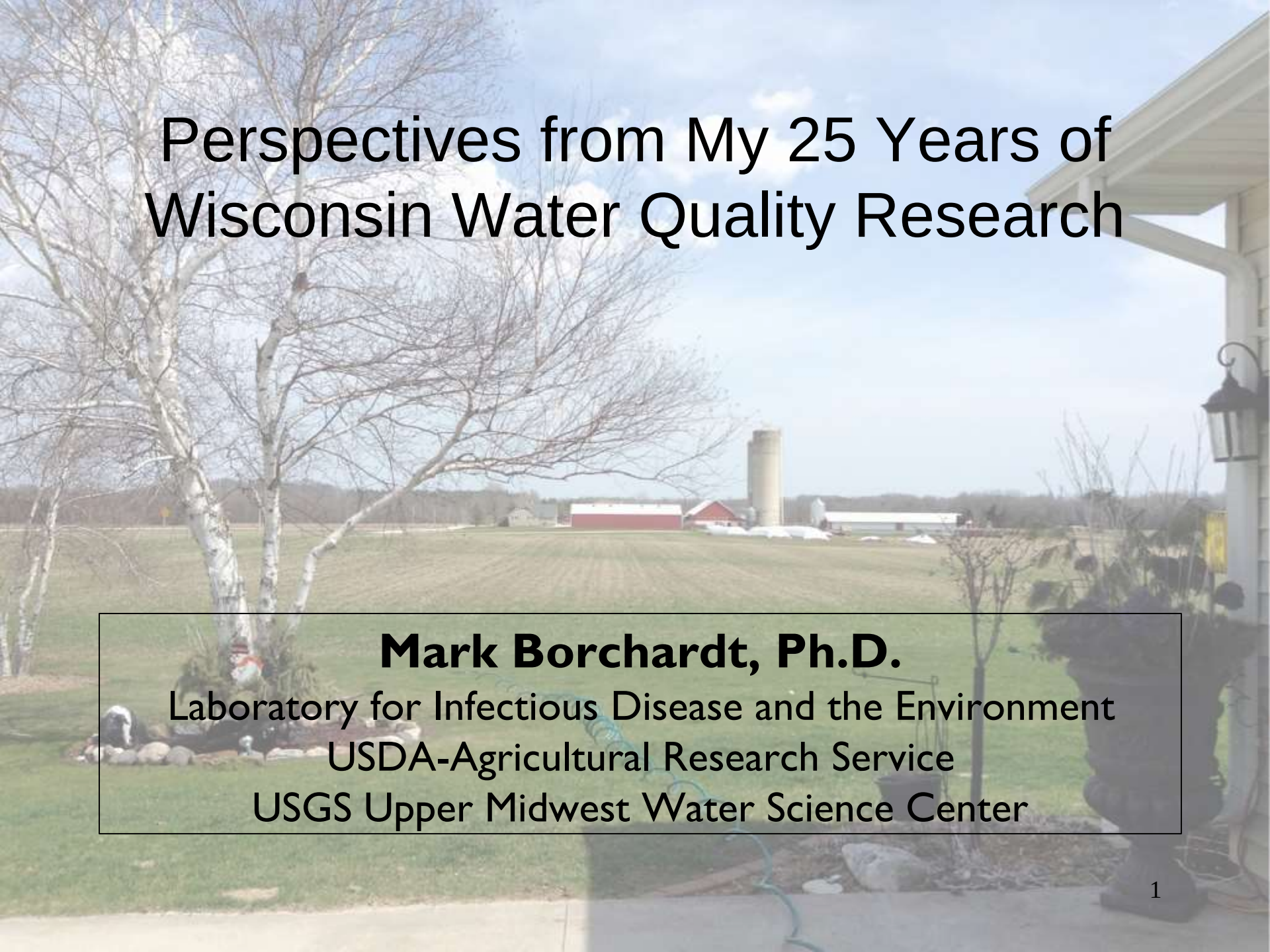
Perspectives from My 25 Years of Wisconsin Water Quality Research



Mark Borchardt, Ph.D.
Laboratory for Infectious Disease and the Environment
USDA-Agricultural Research Service
USGS Upper Midwest Water Science Center

Laboratory for Infectious Disease and the Environment

- Federal interagency research lab, USDA-ARS and USGS
- Study occurrence, transport, and health effects of human pathogens in the environment
- Special focus on water quality and waterborne infectious disease
- Research often located in Upper Midwest, but communications and relevance are worldwide

L·I·D·E

LABORATORY FOR INFECTIOUS DISEASE AND THE ENVIRONMENT

Presentation Organization and Information Sources

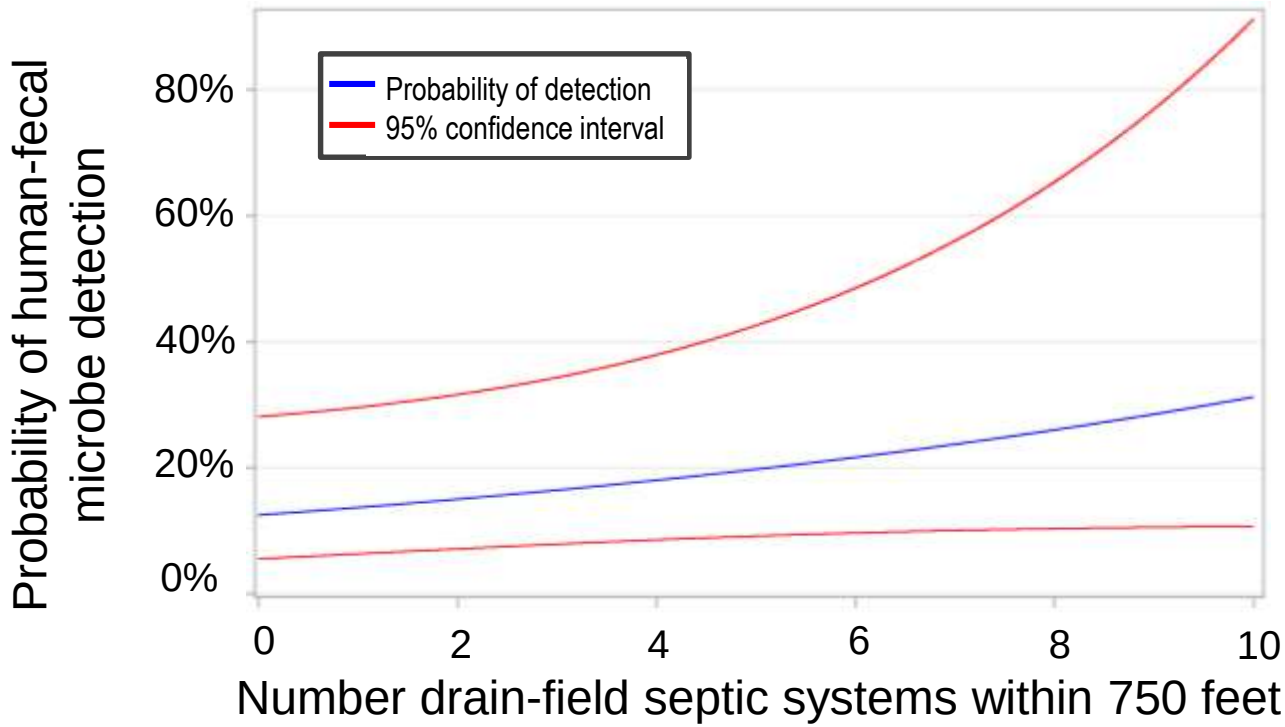
1. Takeaways from Wisconsin-based research
   - Derived from peer-reviewed scientific findings
   - Publications available upon request

2. Recommendations for improving Wisconsin's water quality
   - Derived from experience, collaborations, and scientific literature
   - Opinions expressed are mine and do not represent policies or recommendations from USDA or USGS

Key Takeaway 1

Septic systems are responsible for contamination of groundwater with human fecal wastes and are linked with disease transmission

Kewaunee County: More septic systems around a private well means greater risk for contamination by human fecal microbes



Model accounts for the effects of:

Rainfall total previous 2 days

Depth to groundwater previous 14 days

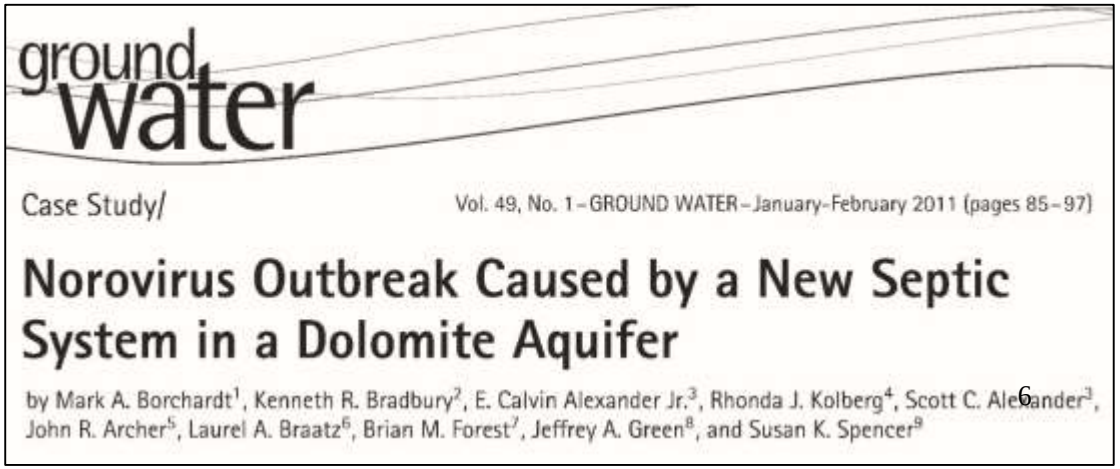
Depth to bedrock

Septic systems can be responsible for groundwater-borne disease outbreaks

Eau Claire: Sports club well water contaminated by norovirus from old septic system

Door County: Restaurant well water contaminated by norovirus from new septic system

- 229 people ill
- 6 people hospitalized



Central Wisconsin: Mismanaged septic holding tanks are linked with infectious diarrhea in children

Children's Health | Article VOLUME 111 | NUMBER 5 | May 2003 • Environmental Health Perspectives

Septic System Density and Infectious Diarrhea in a Defined Population of Children

Mark A. Borchardt,[1] Po-Huang Chyou,[1] Edna O. DeVries,[2] and Edward A. Belongia[1]

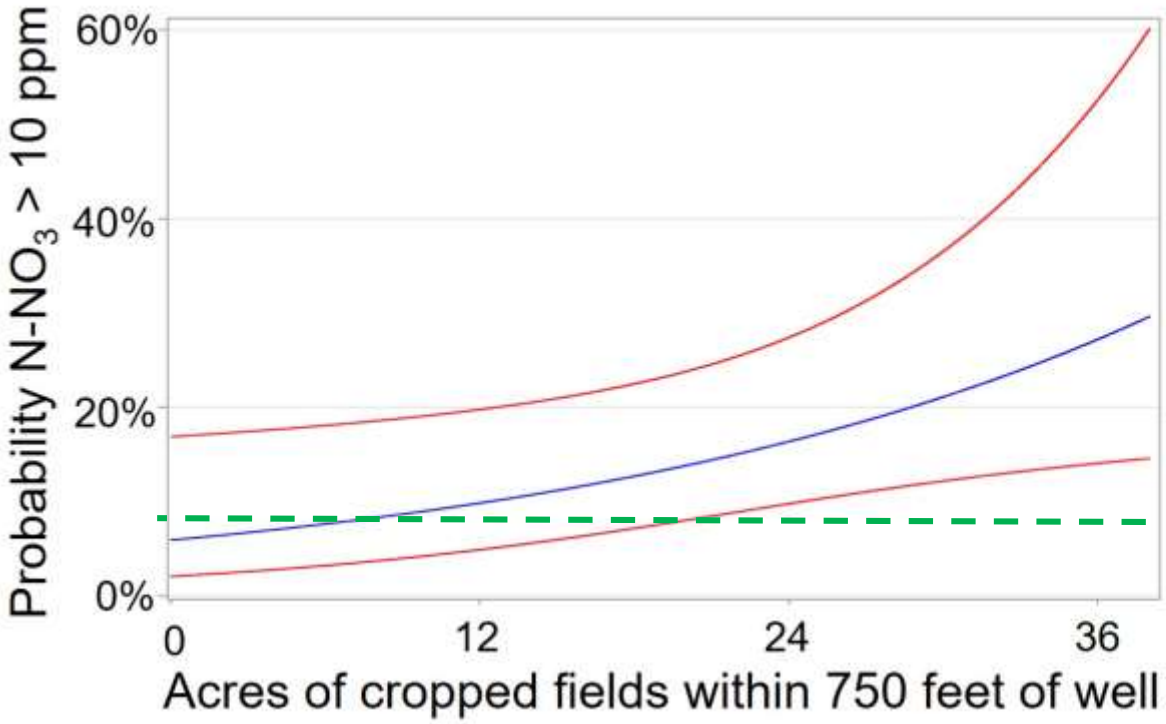
[1]Marshfield Medical Research Foundation and [2]Department of Pediatrics, Marshfield Clinic, Marshfield, Wisconsin, USA

- For every additional holding tank per square mile, children living in the same area had an 8% increase in viral diarrhea
- For every additional holding tank per 40 acres, children living in the same area had a 22% increase in bacterial diarrhea

Key Takeaway 2

Agricultural activities contaminate groundwater with livestock manure and nitrate

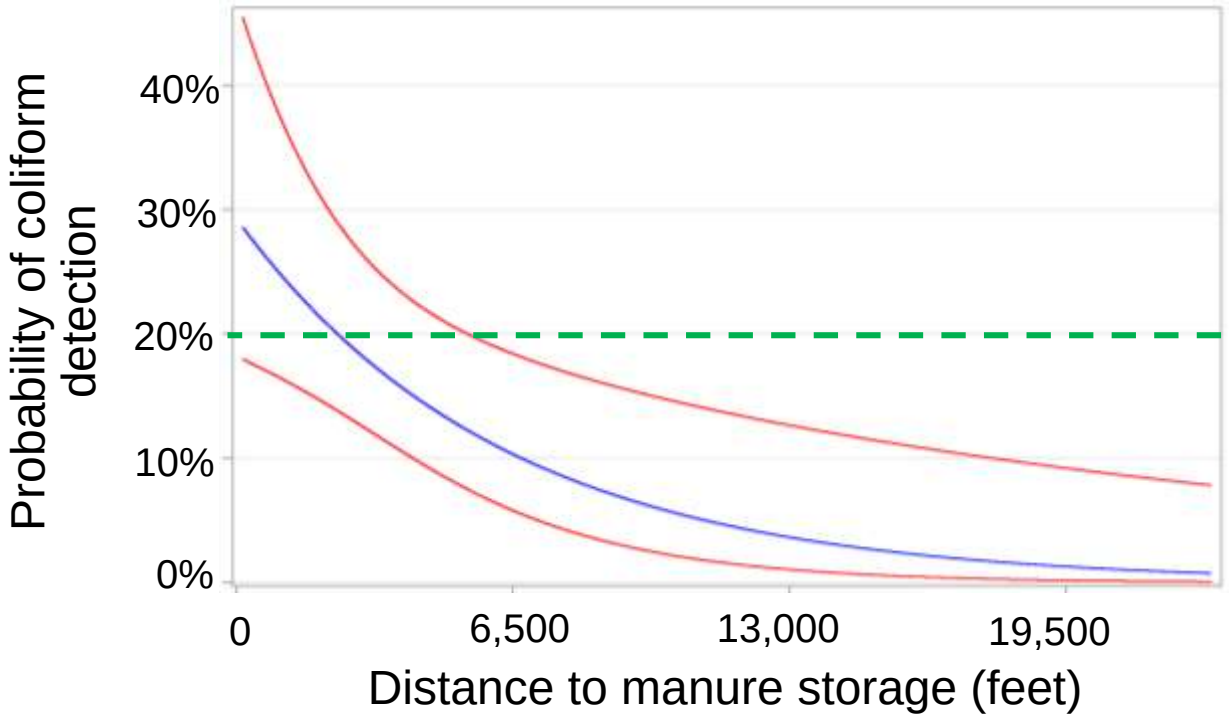
Kewaunee County: More crop land around a private well means greater risk for contamination by high nitrate



Model accounts for the effects of:
Distance to nearest cropped field
Distance to manure lagoon
Depth to bedrock

Probability of detection
95% confidence interval
State-wide average (7%)

Kewaunee County: Private wells located farther from manure storage are less likely to be contaminated with coliform bacteria



Model accounts for the effects of:

Distance to nearest agricultural field

Area of cropped fields within 750 feet of well

Depth to bedrock

Probability of detection

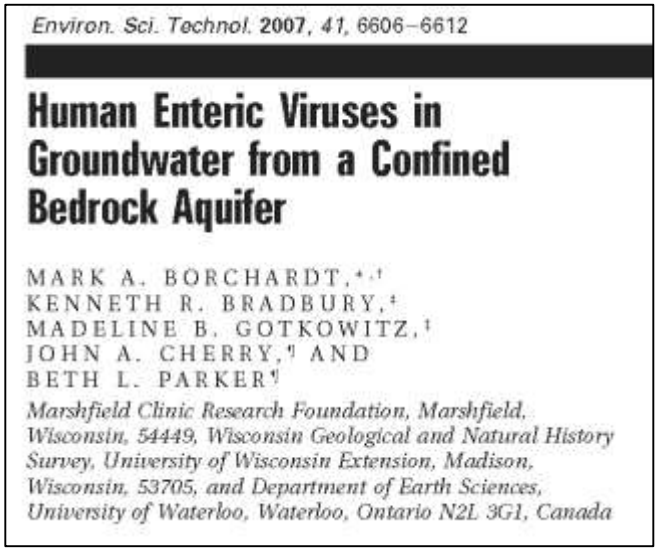
95% confidence interval

State average (~20%)

Key Takeaway 3

Municipal groundwater supplies are contaminated with human pathogens. There is elevated risk for acute gastrointestinal illness when groundwater is not disinfected.

La Crosse, Madison: Sanitary sewers can leak and contaminate municipal wells, even very deep wells, with human pathogens

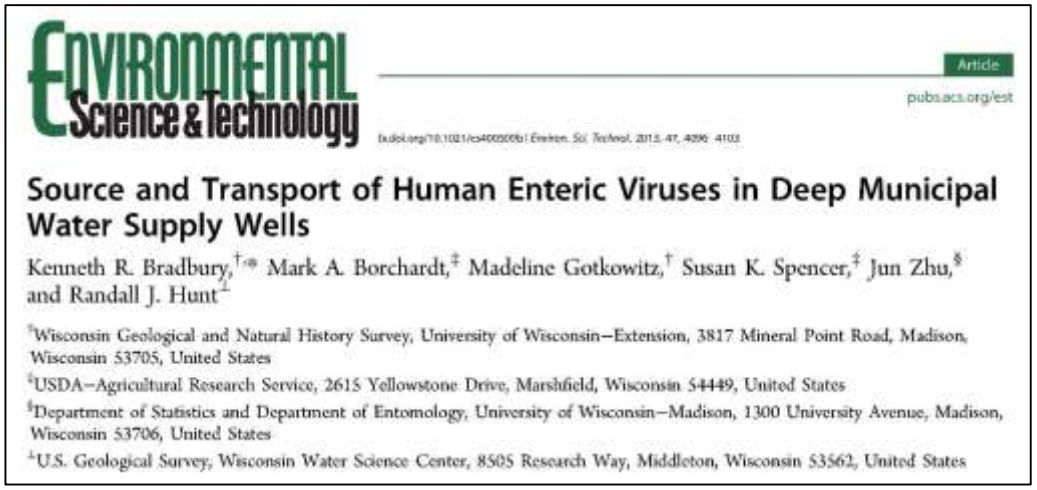


Environ. Sci. Technol. 2007, 41, 6606–6612

Human Enteric Viruses in Groundwater from a Confined Bedrock Aquifer

MARK A. BORCHARDT,*,† KENNETH R. BRADBURY,‡ MADELINE B. GOTKOWITZ,† JOHN A. CHERRY,¶ AND BETH L. PARKER¶

Marshfield Clinic Research Foundation, Marshfield, Wisconsin, 54449, Wisconsin Geological and Natural History Survey, University of Wisconsin Extension, Madison, Wisconsin, 53705, and Department of Earth Sciences, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada



ENVIRONMENTAL Science & Technology

Article

pubs.acs.org/est

Source and Transport of Human Enteric Viruses in Deep Municipal Water Supply Wells

Kenneth R. Bradbury,†,* Mark A. Borchardt,‡ Madeline Gotkowitz,† Susan K. Spencer,‡ Jun Zhu,§ and Randall J. Hunt⊥

†Wisconsin Geological and Natural History Survey, University of Wisconsin–Extension, 3817 Mineral Point Road, Madison, Wisconsin 53705, United States

‡USDA–Agricultural Research Service, 2615 Yellowstone Drive, Marshfield, Wisconsin 54449, United States

§Department of Statistics and Department of Entomology, University of Wisconsin–Madison, 1300 University Avenue, Madison, Wisconsin 53706, United States

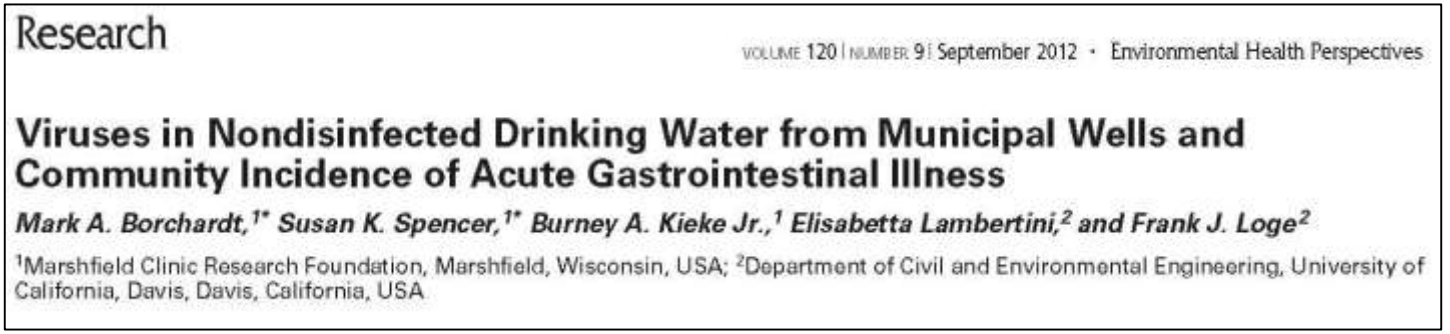
⊥U.S. Geological Survey, Wisconsin Water Science Center, 8505 Research Way, Middleton, Wisconsin 53562, United States

Borchardt, Haas, Hunt. Vulnerability of municipal wells in La Crosse, Wisconsin, to enteric virus contamination from surface water contributions. Applied and Environmental Microbiology, 70: 5937-5946. 2004.

Hunt, Borchardt, Richards, Spencer. Assessment of sewer source contamination of drinking water wells using tracers and human enteric viruses. Environmental Science & Technology, 44:7956-7963. 2010.

Gotkowitz, Bradbury, Borchardt, Zhu, Spencer. Effects of climate and sewer condition on virus transport to groundwater. Environmental Science & Technology, 50:8497-8504. 2016.

14 Rural Wisconsin Communities: Non-disinfected community groundwater supplies cause illness



Research

VOLUME 120 | NUMBER 9 | September 2012 • Environmental Health Perspectives

Viruses in Nondisinfected Drinking Water from Municipal Wells and Community Incidence of Acute Gastrointestinal Illness

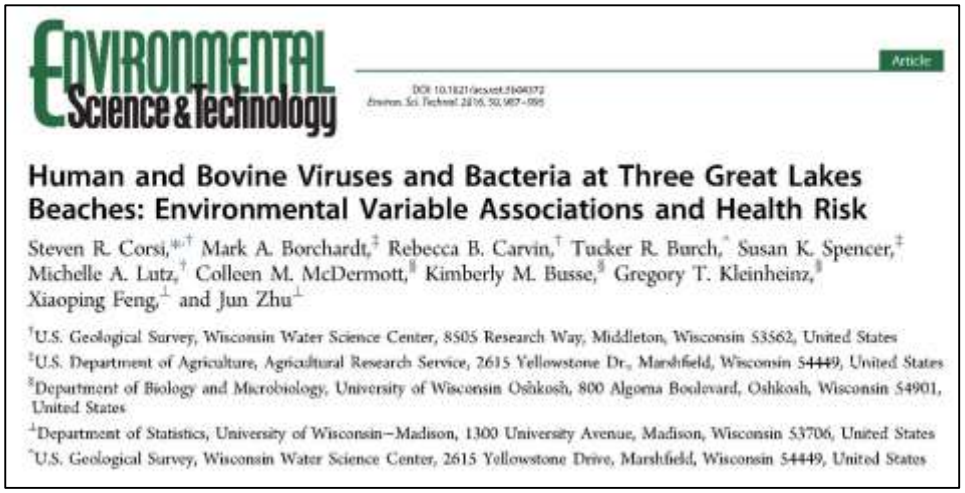
Mark A. Borchardt,[1] Susan K. Spencer,[1]* Burney A. Kieke Jr.,[1] Elisabetta Lambertini,[2] and Frank J. Loge[2]*

[1]Marshfield Clinic Research Foundation, Marshfield, Wisconsin, USA; [2]Department of Civil and Environmental Engineering, University of California, Davis, Davis, California, USA

- Disinfection is not required for groundwater-supplied drinking water.
- About **14%** of acute gastrointestinal illnesses in communities that do not practice disinfection is from their drinking water.

Key Takeaway 4

Lake Michigan beaches and urban waterways of southeastern Wisconsin are contaminated with human pathogens.



ENVIRONMENTAL Science & Technology

Article

Human and Bovine Viruses and Bacteria at Three Great Lakes Beaches: Environmental Variable Associations and Health Risk

Steven R. Corsi,*[,†] Mark A. Borchardt,[‡] Rebecca B. Carvin,[†] Tucker R. Burch,[∥] Susan K. Spencer,[‡] Michelle A. Lutz,[†] Colleen M. McDermott,[§] Kimberly M. Busse,[§] Gregory T. Kleinheinz,[§] Xiaoping Feng,[⊥] and Jun Zhu[⊥]

[†]U.S. Geological Survey, Wisconsin Water Science Center, 8505 Research Way, Middleton, Wisconsin 53562, United States
[‡]U.S. Department of Agriculture, Agricultural Research Service, 2615 Yellowstone Dr., Marshfield, Wisconsin 54449, United States
[§]Department of Biology and Microbiology, University of Wisconsin Oshkosh, 800 Algoma Boulevard, Oshkosh, Wisconsin 54901, United States
[⊥]Department of Statistics, University of Wisconsin−Madison, 1300 University Avenue, Madison, Wisconsin 53706, United States
[∥]U.S. Geological Survey, Wisconsin Water Science Center, 2615 Yellowstone Drive, Marshfield, Wisconsin 54449, United States

Corsi, Borchardt, Spencer, Hughes, Baldwin. 2014. Human and bovine viruses in the Milwaukee River Watershed: Hydrologically relevant representation and relations with environmental variables. Science of the Total Environment, 490:849-860.

Lenaker, Corsi, Borchardt, Spencer, Baldwin, Lutz. 2017. Hydrologic, land cover and seasonal patterns of waterborne pathogens in Great Lakes tributaries. Water Research 113:11-21.

McLellan, Sauer, Corsi, Bootsma, Boehm, Spencer. Borchardt. 2018. Sewage loading and microbial risk in urban waters of the Great Lakes. Elementa Science of the Anthropocene, 6: 46.

Key Takeaway 5

800,000 households in Wisconsin rely on private wells. Many wells exceed health standards for drinking water quality.

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

Mark A. Borchardt,[1]* Phil D. Bertz,[1] Susan K. Spencer,[1] and David A. Battigelli[2]†

Marshfield Medical Research Foundation, Marshfield, Wisconsin 54449,[1] and University of Wisconsin, State Laboratory of Hygiene, Madison, Wisconsin 53708[2]

Wisconsin Private Well Data

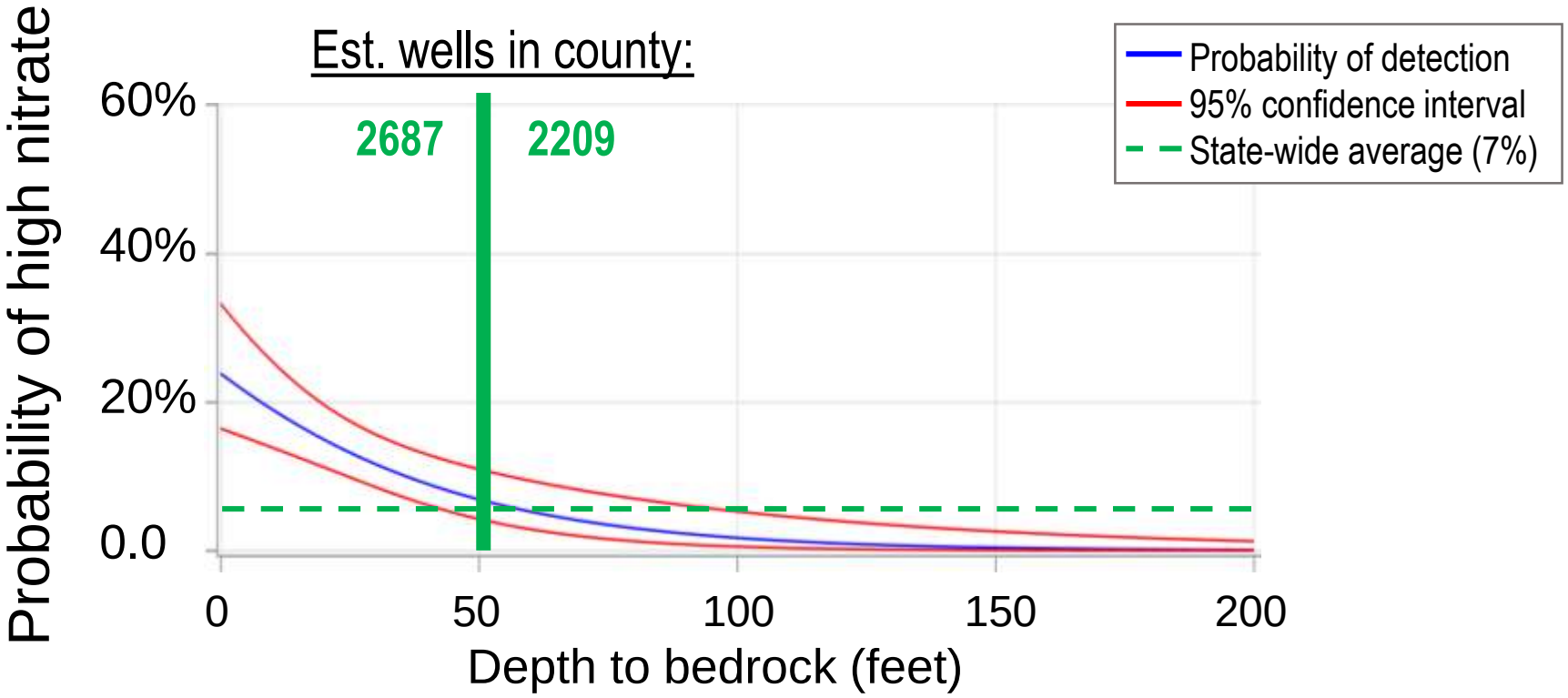
	Wells sampled	Total coliform	*E. coli*	$NO_3 - N$ > 10 ppm	Total coliform or $NO_3 - N$ > 10 ppm
Kewaunee 1	316	21%	0.4%	7%	26%
Kewaunee 2	400	22%	1%	7%	28%
Southwest WI 1	301	34%	4%	16%	42%
Southwest WI 2	539	16%	2%	15%	27%
Statewide 1997[a]	534	23%	3%	7%	-
Statewide 2013[b]	3838	18%	-	10%	-
Statewide 2017[c]	401	-	-	8%	-

[a] Information on the quality of water found at community water systems and private wells. United States GAO/RECD-97-123, June 1997

[b] Knobeloch et al. 2013. Private drinking water quality in rural Wisconsin. Journal of Environmental Health 75:16-20.

[c] Agricultural chemicals in Wisconsin groundwater. Wisconsin Department of Agriculture, Trade, and Consumer Protection, ARM-PUB-264.indd, April 2017.

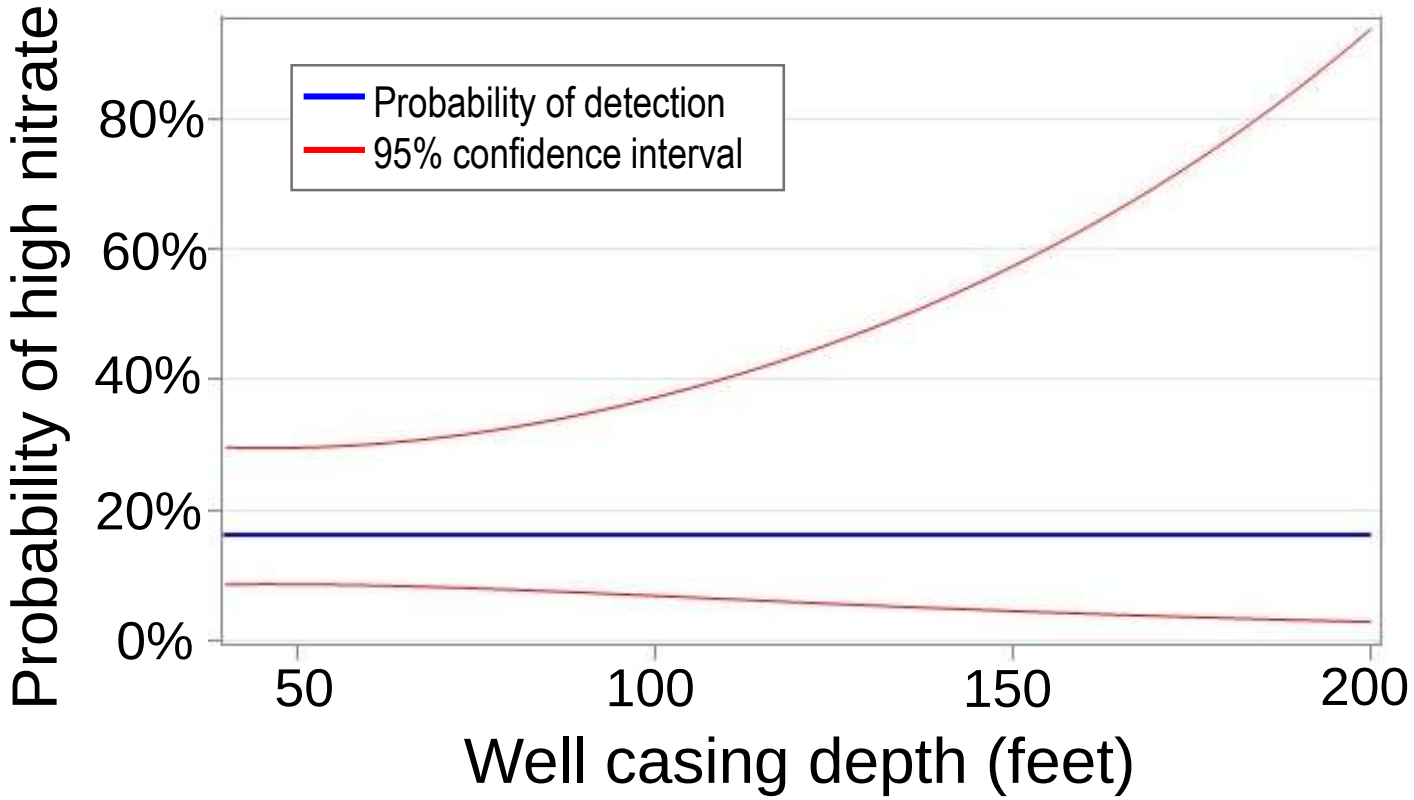
Kewaunee County: Depth to Bedrock Affects Nitrate Contamination of Private Wells



High nitrate: exceeds health standard $N\text{-}NO_3^-$ > 10 ppm

Key Takeaway 6

Kewaunee County: Well construction is not as important as surrounding land use in private well contamination.



Model accounts for the effects of:
Depth to bedrock

Data restricted to casing depths between 40 and 200 feet

Presentation Organization and Information Sources

1. Takeaways from Wisconsin-based research

2. Recommendations for improving Wisconsin's water quality

Resources for Specific Recommendations for Improving Wisconsin's Water Quality

Food · Land · & Water
Toward a Sustainable Wisconsin

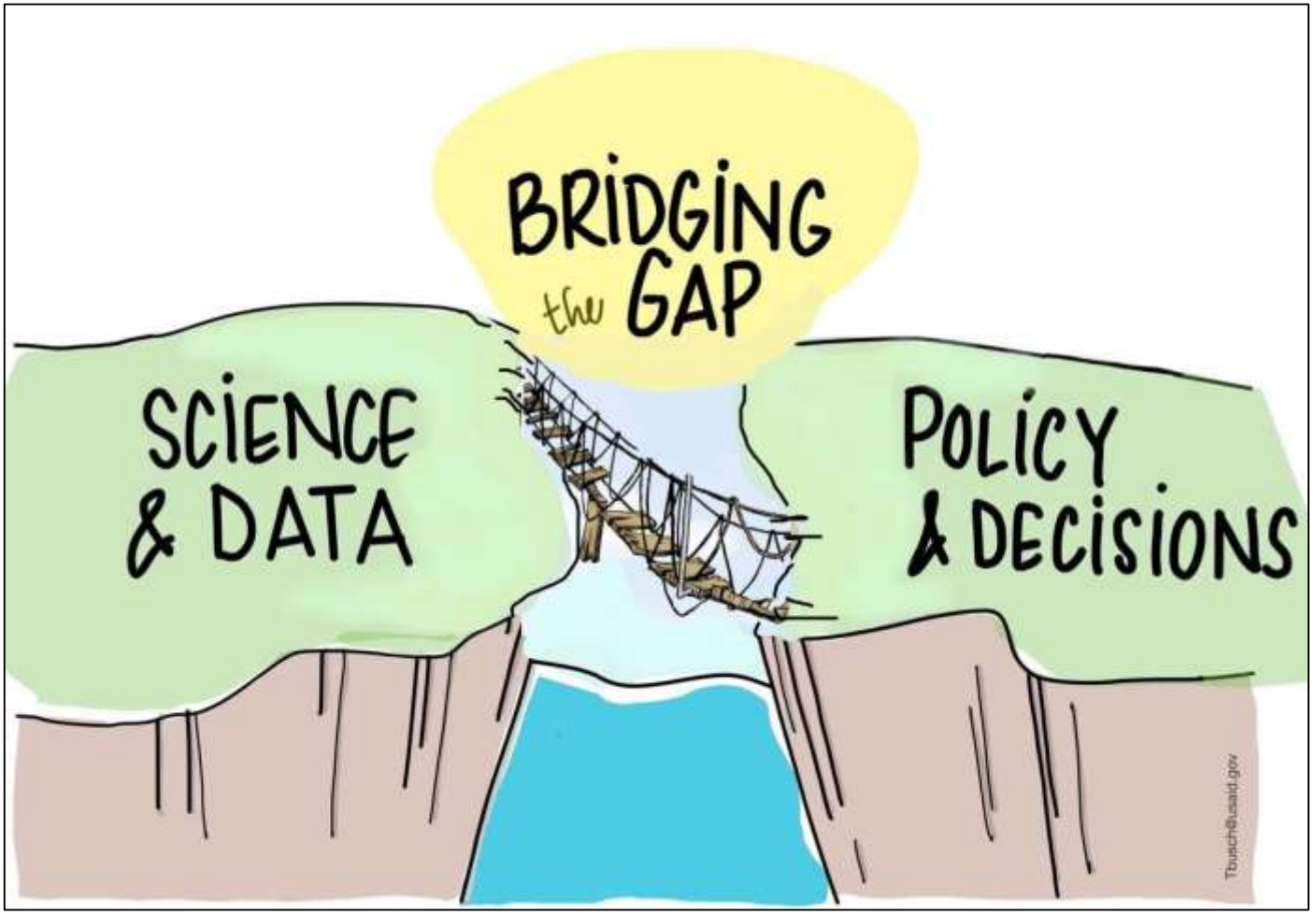
Published in 2017 by the Wisconsin Land and Water Conservation Association, available at https://wisconsinlandwater.org/programs/food-land-water-project

Published in 2019 by Wisconsin's Greenfire, available at https://wigreenfire.org/

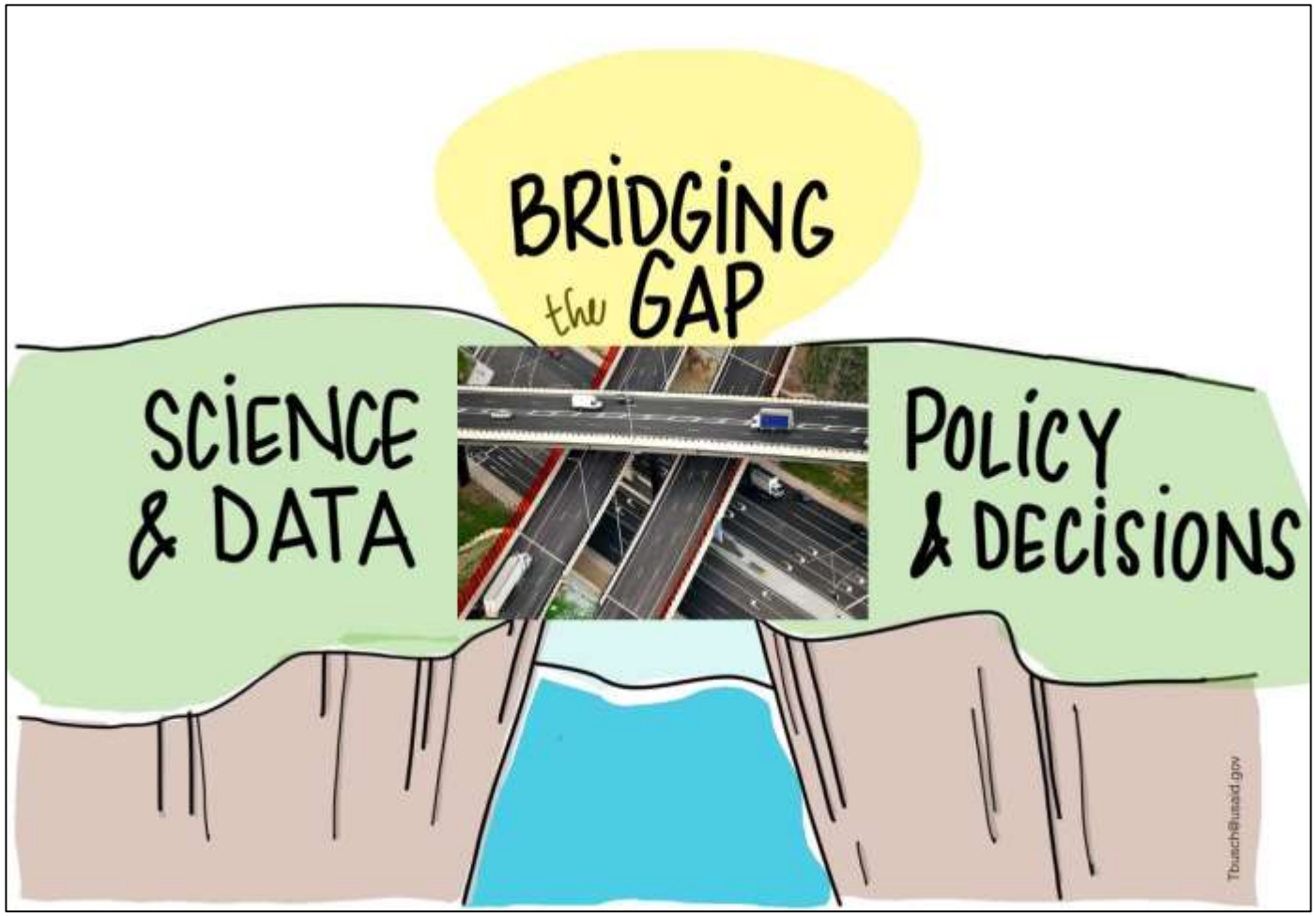
Recommendations for Improving Wisconsin's Water Quality

1. Connecting science to policy
2. Practices and studies
3. Funding

Connecting Science to Policy



Connecting Science to Policy

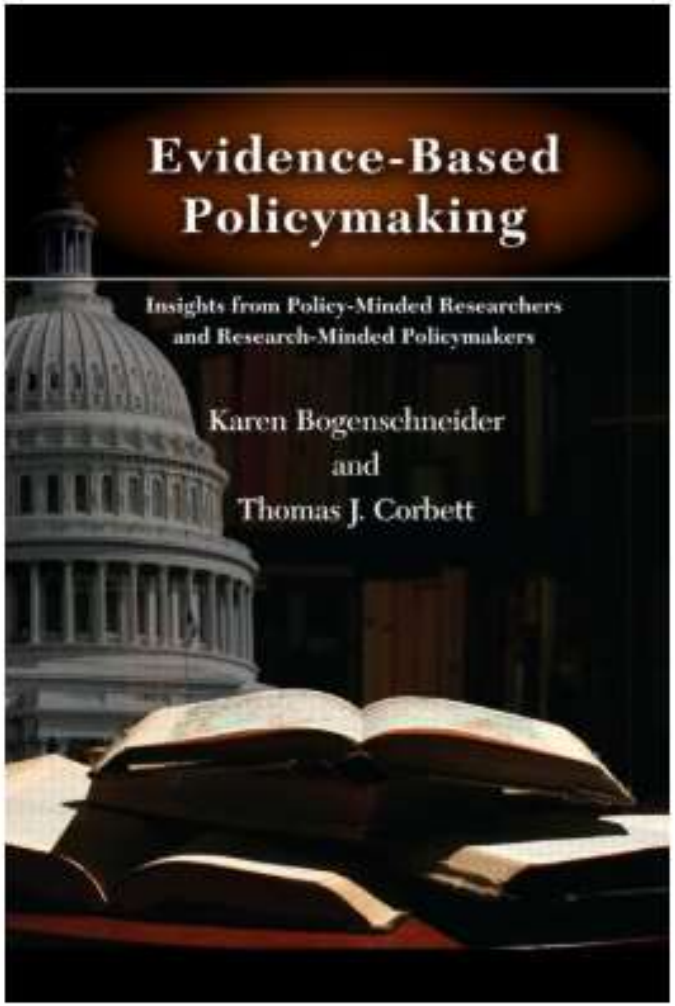


Connecting Science to Policy

- Systematic reviews:
  - A new tool for environmental management
  - Derived from medical research methods
  - Structured methods synthesize existing scientific evidence
  - Addresses specific question, problem, or policy
  - More information at The Collaboration for Environmental Evidence https://www.environmentalevidence.org/

Connecting Science to Policymakers

- Create opportunities for policymakers and water quality scientists to interact
- Topic based interactions, e.g., Wisconsin Family Impact Seminars, developed by Karen Bogenschneider at UW-Madison
- Casual interactions, e.g., Office Hours at the Capitol, sponsored by the La Follette School for Public Affairs



Recommendations continued… Practices and Studies

- Establish statewide, scientifically robust groundwater quality monitoring to assess trends and identify beneficial practices
- Determine effective setback distances between contamination sources and wells/surface waters using scientific studies
- Treatment is not the first option for drinkable private well water

Recommendations continued… Practices and Studies

- Look to the country of Denmark for practices for reducing high nitrate in the Central Sands groundwater.
- Multiple publications in the literature on Denmark's efforts.

Environ. Sci. Technol. **2011**, *45*, 228–234

Trend Reversal of Nitrate in Danish Groundwater - a Reflection of Agricultural Practices and Nitrogen Surpluses since 1950

BIRGITTE HANSEN,*,† LÆRKE THORLING,† TOMMY DALGAARD,† AND MOGENS ERLANDSEN§

Geological Survey of Denmark and Greenland (GEUS), Denmark, Department of Agroecology, Aarhus University, Denmark, and Department of Biostatistics, Aarhus University, Denmark

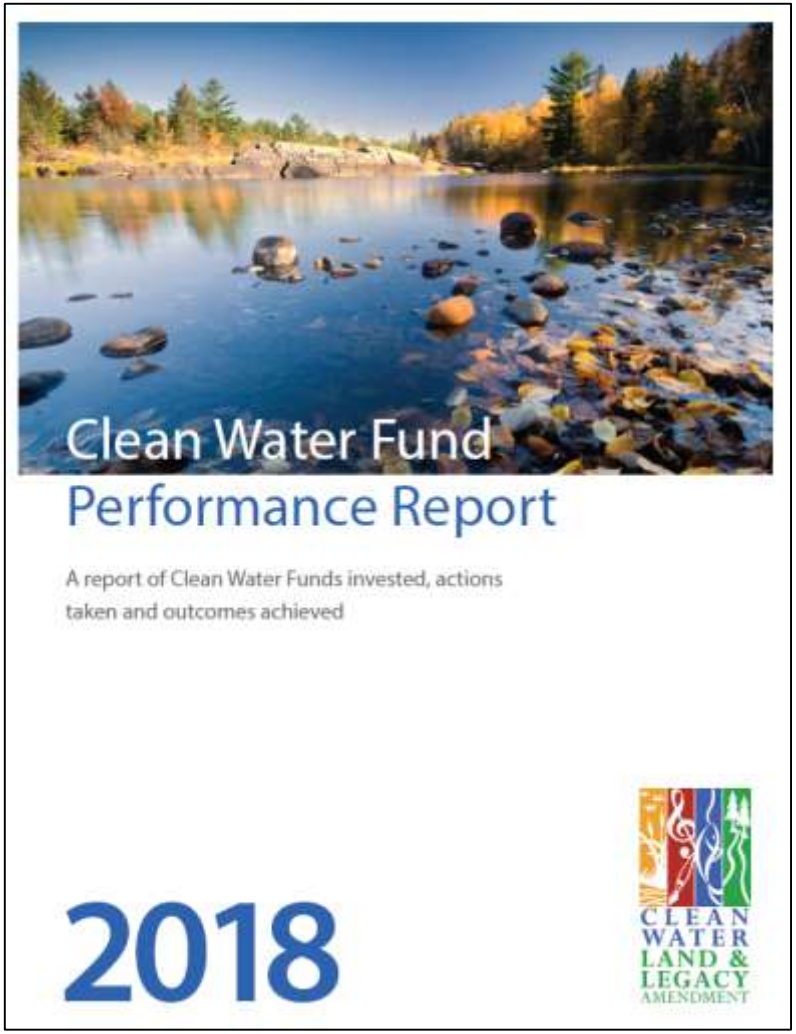
Received August 11, 2010. Revised manuscript received November 18, 2010. Accepted November 18, 2010.

Recommendations continued… Funding

- Enhance state and university laboratory water quality testing capabilities
- Fund counties to support scientific studies to address their local water quality issues
- Ensure adequate research funding for the Joint Solicitation for Groundwater Research administered by the State Groundwater Coordinating Council

Minnesota Clean Water, Land, and Legacy Amendment Fund

Hold statewide referendum whether Wisconsin, like Minnesota, should add 0.375% sales tax to fund improvements in water quality, wildlife habitat, parks, and the arts.



https://www.pca.state.mn.us/sites/default/files/lrp-f-3sy18.pdf

Preventing It from Hitting the Fan…

Working together Wisconsin scientists and policymakers can:

- Identify research priorities
- Generate ideas
- Test potential solutions

Contact Information
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