When It Hits The Fan…Pathogens from Human and Bovine Sources in the Environment

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Biological Fact #1

Cows poop

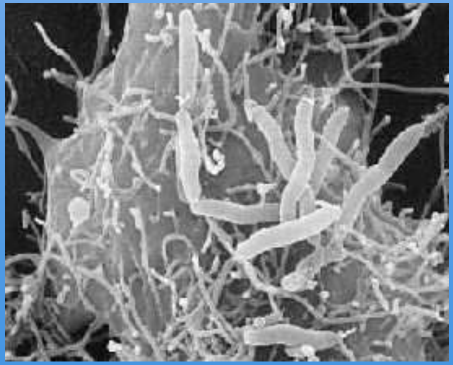
Biological Fact #2

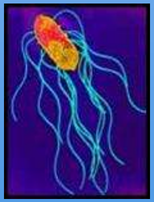
Humans poop, too!

Biological Fact #3

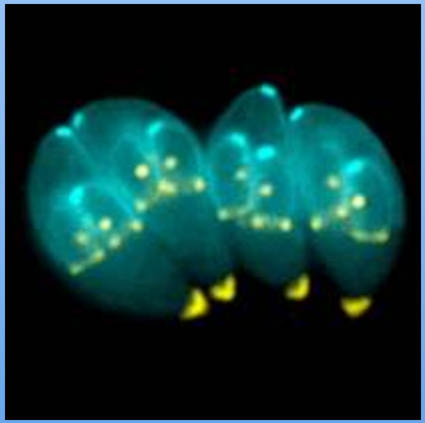
Pathogens are present in poop

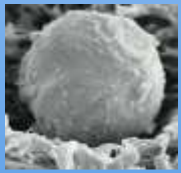
Bacteria (e.g., *Campylobacter*, *Salmonella*, *E. coli* O157:H7, *Aeromonas)*



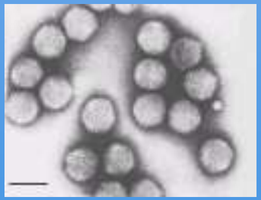


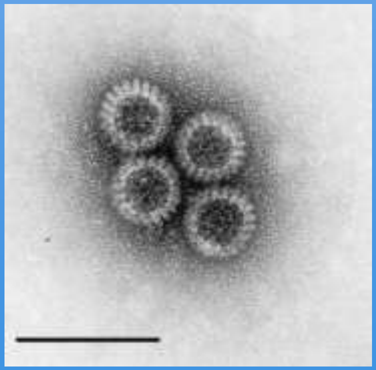
Protozoa, (e.g., *Cryptosporidium*, *Giardia*, *Toxoplasma)*





Viruses (e.g., adenovirus, enterovirus, rotavirus)





What Happens When It Hits…

Listeria monocytogenes outbreak from eating contaminated cantaloupe

August – December 2011, 28 states

146 sick, 30 dead, one miscarriage

Lawsuits are expected to result in settlements of $125 million to $150 million

Manure on a truck used to haul culled melons to a cattle operation suspected to have introduced *Listeria* into the melon packing shed.

Manure's Double-Edged Sword

Manure as Asset

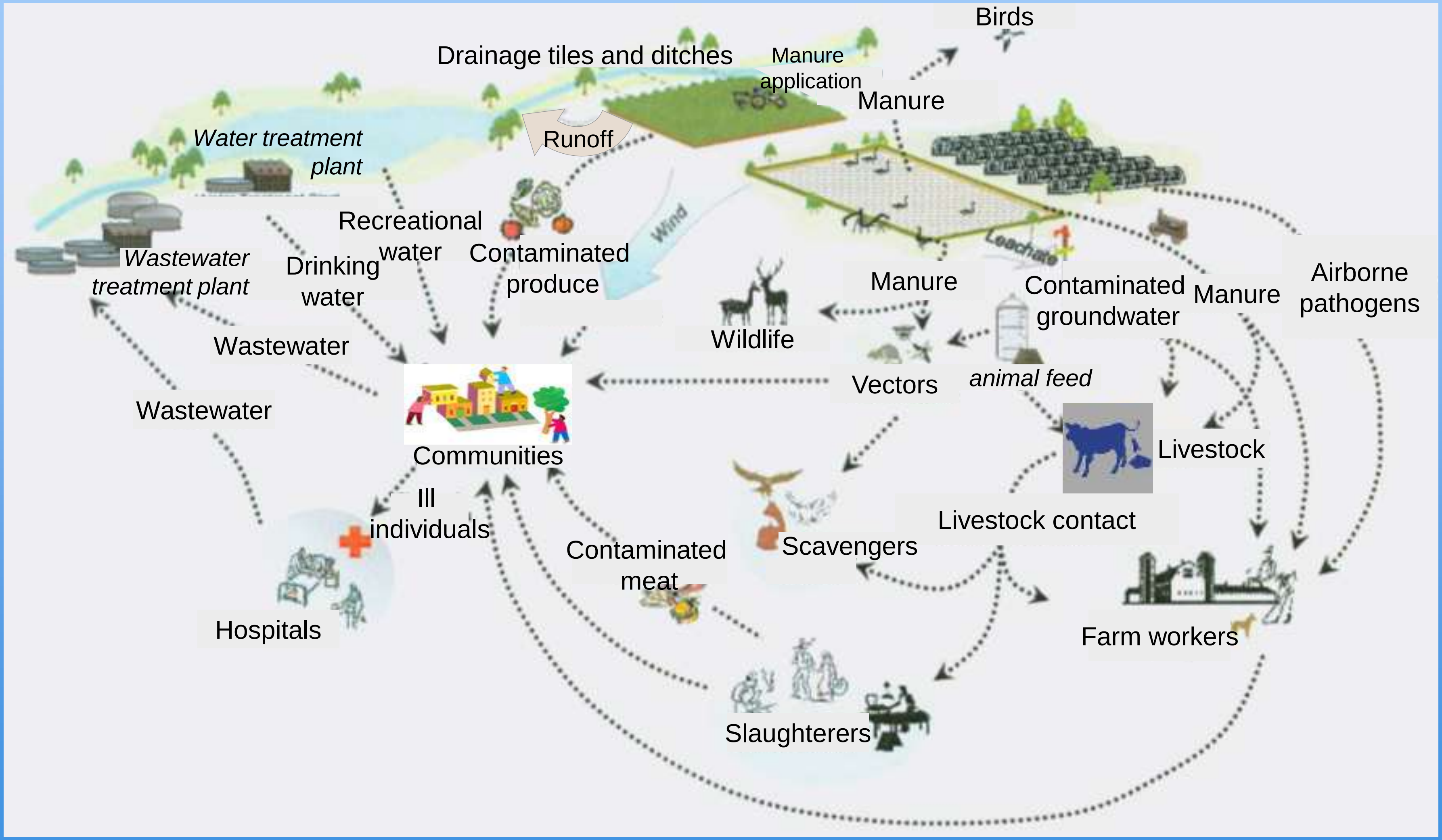
Manure field-application is a cost-effective and sustainable approach for optimal soil tilth and fertility

Manure as Liability

Manure may contain pathogens harmful to both humans and livestock

Societal goal: Maximize the beneficial uses of manure while minimizing environmental pathogen transmission

Human and Livestock Pathogen Movement in the Environment



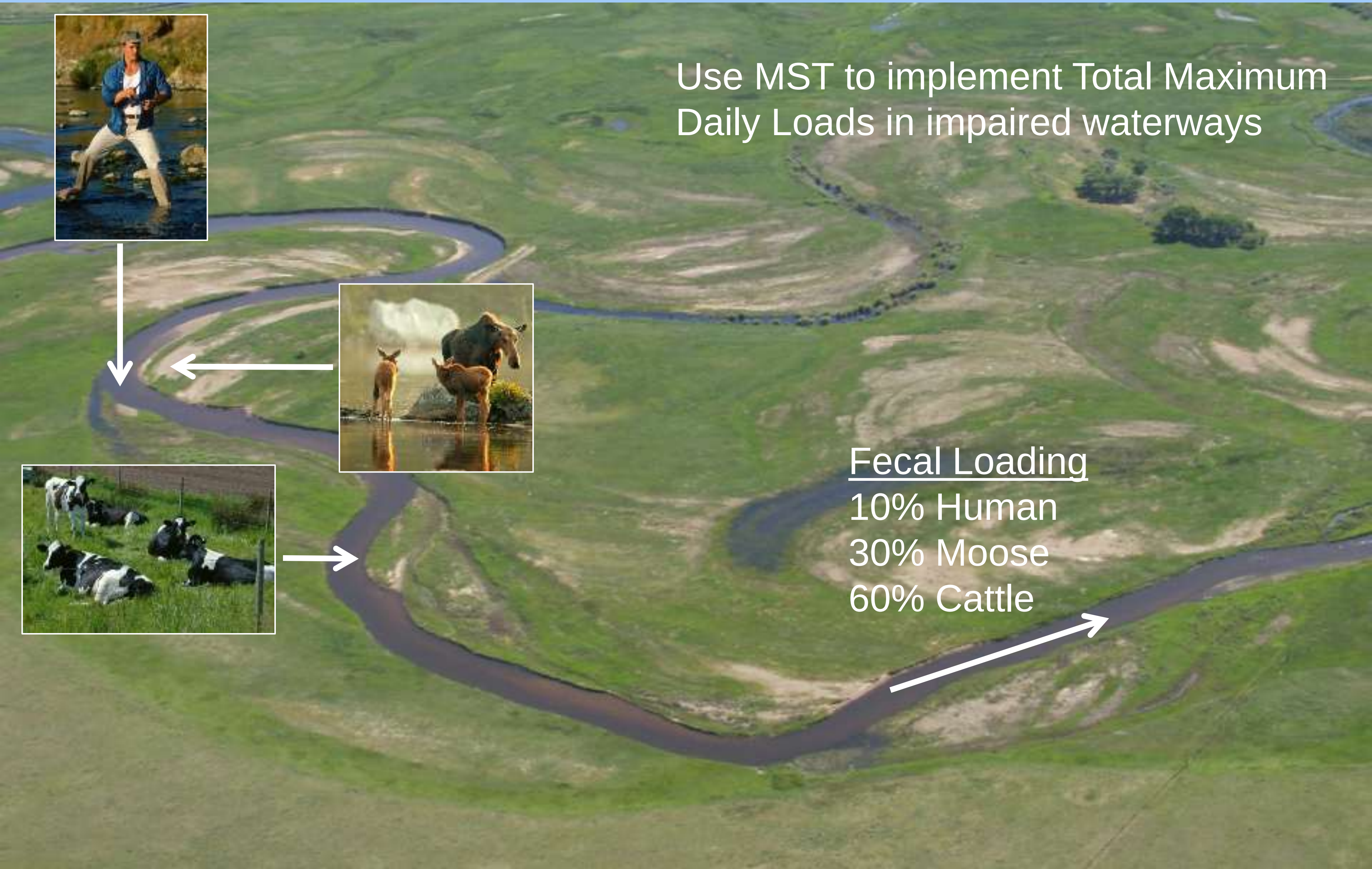
Rogers and Haines, 2005, EPA/600/R-06/021

Microbial Source Tracking – The Principle

The microbes present in feces are specific to the animal source, (e.g., an *E. coli* from humans is different from an *E. coli* from cattle)

These same microbes can be measured in water that has fecal pollution and the animal source identified.

Microbial Source Tracking – The Goal



Microbial Source Tracking – Current Limitations

MST cannot quantify fecal loading yet because:

- Microbes are not 100% specific to animal type
- Microbes from different animals die-off in the environment at different rates
- Microbe abundance in the host animal can change so the signal in the environment changes
- The animal-specific microbe might not be the same at a different time or location
- Methods issues e.g., differing limits of detection

Wisconsin WAHTER Study

Wisconsin Water And Health Trial for Enteric Risks (WAHTER Study)

Estimating Illness Risk from Drinking Non-Disinfected Municipal Groundwater

Mark Borchardt and Susan Spencer

USDA – Agricultural Research Service

Burney Kieke

Marshfield Clinic Research Foundation

Elisabetta Lambertini and Frank Loge

University of California - Davis

Human viruses are present in…

Applied and Environmental Microbiology, Feb. 2003, p. 1172–1180 Vol. 69, No. 2
0099-2240/03/$08.00+0 DOI: 10.1128/AEM.69.2.1172–1180.2003

Incidence of Enteric Viruses in Groundwater from Household Wells in Wisconsin

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Private domestic wells

Environ. Sci. Technol. **2007**, *41*, 6606–6612

Human Enteric Viruses in Groundwater from a Confined Bedrock Aquifer

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Applied and Environmental Microbiology, Oct. 2004, p. 5937–5946 Vol. 70, No. 10
0099-2240/04/$08.00+0 DOI: 10.1128/AEM.70.10.5937–5946.2004

Vulnerability of Drinking-Water Wells in La Crosse, Wisconsin, to Enteric-Virus Contamination from Surface Water Contributions

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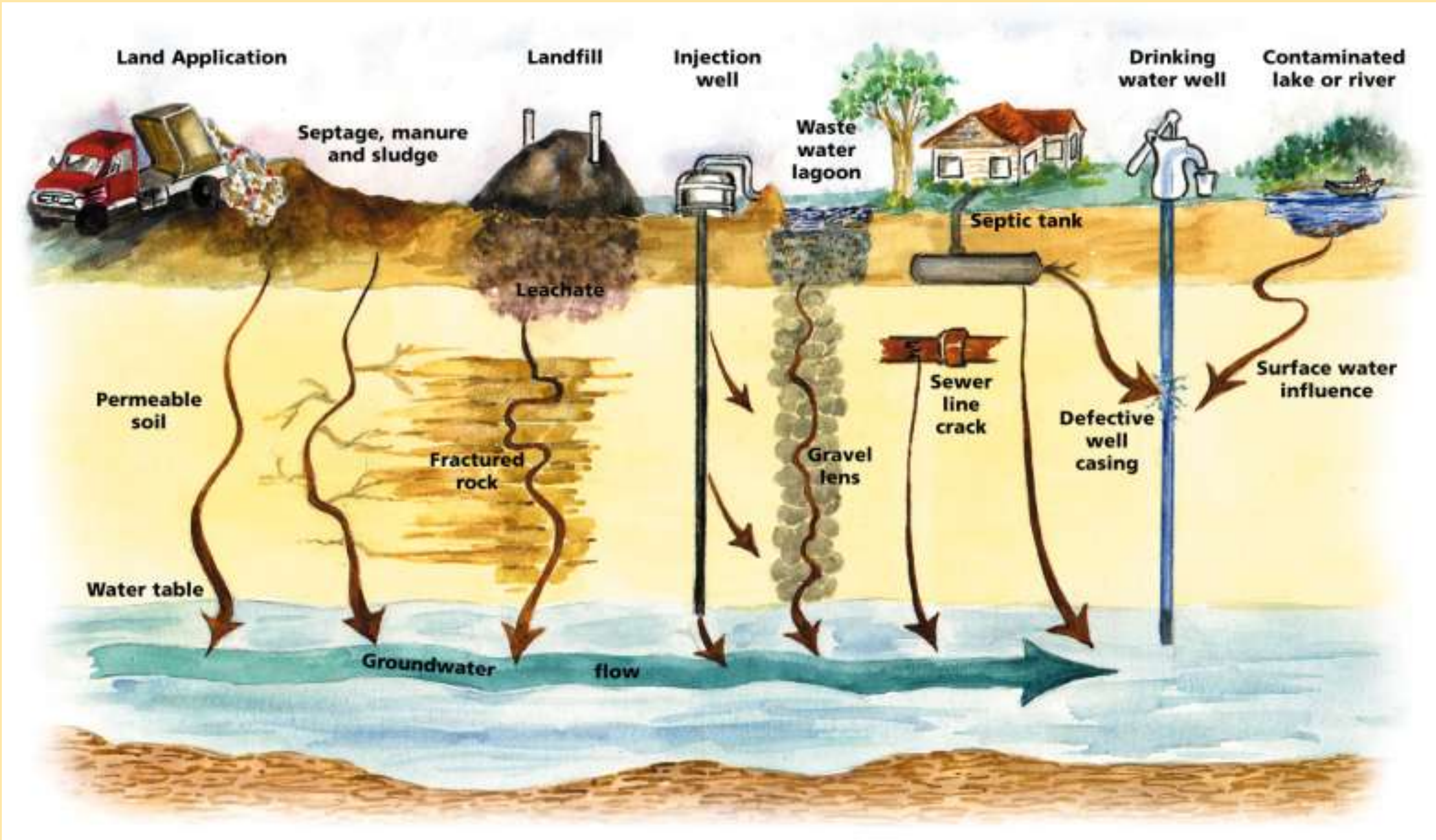
Received 11 December 2003/Accepted 27 May 2004

Municipal wells in an alluvial aquifer

Even in a confined aquifer

Virus Sources and Infiltration Routes into Groundwater



Wisconsin WAHTER Study

Health Risk or Non-Issue?

- So viruses are present in public water supply and domestic wells …
- Does it matter?
- Is there any effect on public health?

Wisconsin WAHTER Study Design

Intervention trial in 14 groundwater-source communities

	Two 3-month Surveillance Periods	Cross-over Period	Two 3-month Surveillance Periods
UV Light Intervention	***Communities Set 1***		***Communities Set 2***
Control	***Communities Set 2***		***Communities Set 1***

WAHTER Study Participating Communities

Wisconsin WAHTER Study

Populations: 1,200 – 8,300

Number Wells: 2 – 5

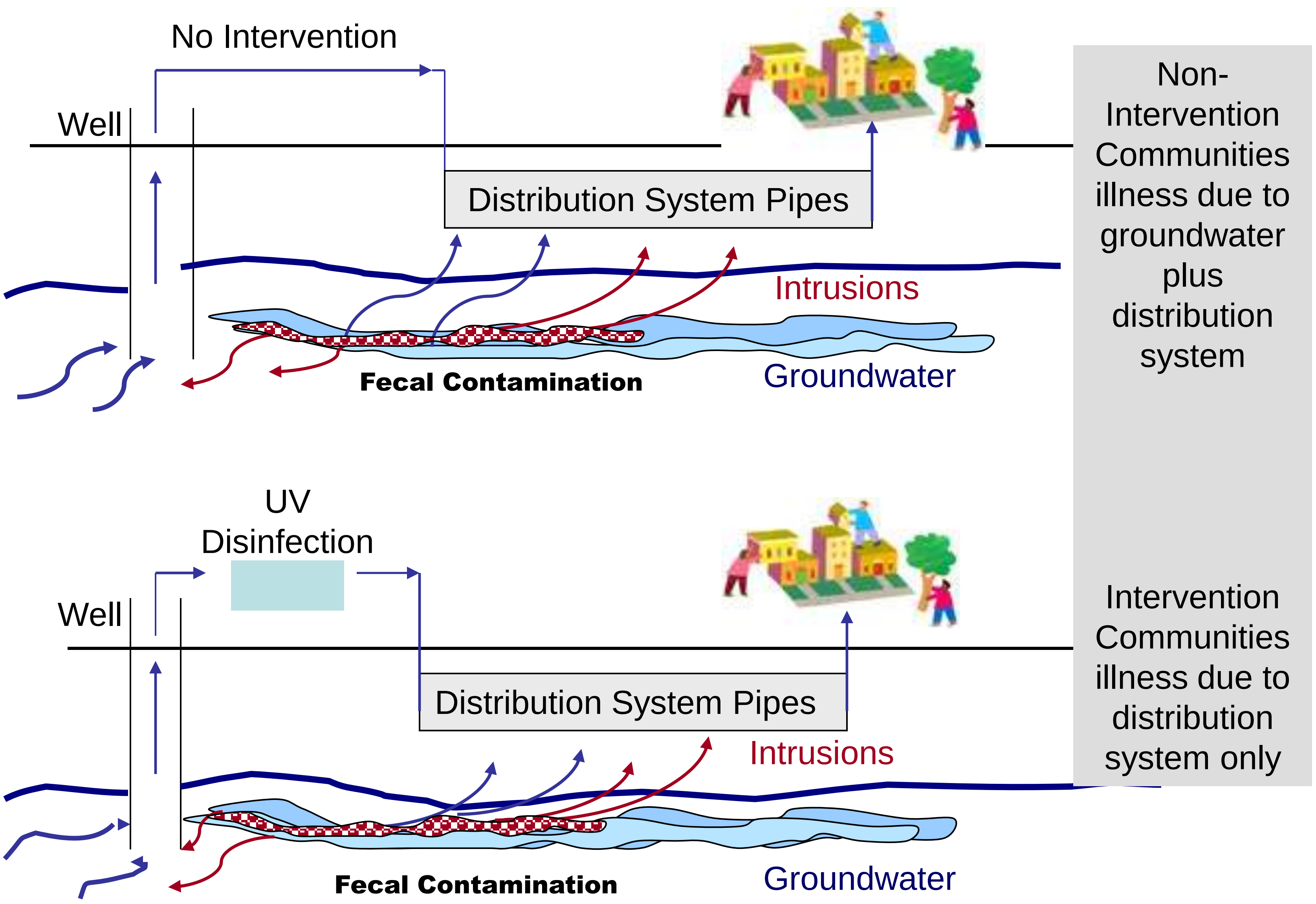
Pumpage: 0.13 – 2.1 MGD

Hydrogeology: sand, sandstone, limestone

No surface water influence

No disinfection

UV Intervention Effect




UV dose = 50 mJ/cm^2

Wisconsin WAHTER Study

Epidemiological Study Design

- Acute gastrointestinal illness (AGI) surveillance for four 12 week periods, spring and autumn 2006 and 2007
- AGI defined as ≥ three episodes loose watery stools OR ≥ one episode vomiting in 24 hour period
- Eligibility: family served by study community’s water system and have at least one child 6 months to 12 years old
- Exclusions: chronic GI illness; child attends daycare or school outside of community > 20 hrs/week
- Participants submitted an illness symptom checklist every week

Wisconsin WAHTER Study

Participating Households' Characteristics

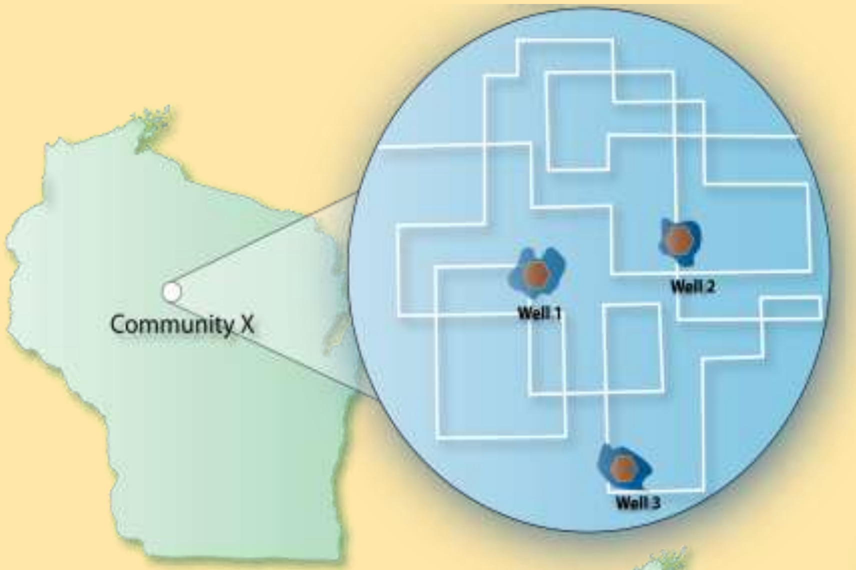
Characteristic	Number	%
Household size (no. of persons)		
2	17	(3)
3	159	(26)
4	246	(40)
5	136	(22)
≥6	63	(10)
Residence type		
Single family home	572	(92)
Apartment or condo	43	(7)
Other	6	(1)
Faucet or plumbing filtering device		
Yes	73	(12)
No	547	(88)
Don't know	1	(<1)
Primary drinking water source		
Municipal	1546	(93)
Bottled water	58	(3)
Other	1	(<1)
Missing	54	(3)

- **Beginning enrollment: 621 households**
- **Ending enrollment: 440 households**
- **Beginning enrollment: 1,079 children, 580 adults**
- **Ending enrollment: 765 children, 413 adults**

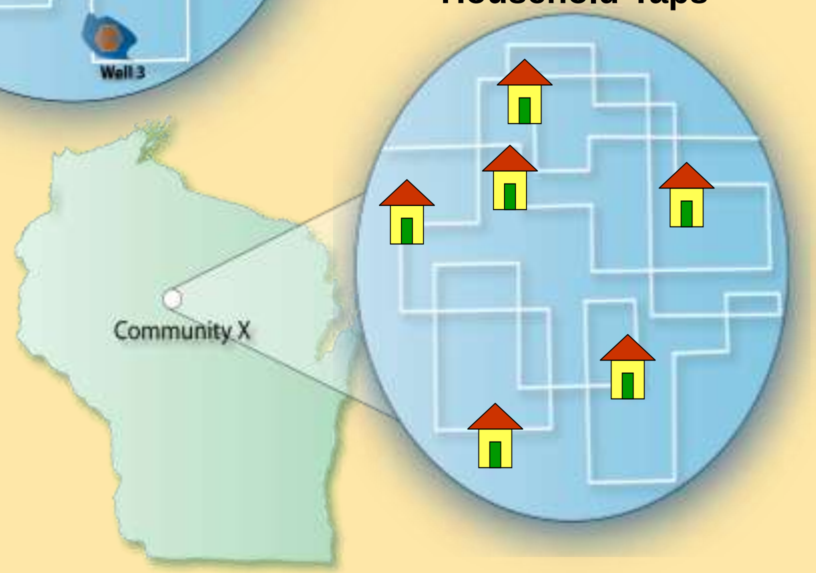
Wisconsin WAHTER Study

Exposure Assessment: Virus Concentrations at Wells and Taps

Wells



Household Taps



14 communities
- 1 – 4 wells/month/community
- 5 – 8 tap samples/month/ community

Wisconsin WAHTER Study

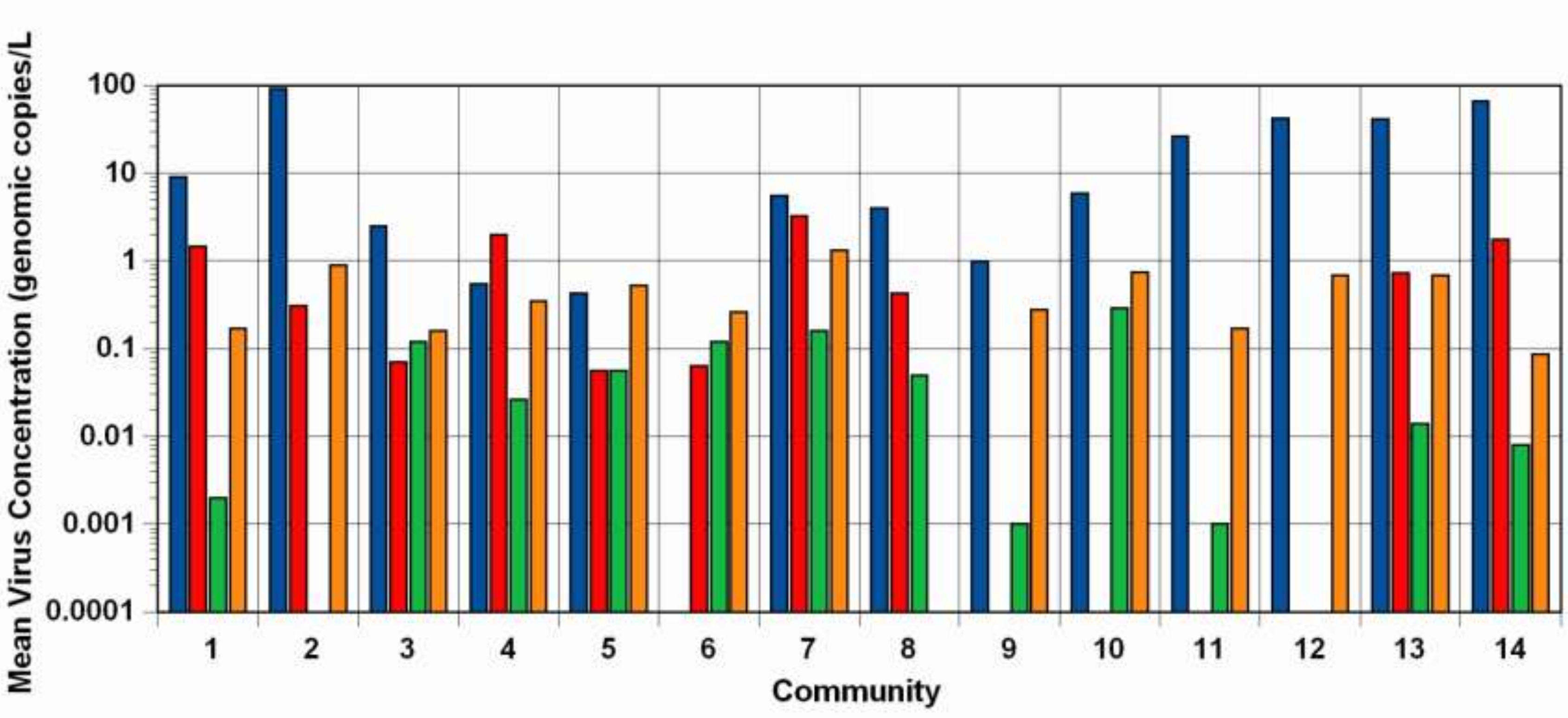
Virus Types, Frequencies, and Concentrations in Tap Water

Virus Type	Number qPCR Positive Samples (%)	Virus Concentration Genomic Copies/L		
		Mean	Median	Maximum
Adenovirus	157 (13)	0.07	0	9.5
Enterovirus	109 (9)	0.8	0	851.1
GI Norovirus	51 (4)	0.60	0	115.7
GII Norovirus	0 (0)	0	0	0
Hepatitis A Virus	10 (1)	0.006	0	4.1
Rotavirus	1 (0.1)	$2X10^{-5}$	0	0.03
All Viruses	287 (24)	1.5	0	853.6

N = 1,204 samples

Viruses in the Study Wells

In the 14 study communities, of all 36 wells tested, 34 were virus-positive (139 positive samples out of 392 (36%))



Wisconsin WAHTER Study

Proportion of AGI Reduced by UV Disinfection of Groundwater

- In adults in 2007, AGI was reduced by 13% (95% Confidence Interval: 0% - 22%)
- In children < 5 years old in the Spring of 2006, AGI was reduced by 13%, (95% Confidence Interval: 0% - 41%)
- Independent analysis using quantitative microbial risk assessment estimated 10% to 20% of the AGI was from drinking water

Wisconsin WAHTER Study

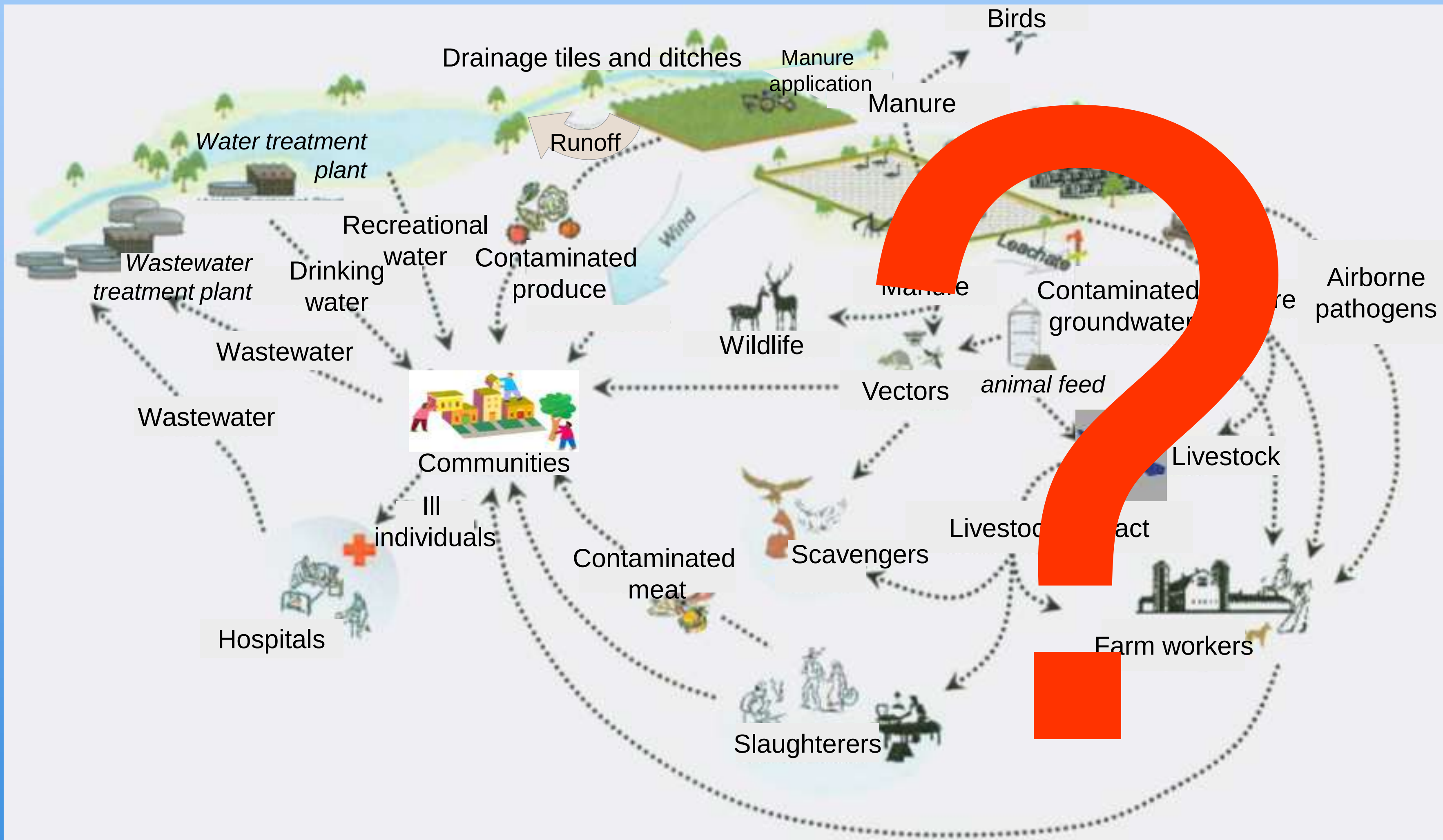
Does Groundwater-borne Illness Risk Meet EPA Standards?

- Acceptable EPA risk for waterborne disease is 1 infection in 10,000 people/year
- Assume every infection leads to an illness, then the acceptable illness rate is 0.0001 illness/person-year
- In the spring of 2006 the WAHTER Study measured 0.44 illness/person-year in children < 5 years old that was attributed to groundwater
- 4,400 times higher than EPA acceptable risk

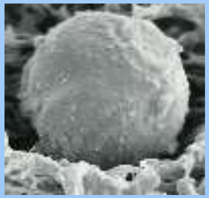
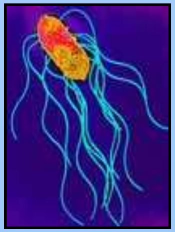
What Happens When It Hits…

- WI Code NR 810 revised to require disinfection of municipal water supplies
- Public hearings completed October, 2009
- DNR Board approved on April 28 2010
- Legislative approval in July 2010
- November 2010 election brings new political direction to Wisconsin
- New legislation prohibiting DNR from requiring drinking water disinfection signed in May 2011

Human and Livestock Pathogen Movement in the Environment



Rogers and Haines, 2005, EPA/600/R-06/021

Transport of Bovine Manure-Borne Pathogens in Surface Runoff in a Corn Silage System

Mark Borchardt, Susan Spencer,

Matt Volenec, Sherif Nagi

Craig Simson and Bill Jokela

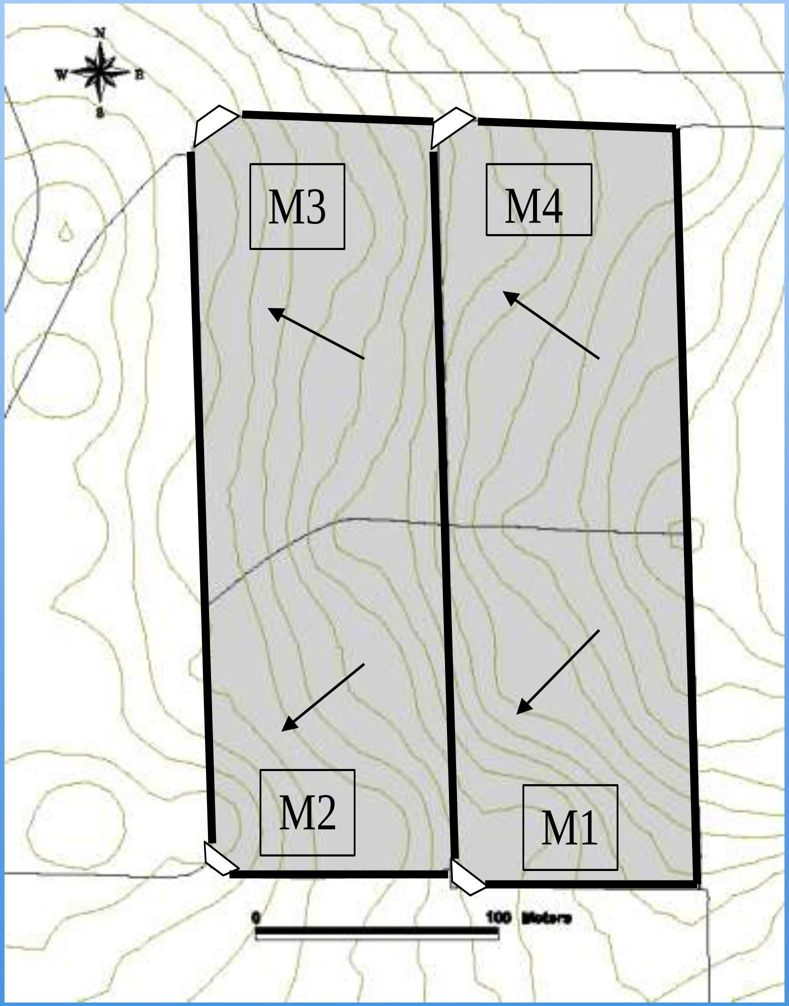
USDA-ARS Institute for Environmentally Integrated Dairy Management

Study Objectives

1. Quantify bovine pathogens in runoff from manure-applied fields
2. Use paired-watershed design to identify cropping, tillage, and manure application practices that minimize pathogen runoff

Objective 2 is only in the early phases of experimentation

Field Site



Located at the North farm of the UW/USDA-ARS Research Station in Marshfield, WI

Withee silt loam with 1-3% slope

Fields divided by drainage ditches and berms into four drainage areas

Each field about 4 acres, cropped in corn

Manure application once per year, about 5,800 gallons/acre

Runoff Monitoring Stations

H-flume: stage measured using bubble-pressure transducer

Pathogens: refrigerated glass wool filtration; event-based sampling, not flow-weighted

Nutrients, sediment, and indicator *E.coli*: automated refrigerated sampler with time-based sampling

Controlled remotely by radio telemetry

Fall Manure and Chisel Plow (Control, M1)

Fall after chisel plow

Spring after field cultivate/plant

Rye Cover Crop with Spring Manure and Chisel Plow (M2)

Fall

11/7/08

Spring

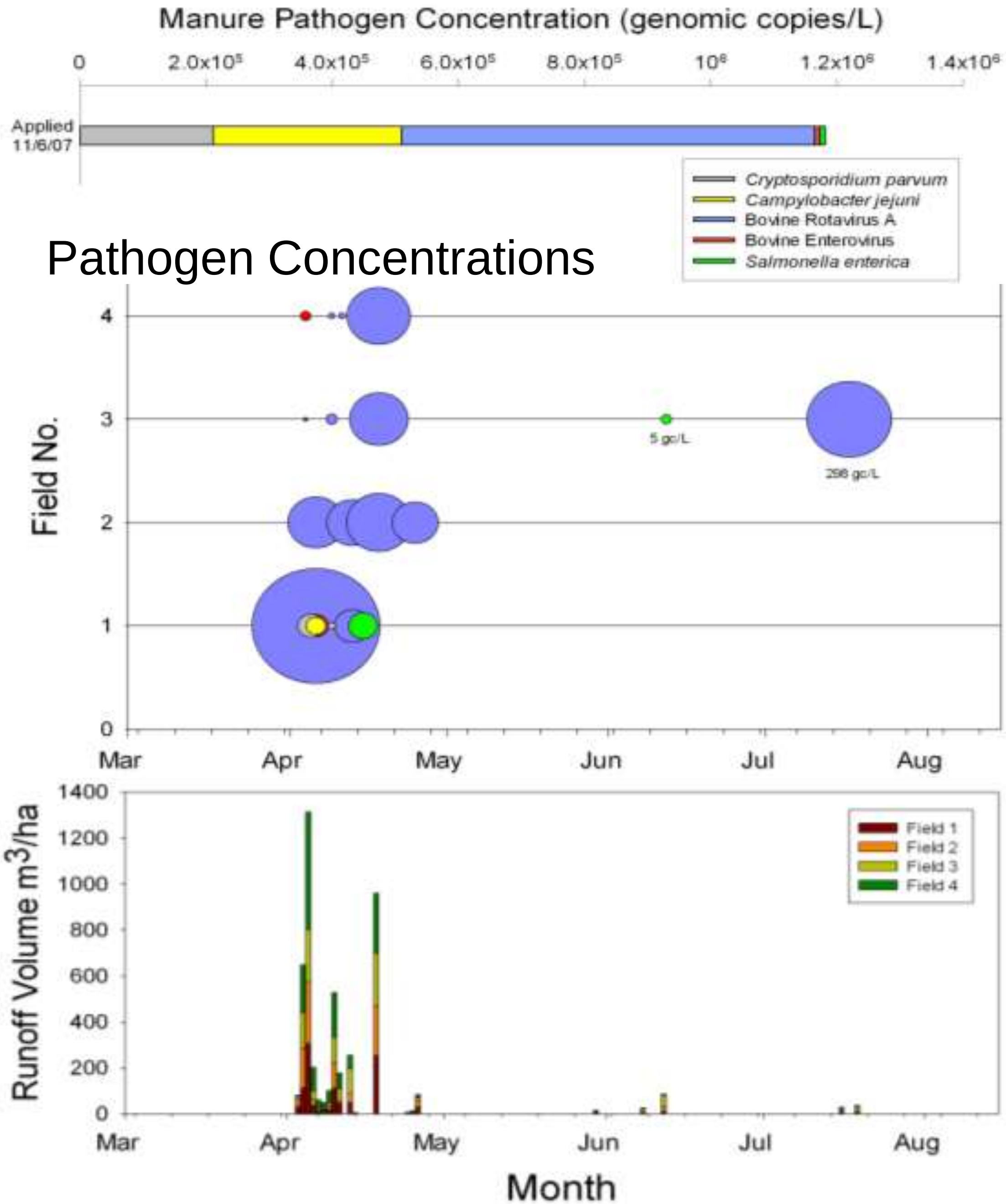
5/8/09

Fall Surface-applied Manure with Spring Chisel Plow (M3)

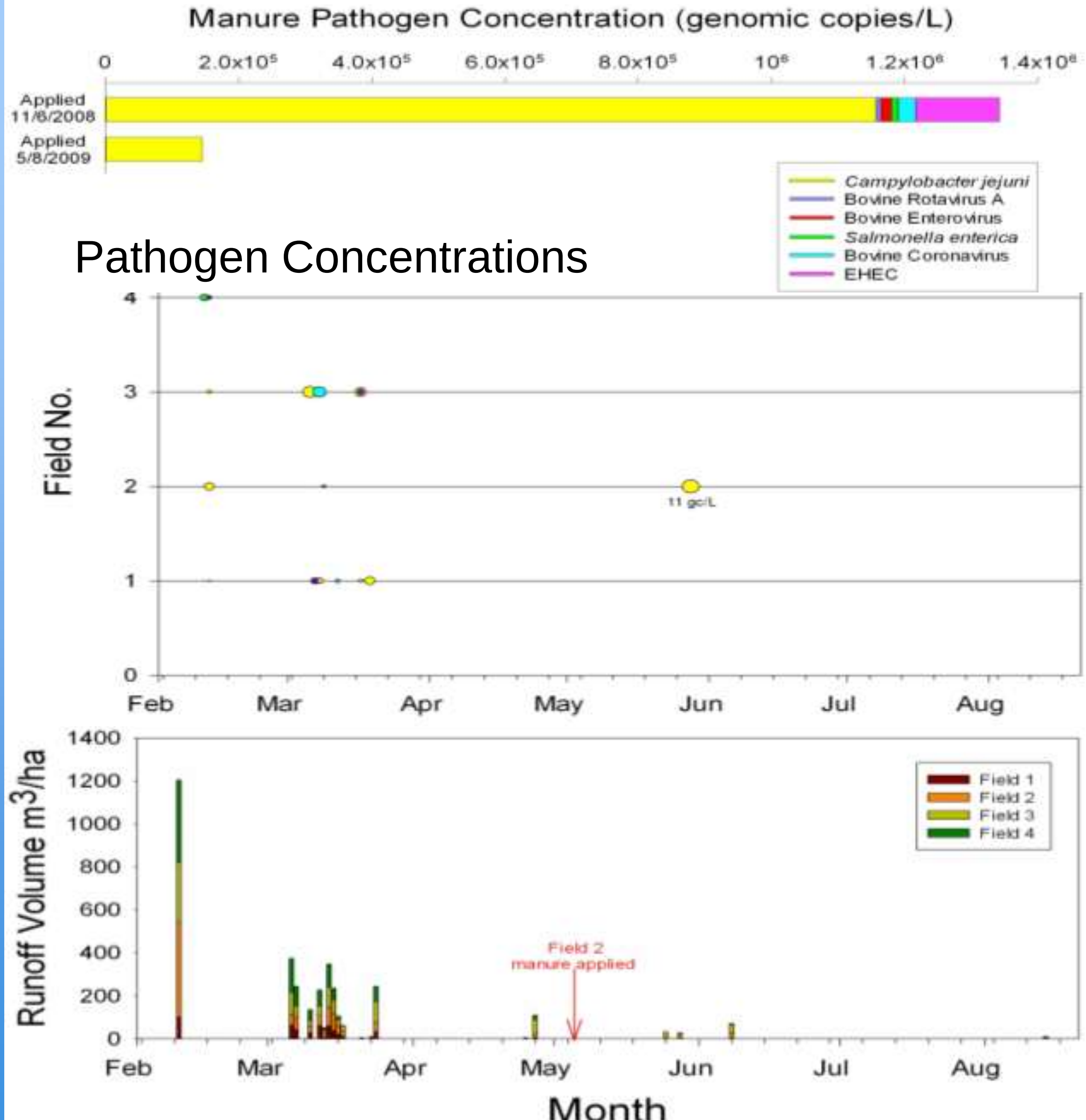
Vegetative Waterway/ Buffer-Field Border with fall manure and chisel plow (M4)

Year 2008

Pathogen Concentrations

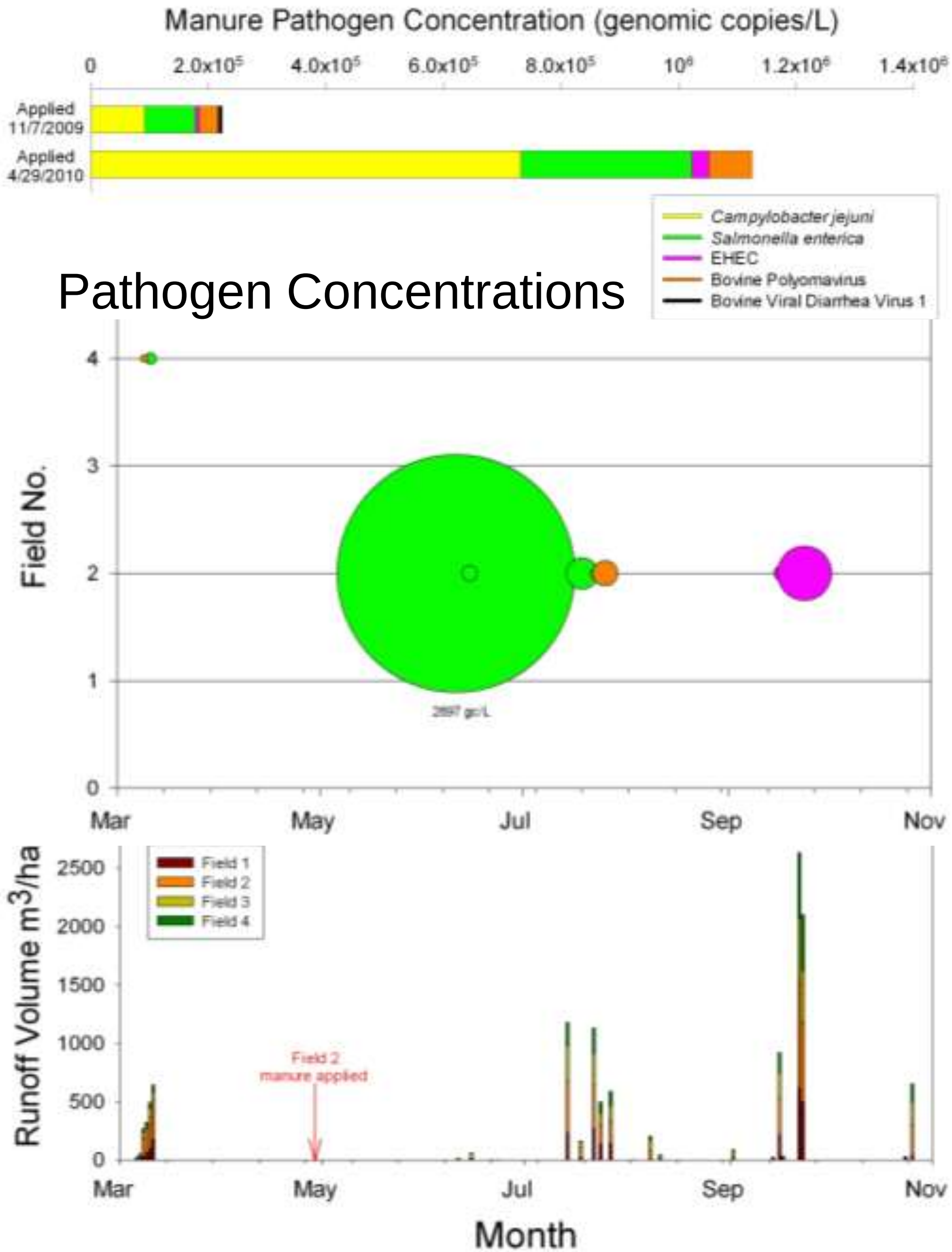


Year 2009



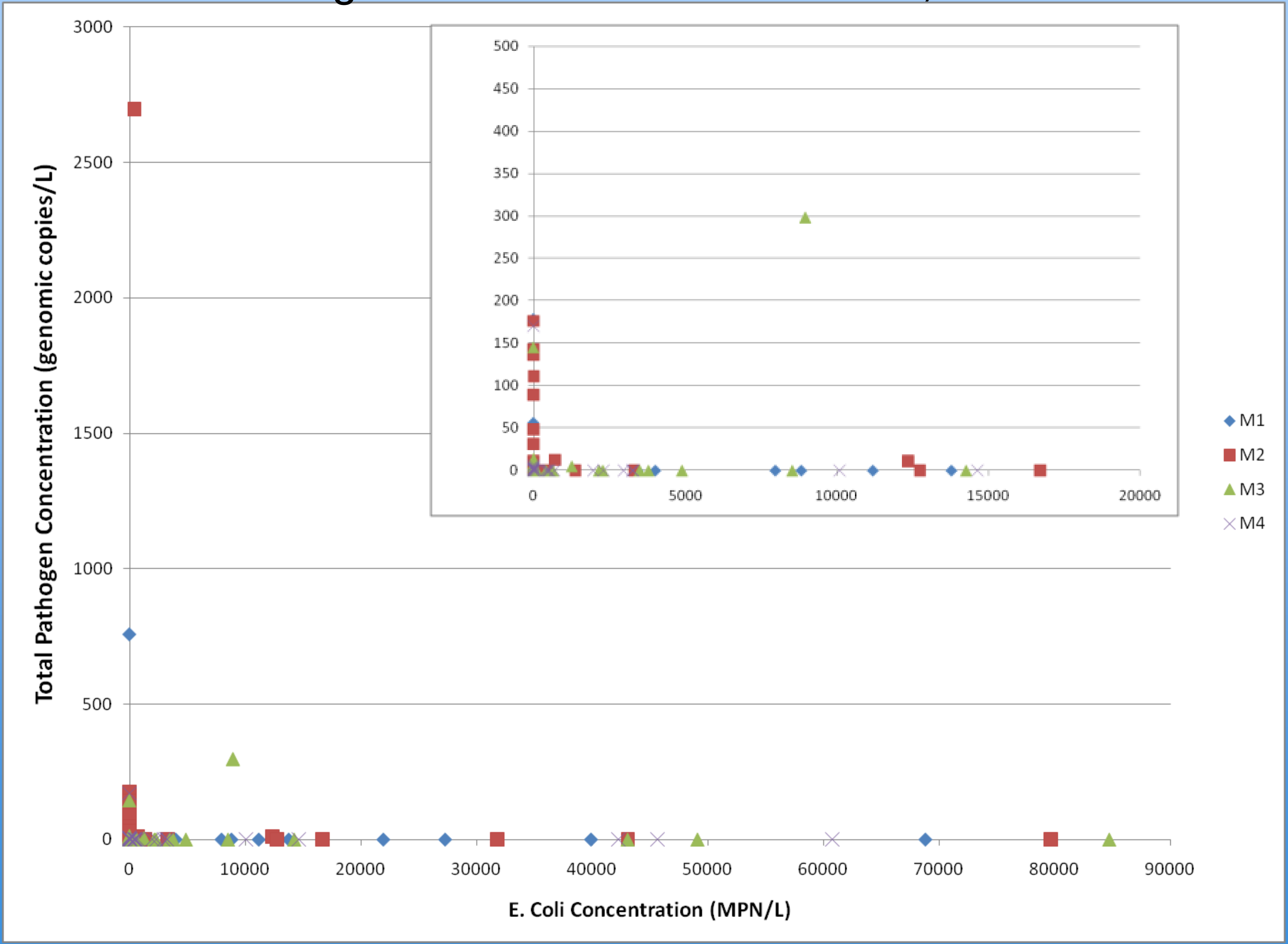
Manure Pathogen Concentration (genomic copies/L)
0
2.0x10⁵
4.0x10⁵
6.0x10⁵
8.0x10⁵
10⁶
1.2x10⁶
1.4x10⁶
Applied 11/6/2008
Applied 5/8/2009
Campylobacter jejuni
Bovine Rotavirus A
Bovine Enterovirus
Salmonella enterica
Bovine Coronavirus
EHEC
Pathogen Concentrations
Field No.
11 gc/L
Feb
Mar
Apr
May
Jun
Jul
Aug
Runoff Volume m3/ha
Field 1
Field 2
Field 3
Field 4
Field 2 manure applied
Month

Year 2010

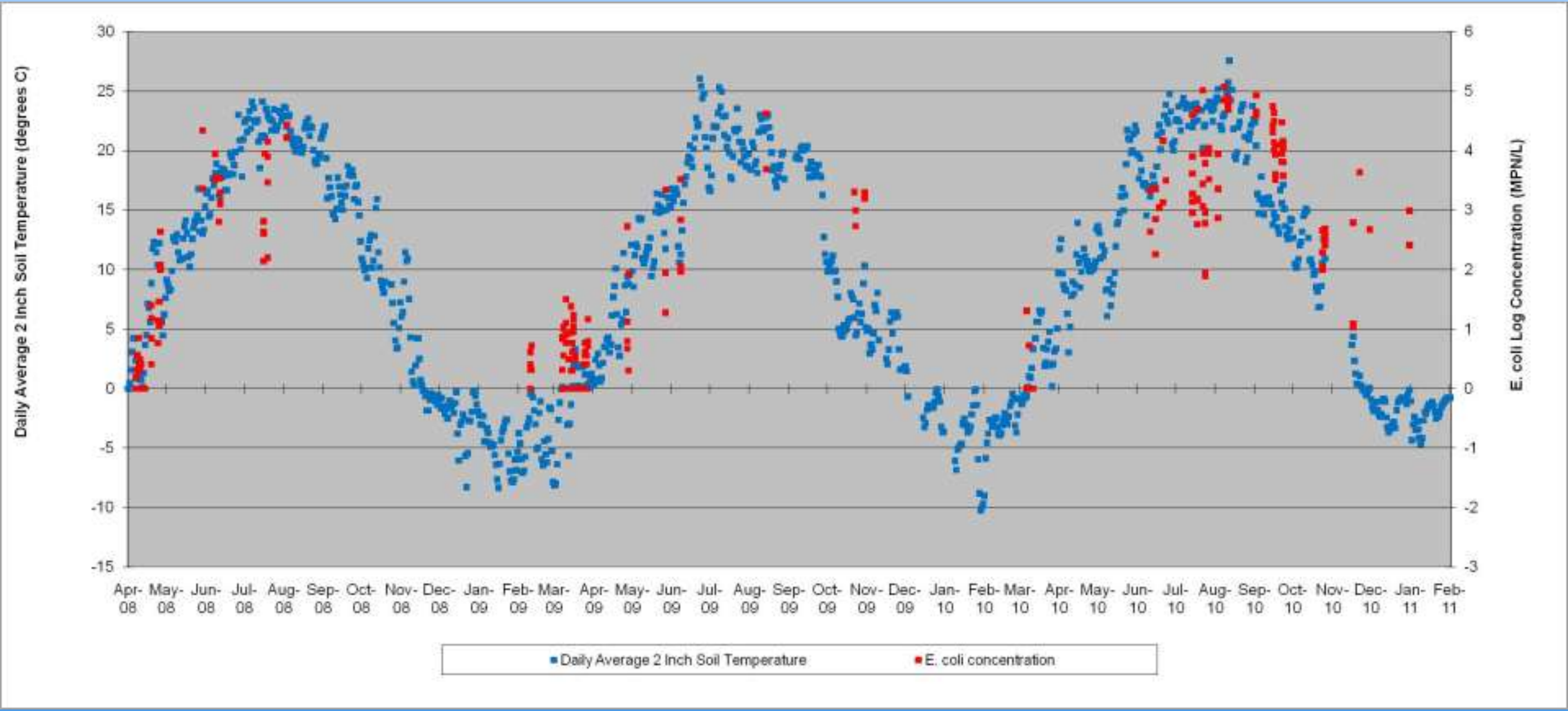


Manure Pathogen Concentration (genomic copies/L)
0
2.0x10^5
4.0x10^5
6.0x10^5
8.0x10^5
10^6
1.2x10^6
1.4x10^6
Applied 11/7/2009
Applied 4/29/2010
Campylobacter jejuni
Salmonella enterica
EHEC
Bovine Polyomavirus
Bovine Viral Diarrhea Virus 1
Pathogen Concentrations
Field No.
0
1
2
3
4
Mar
May
Jul
Sep
Nov
Runoff Volume m3/ha
0
500
1000
1500
2000
2500
Field 1
Field 2
Field 3
Field 4
Field 2 manure applied
Mar
May
Jul
Sep
Nov
Month

Total Pathogen vs *E. coli* Concentrations, 2008-2010

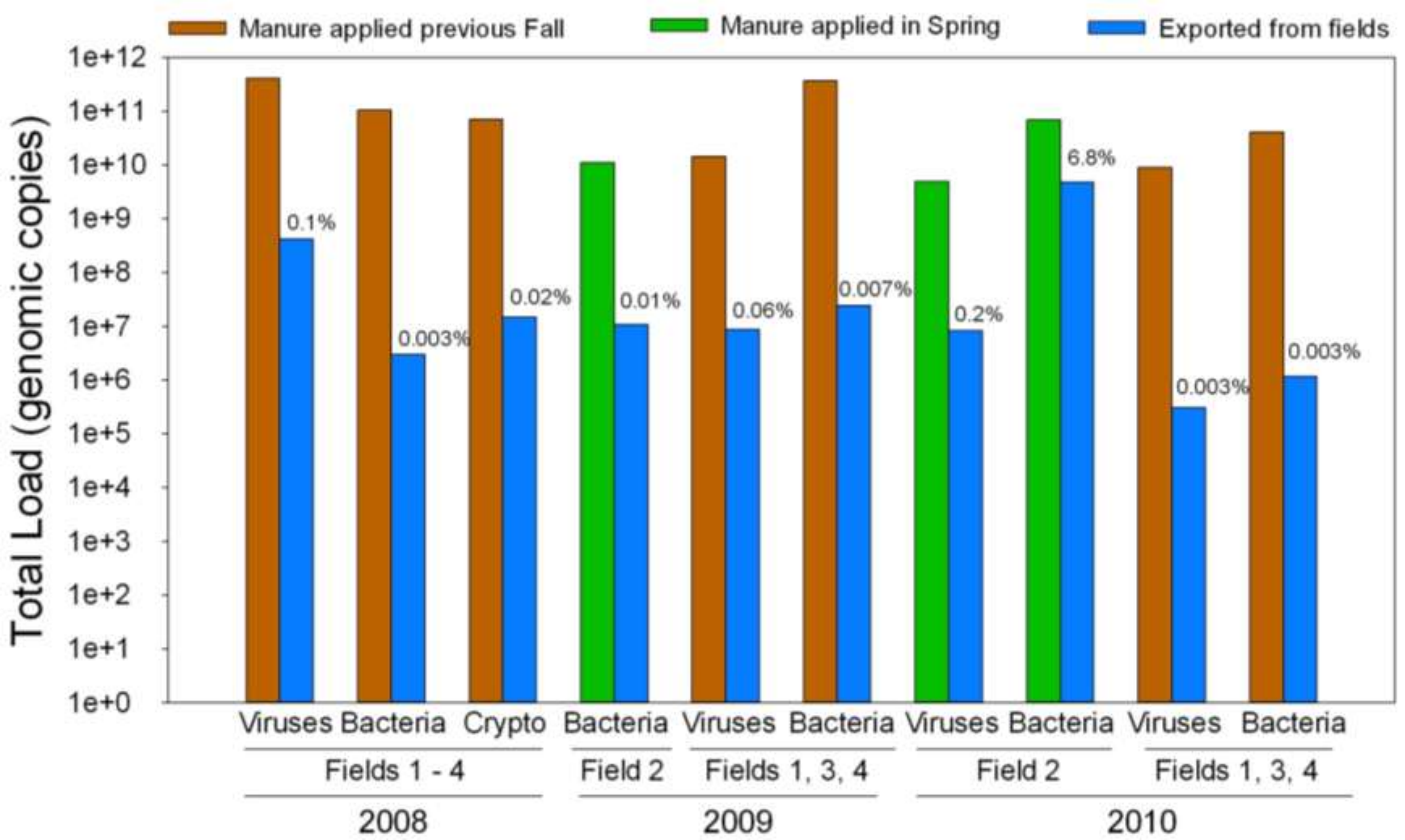


Daily 2 Inch Soil Temperature vs *E. coli* Log Concentration



Pathogen Cumulative Export

Caveat: Export values are not-flow-weighted



Summary of Preliminary Conclusions

- Pathogen types and concentrations in field runoff are highly variable.
- Runoff may contain pathogens many months after manure application; e.g. rotavirus applied in Fall 07 ran off in April 08 and EHEC applied in April 2010 ran off 5 months later.
- In two of the three study years, the majority of pathogen runoff occurred in the spring time.
- Exposure risk to pathogen-contaminated runoff is not necessarily shown by measuring indicator *E. coli* because *E. coli* and pathogen quantities in field runoff are not related.
- Estimated from export rates, fall-applied manure resulted in a 3 to 5 log reduction in pathogens in runoff.

Healthy Humans
Healthy Livestock
Solutions for Preventing Exposure to Pathogens in the Environment

Solutions ?

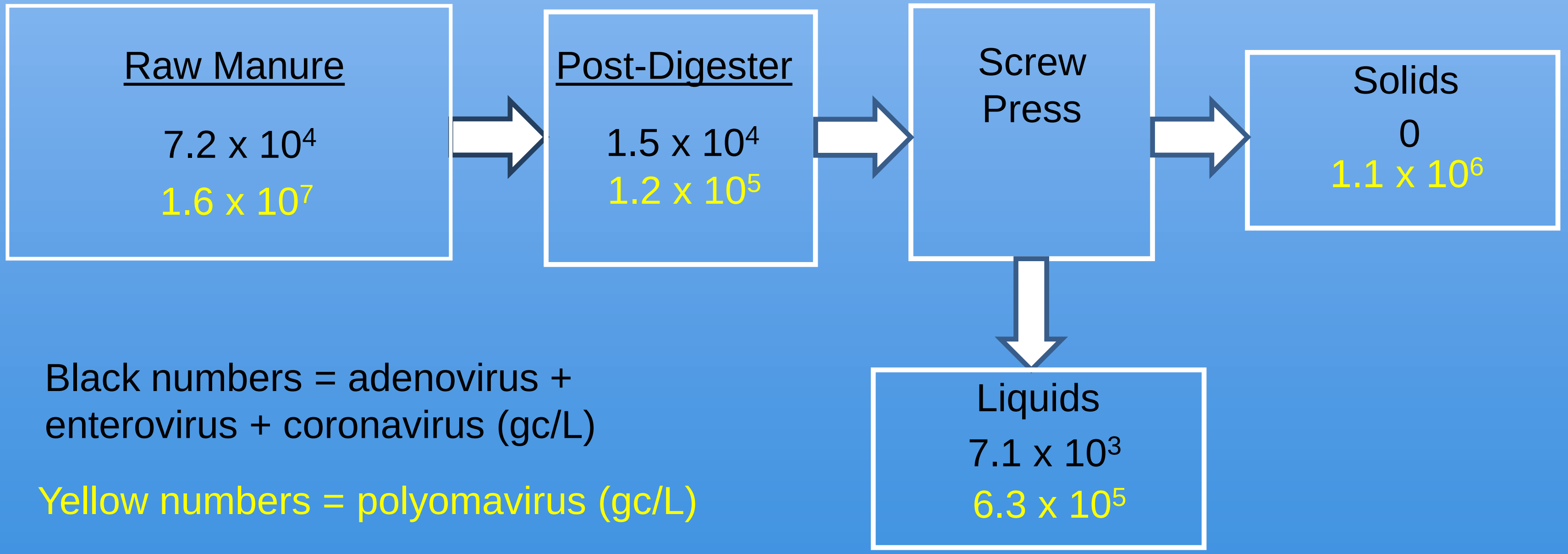
Solutions for Preventing Exposure to Manure-borne Pathogens in the Environment

Practices to Minimize Transport	Practices to Maximize Inactivation
Distance between livestock and waterways	Storage time
Vegetated treatment areas	Chemical treatment (e.g., lime)
Settling basins and wetlands	Thermophilic processes (e.g., aerated composting)
Manure storage and treatment lagoons	Anaerobic digestion?

From: Atwill et al. 2011 An Introduction to Waterborne Pathogens in Agricultural Watersheds, NRCS Draft document

Anaerobic Digester Pathogen Removal

- Collaboration with Dr. Rebecca Larson, University of Wisconsin, Dept of Biological Systems Engineering
- Anaerobic digesters: 5 plug flow, 2 completely mixed, all mesophilic
- Mean concentrations (genomic copies/L) of the seven digesters reported.
- Data reported for first sampling only!!



Preventing It from Hitting the Fan…

Working together the dairy industry, researchers, and policymakers can:

- Identify research priorities
- Generate ideas
- Test potential solutions

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