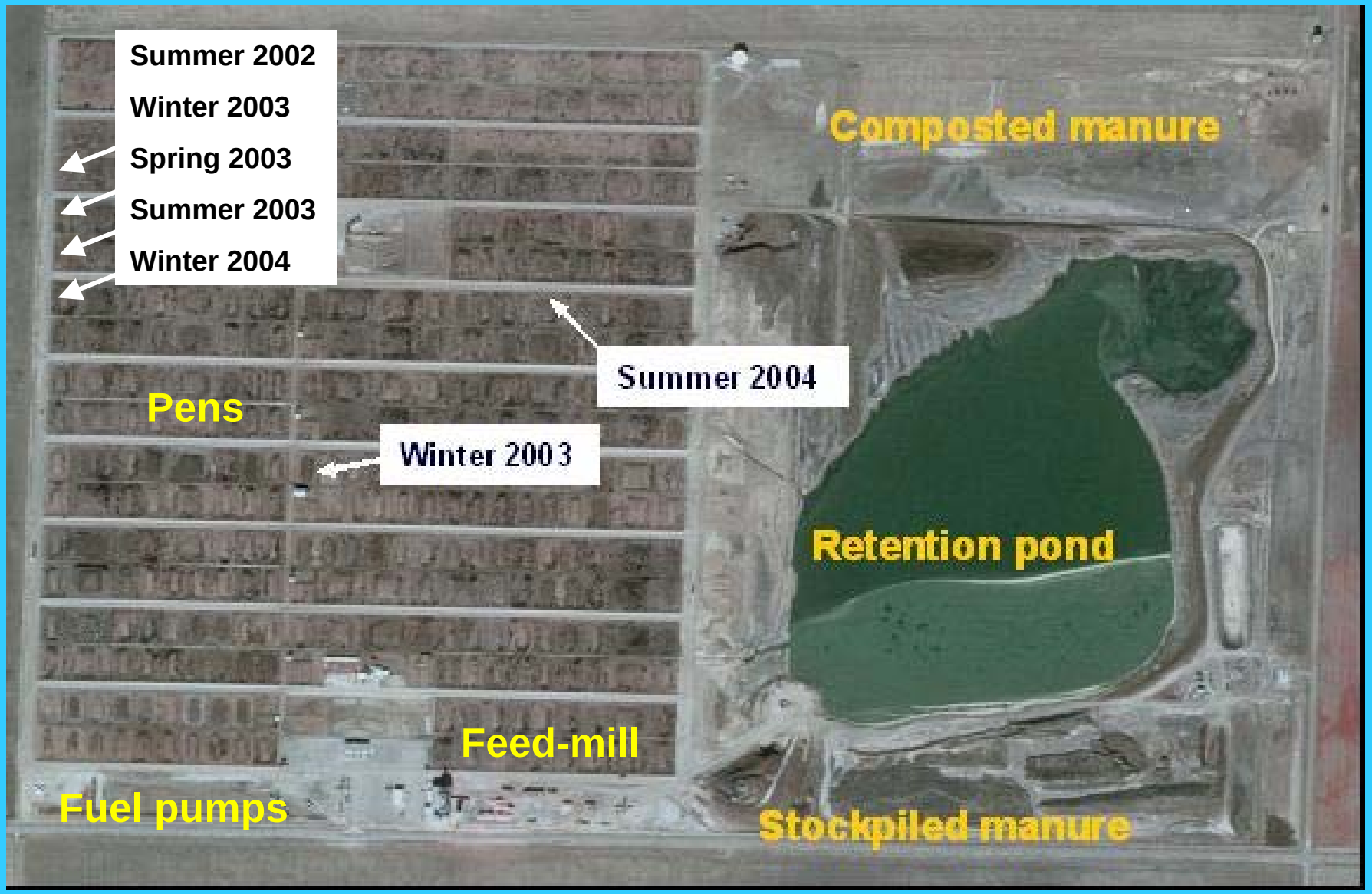
Beef production in Texas

Beef production area

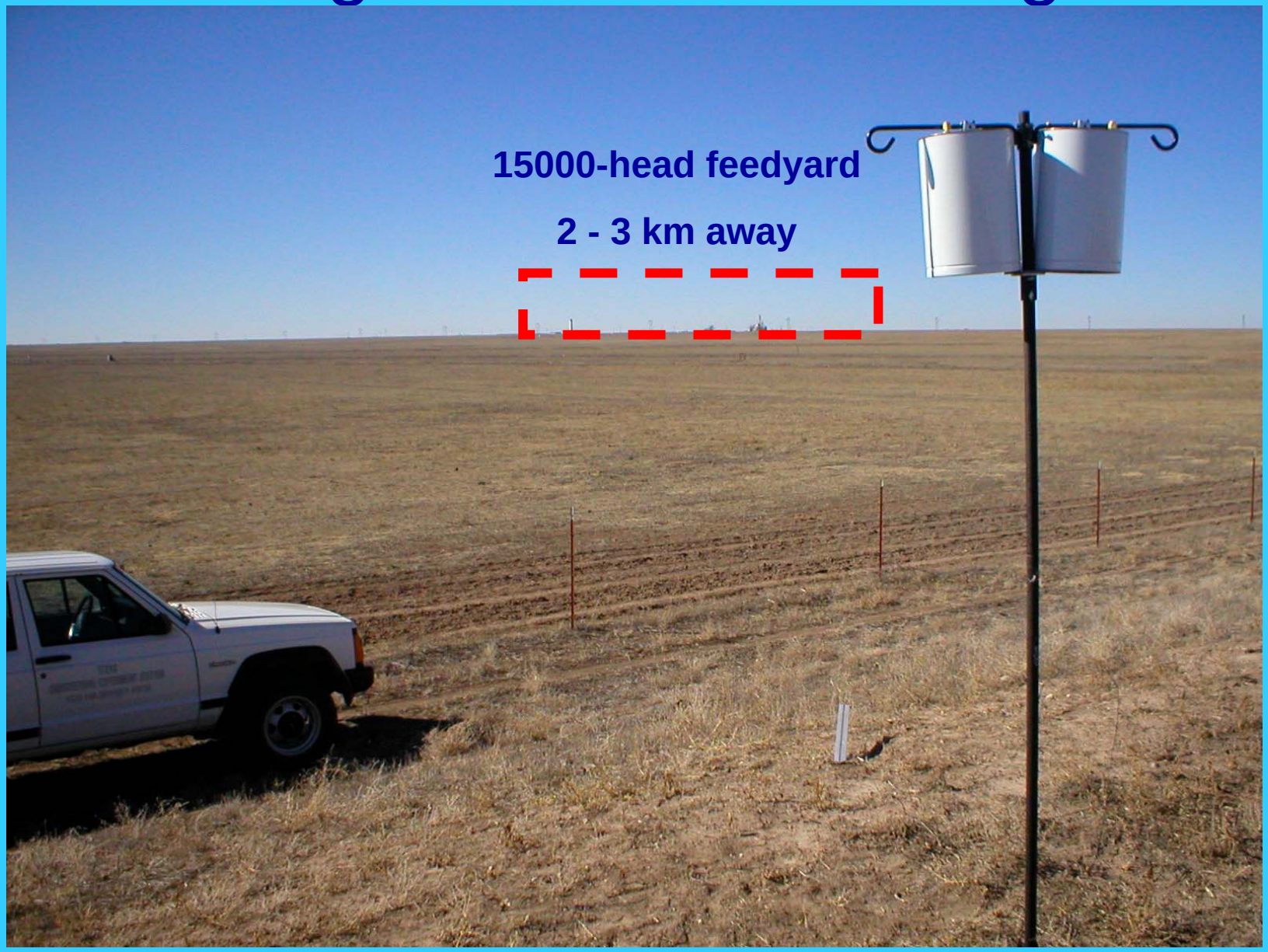
Annual rainfall = 40 cm



Large beef cattle feedyard in Texas



Texas High Plains from the ground



Large beef cattle feedyard in Texas

- 50000-head capacity
- year round operation
- large area (~1 km × 1 km)
- 20 week finish
- corn-based diet
- 11 to 15 m^2/head stocking density

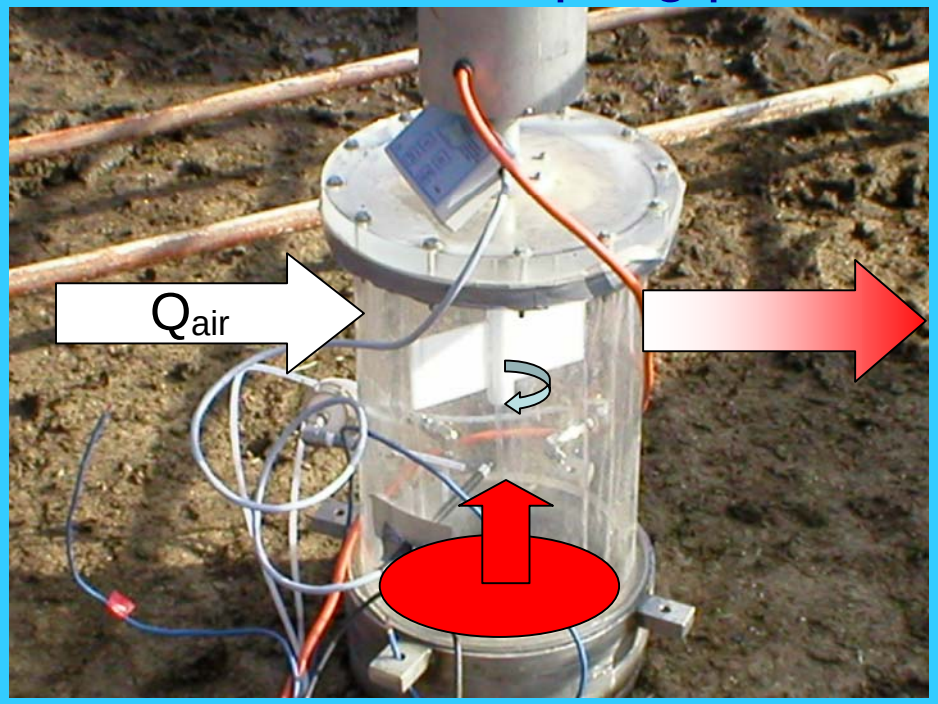
<u>Air Quality Concerns</u>:

- PM-10
- Ammonia, PM-2.5, hydrogen sulfide
- Odor, VOC, ROGs, HAPs

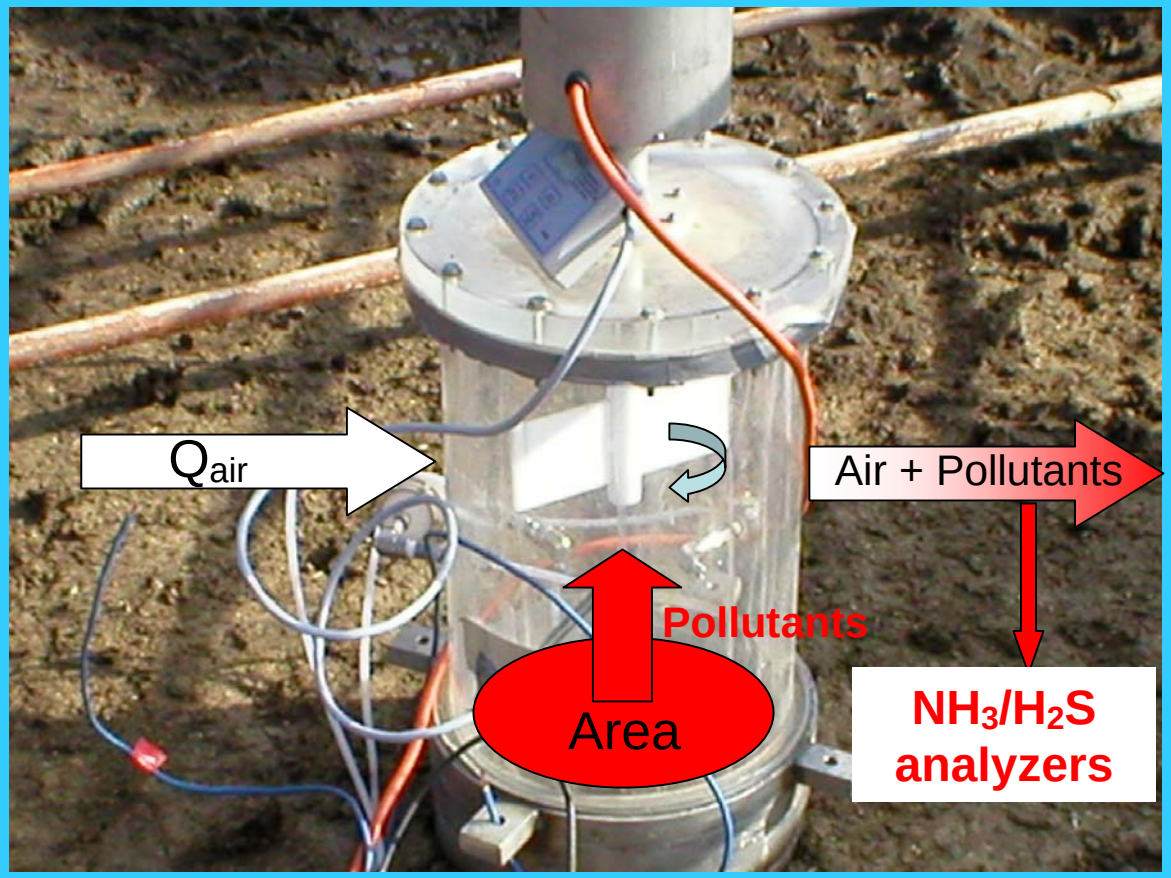
Emissions measurements

Chamber method & micrometeorology-based method

7 seasonal sampling periods between June 2002 – July 2004



Dynamic surface isolation flux chamber 5 seasons



Flux chamber is identical to the chamber used by Aneja et al. (North Carolina State University)

- Chamber techniques are suited for measurement of process-based fluxes, e.g., pen surface, holding pond, aged manure storage area, comparison of treatments

<u>Continuous measurements</u>:

- NH_3, H_2S concentrations, Q_{air}

-T inside, T outside, T manure pack, RH inside chamber

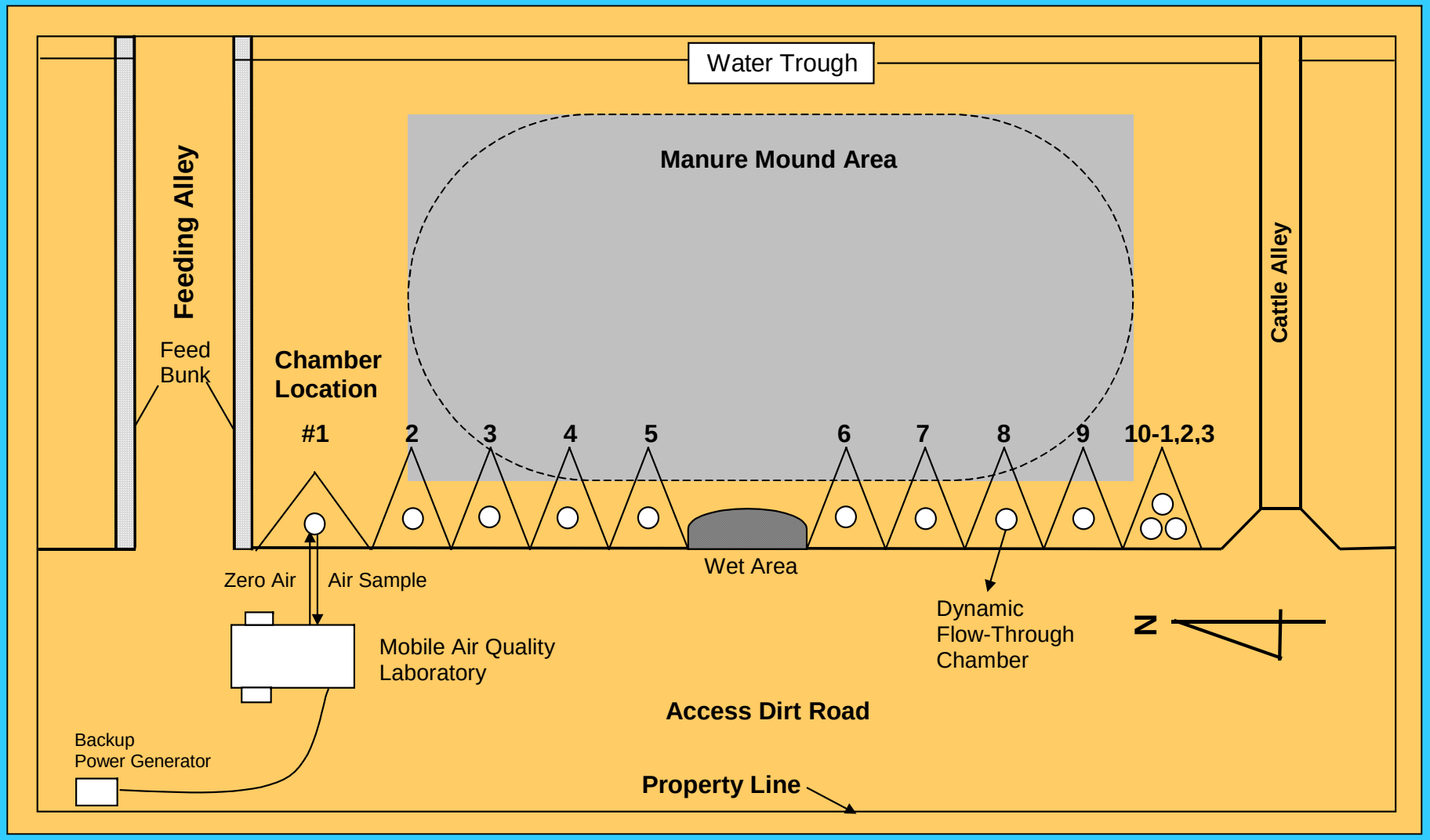
<u>Daily measurements</u>

- Manure characteristics (M.C., pH, TKN, NO_2/NO_3

$$\text{Flux} = C_{NH3,H2S}\left(\frac{Q_{air}}{\text{Area}}\right)$$

Vertical gradient flux method
(2 seasons, collaboration with USDA-ARS)

Cattle pen and chamber for NH_3 and H_2S flux measurements



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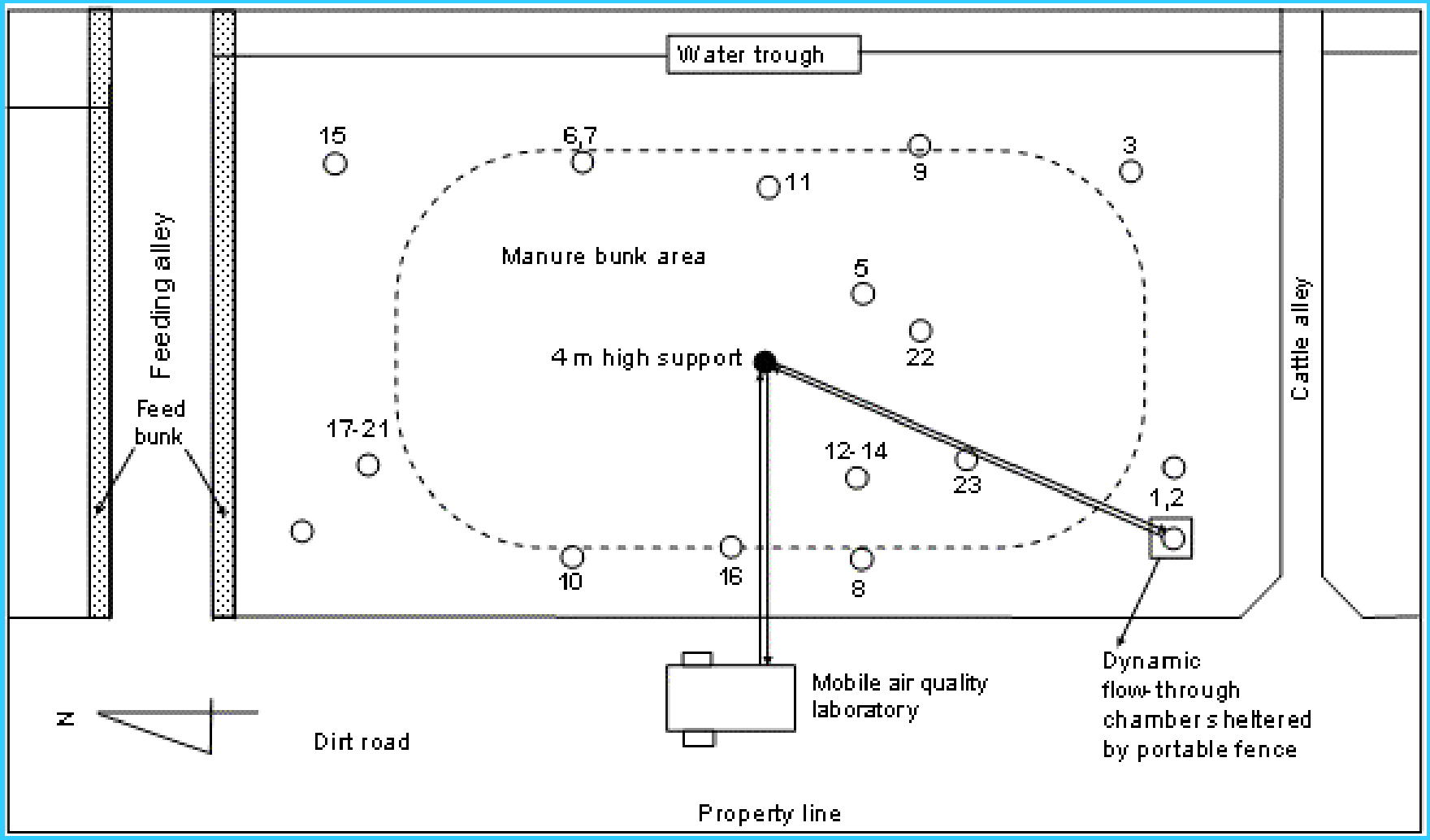
On-site instrument shelter with continuous NH_3 and H_2S analyzers

- Certified EPA-grade calibration gas standards for NH_3, NO, H_2S
- Zero air generator

On-site instrument shelter with continuous NH_3 and H_2S analyzers

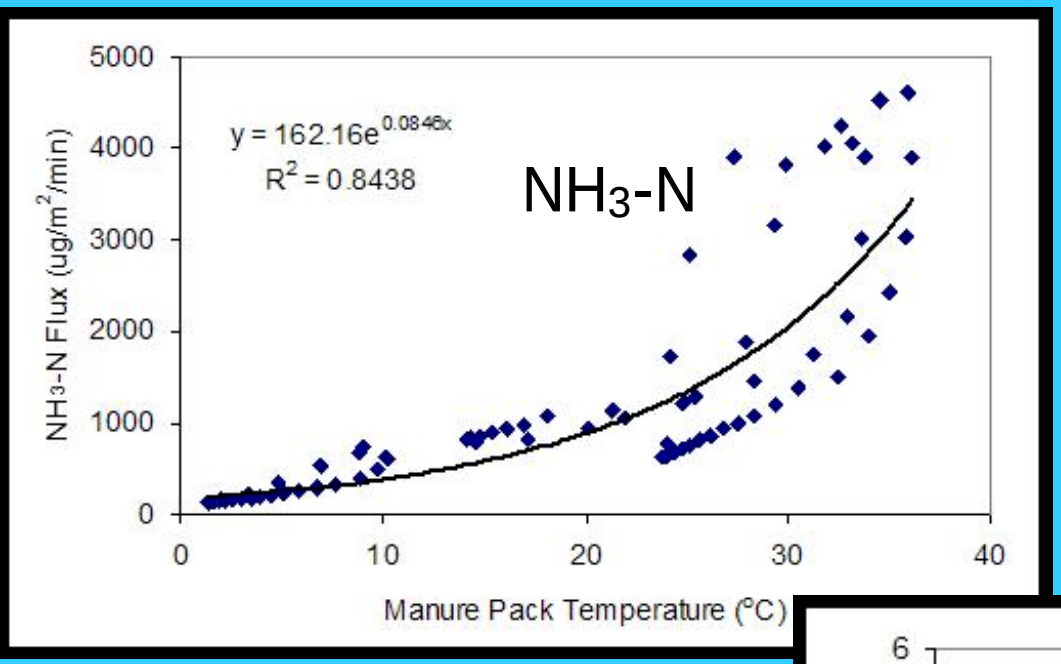


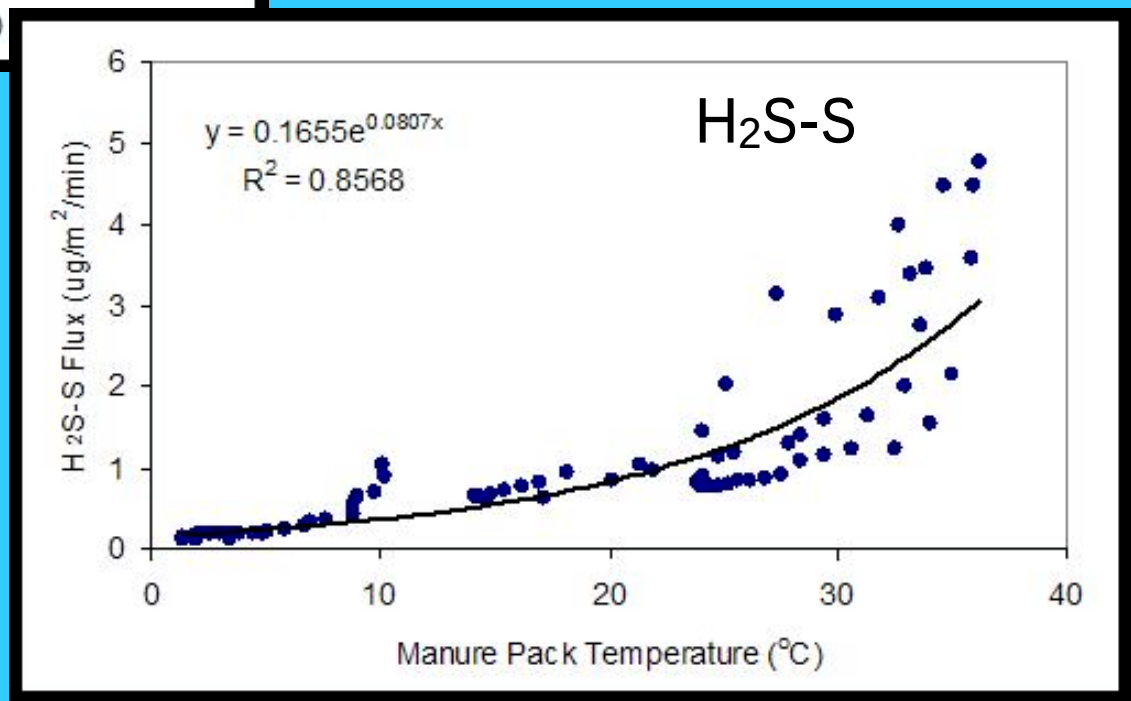
Flux chamber inside cattle pen

<u>Field data availability</u>

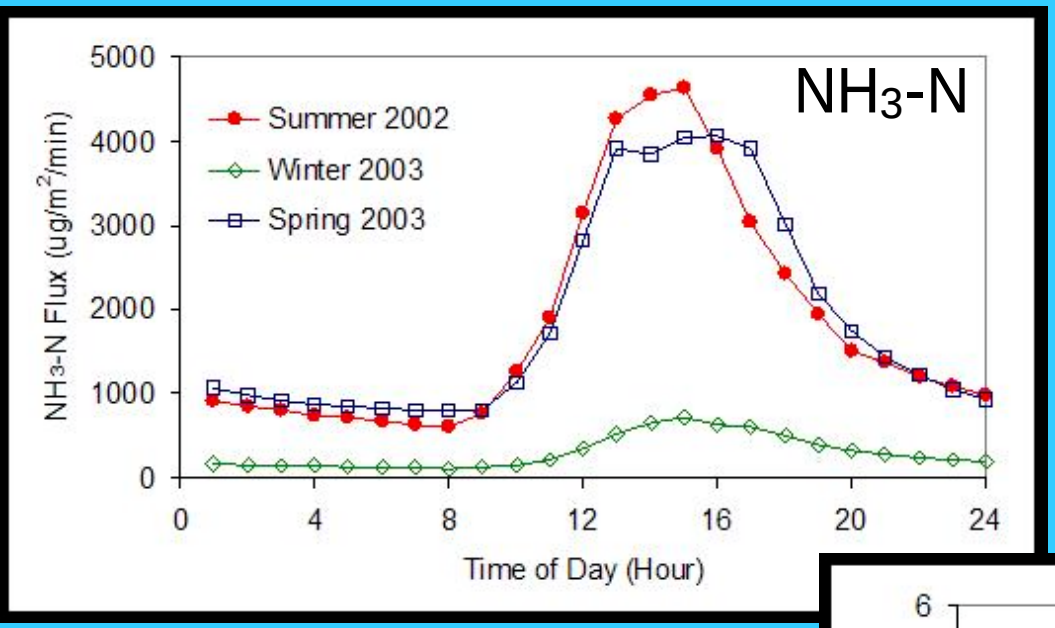
- **7 seasons, total ~ 100 days of continuous measurements**
- **1 pen per season**
- **30 m × 53 m pen**
- **10 to 14 random spots per pen**
- **23-24 hrs of data per spot**

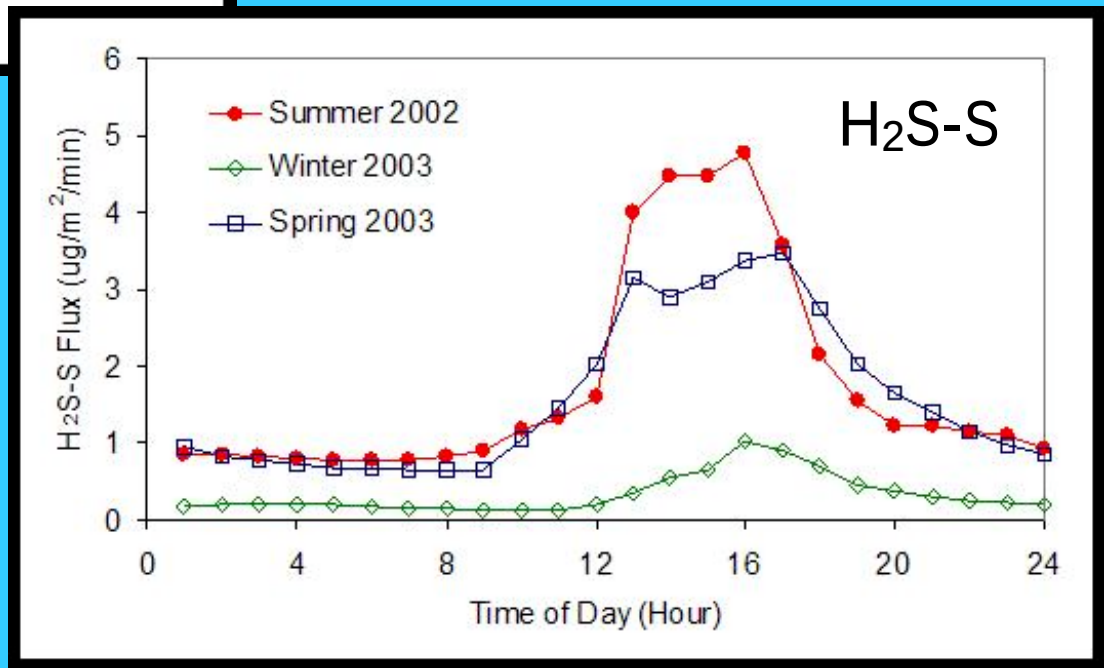
NH_3-N and H_2S-S flux vs. manure pack temperature (Chamber method)



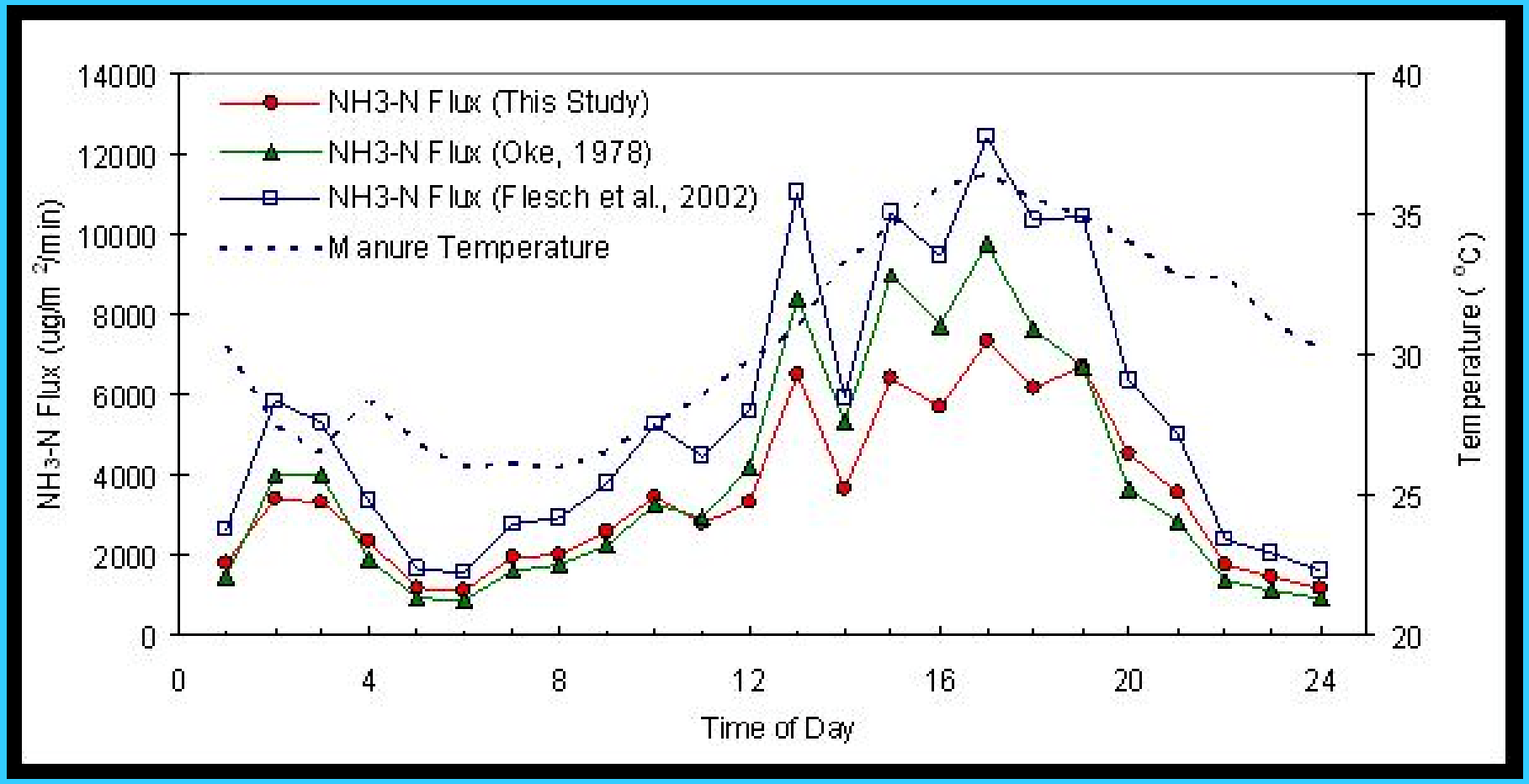


Daily variations of NH_3-N and H_2S-S flux from cattle pens (chamber method)



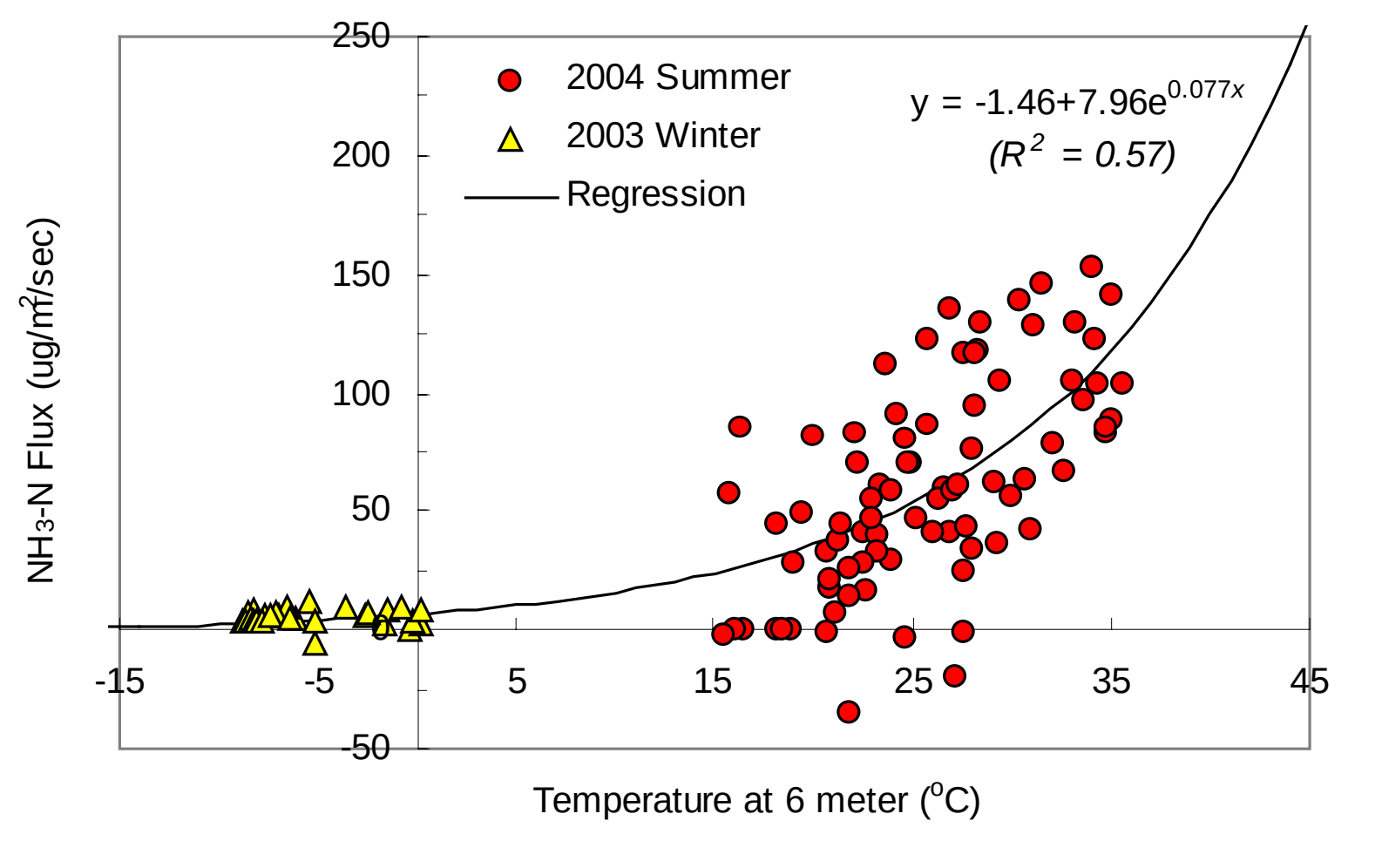


Daily variations of NH_3-N flux from cattle pens (Micrometeorology method –VGF)

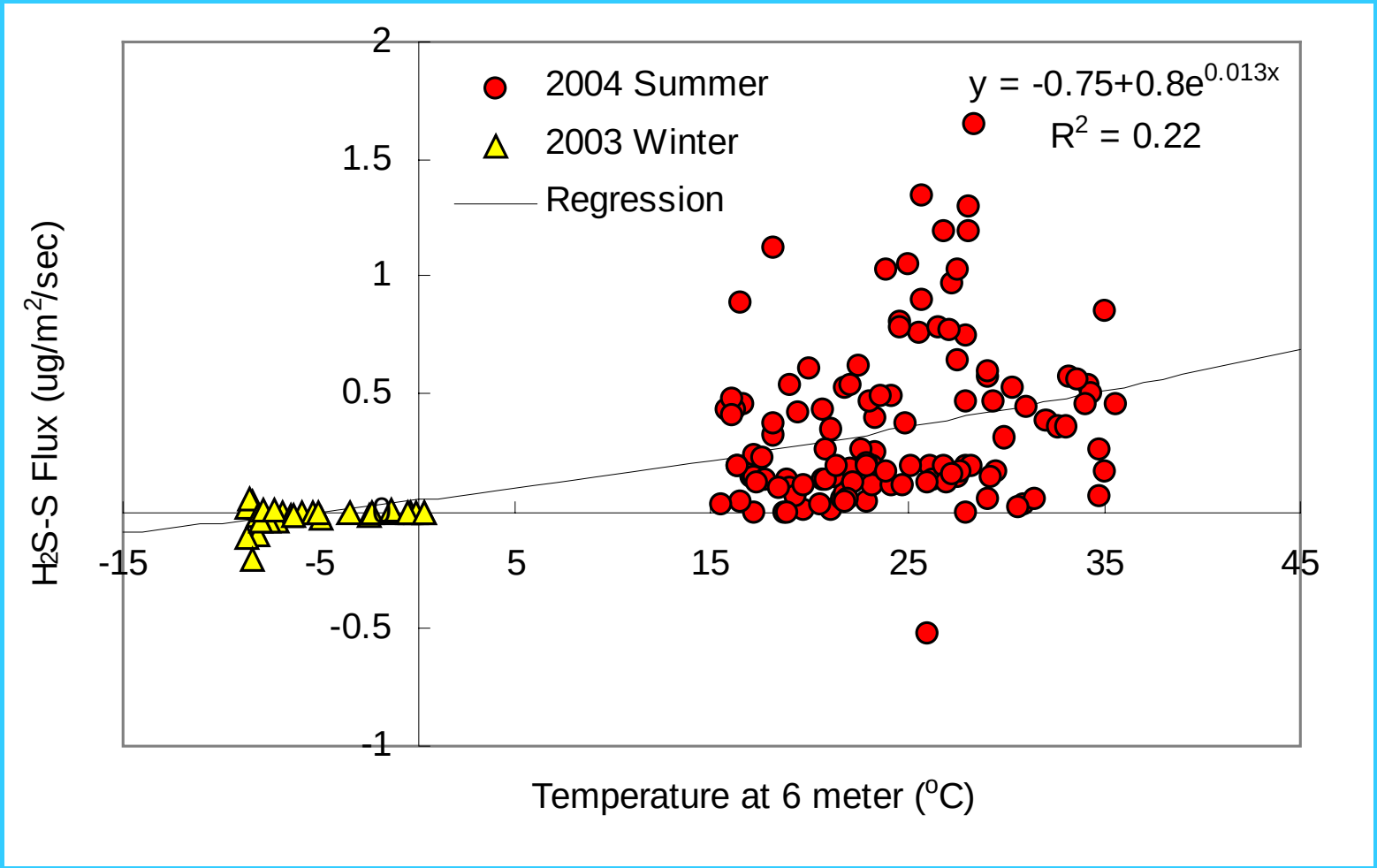


Manure Temp. vs. ammonia flux R^2 = 0.56

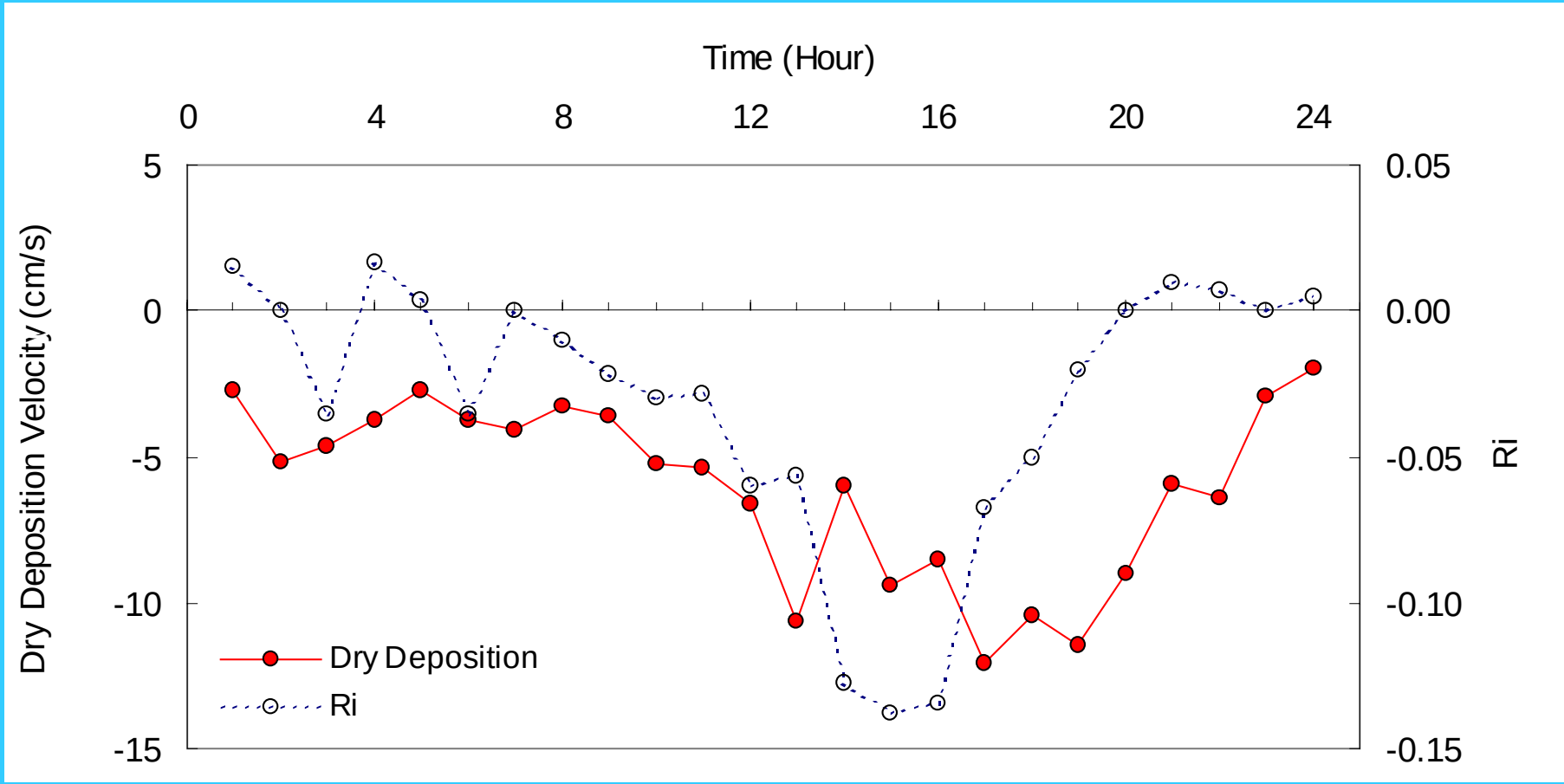
Air temperature at 6 m vs. NH_3-N flux from cattle pens (Micrometeorology method –VGF)



Air temperature at 6 m vs. H_2S-S flux from cattle pens (Micrometeorology method –VGF)



Dry deposition of ammonia vs. atmospheric stability



ammonia flux vs. Ri $R^2 = 0.74$

Hydrogen sulfide flux vs. Ri $R^2 = 0.74$

Mean NH_3-N and H_2S-S flux (µg/m²/min) beef cattle pens

Flux chamber method

	NH_3-N		**H_2S-S**		**Moisture (%)**	Temp.	**Temp.**
	Mean	STD	Mean	STD	**Manure Pack**	Ambient air	**Manure Pack**
Summer 2003	**1,681**	1,931	**1.21**	1.08	**78.1**	27.1	**27.1**
Winter 2004	**2,552**	2,259	**1.73**	1.54	**60.0**	1.7	**4.1**
Summer 2002*	**1,666**	1,642	**1.28**	1.06	**41.5**	25.0	**28.8**
Winter 2003	**289**	237	**0.31**	0.63	**33.1**	6.8	**5.2**
Spring 2003	**1,816**	1,520	**1.52**	1.67	**81.9**	23.8	**23.1**
Vertical Gradient Flux Method							
Winter 2003	**313**	210	**-0.99**	2.91		25.7	
Summer 2004	**3,617**	2,624	**21.7**	20.7		-5.3	

***NH_3-N and H_2S-S flux represent ~16% and ~0.14% of N and S fed, respectively.**

NH_3-N and H_2S-S emission rates from beef cattle pens

	Emissions per Pen (g/day)		**Emissions per Head (g/day/head)**		**Emissions per Animal Unit (g/day/AU)**	
	NH_3-N	H_2S-S	NH_3-N	H_2S-S	NH_3-N	H_2S-S
Summer 2003	3,936	2.84	**34.8**	**0.025**	34.2	0.0266
Winter 2004	5,974	4.04	**42.2**	**0.029**	50.7	0.0349
Summer 2002	3,900	3.00	**34.5**	**0.087**	47.9	0.0369
Winter 2003	678	0.72	**4.4**	**0.163**	5.8	0.0061
Spring 2003	4,250	3.56	**30.9**	**0.115**	38.6	0.0323

Vertical gradient flux method

Winter 2003 **329 kg NH_3-N/day**

Summer 2004 **3,795 kg NH_3-N/day and 22.5 kg H_2S-S/day (entire area of pens)**

Comparison of summertime NH_3-N flux with previous studies

Reference	Measurement Period	Sampling/ Analysis Technique	Site Description	Stocking density (m^2/head)	**NH_3-N flux** (st. dev) **($\mu g/m^2/min$)**
Baek, Koziel et al. 2003	**August 2002**	**Dynamic flux chamber/cont. analyzer**	**50,000-head capacity commercial cattle feedlot, TX**	**14.5**	**1,666** (1,642)
Hutchinson, et al., 1982	April to July, 1977	Micrometeorology/ acid trap	120,000-head commercial cattle feedlot, CO	11.9	**2,333** (1,167) (Daytime only)
Miner and Stroh, 1976	June to August, 1975	Flux chamber/ acid trap	24,000-head capacity commercial cattle feedlot, ID	~20.4	**239** (196) (old AP-42)
Duysen et al., 2003	August to September,	Wind tunnel/ acid trap	2,000-head capacity research feedlot, NE	28.6	**410 to 1,003**
Koziel Baek, et al. 2004	**July/August 2003**	**Dynamic flux chamber/cont. analyzer**	**50,000-head capacity commercial cattle feedlot, TX**	**14.4**	**1,681 (1,931)**
Baek et al., 2005	**June/July 2005**	**Micrometeorology/ cont. analyzers**	**50,000-head capacity commercial cattle feedlot, TX**		**3,617 (2,624)**

Conclusions

- NH_3 and H_2S concentrations and emissions have a diurnal and seasonal patterns.
- Manure T and moisture content, air temperature, atmospheric stability appear to be correlated with NH_3 and H_2S flux.
- NH_3 = ~1000 H_2S

» **Chamber method**

- Emission rates NH_3-N ranged from 4.4 to 42.2 g/day/head
- Emission rates for H_2S-S ranged from 0.029 to 0.163 g/day/head

» **Micrometeorology (VGF) method**

- Emission rates NH_3-N ranged from 6.6 to 75.9 g/day/head
- Emission rate for H_2S-S 0.045 g/day/head (summer)

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