

# Water Supply and Distribution System Vulnerabilities

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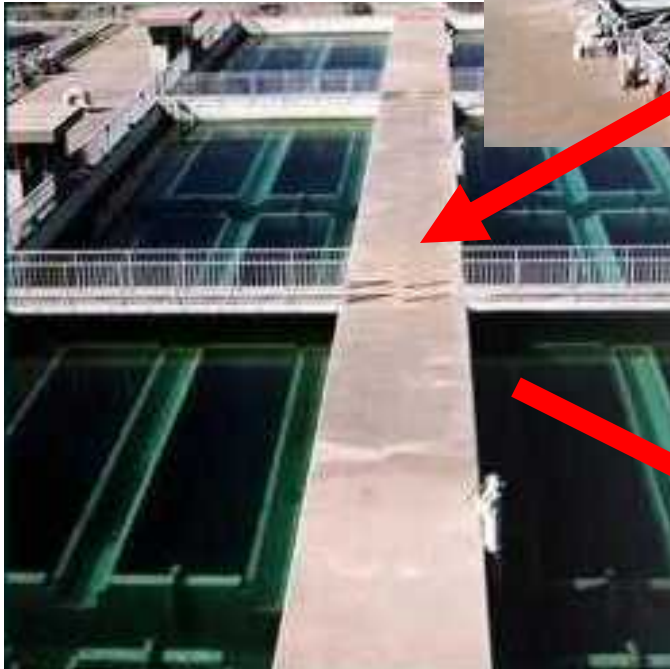
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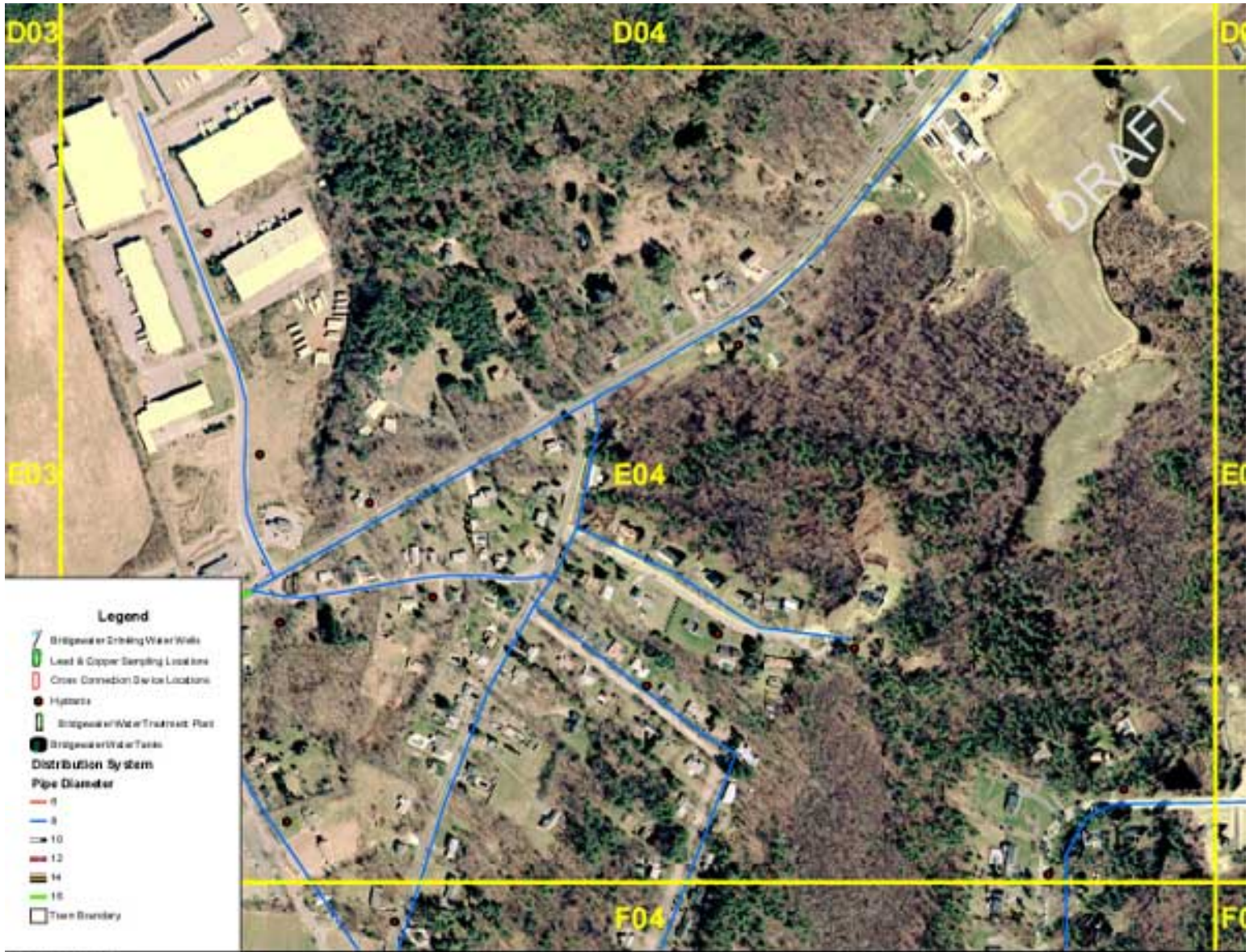
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# Drinking Water Systems





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**Civil and Environmental**

**Carnegie Mellon**

**ENGINEERING**



# Drinking Water Security

- The Homeland Security Presidential Directives (HSPDs) and the Public Health Security and Bioterrorism Preparedness and Response Act (Bioterrorism Act) of 2002 specifically denote the responsibilities of EPA and the water sector in:
  - Assessing vulnerabilities of water utilities
  - Developing strategies for responding to and preparing for emergencies and incidents
  - Promoting information exchange among stakeholders
  - Developing and using technological advances in water security

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  - **Developing and using technological advances in water security**

# Securing the Water Supply

- Prevention
  - limit access and secure critical infrastructure
  - Implement control measures to evaluate security and access restriction
  - Vigilance



# Securing the Water Supply

- Prevention

- limit access
- Implement controls
- access restrictions
- Vigilance



- Detection

- Develop methods to identify intrusion events and detect specific agents
- Evaluate vulnerabilities to place detectors at optimal locations to minimize effects following an intrusion
- Understand uncertainties

# Securing the Water Supply



[Home](#) > **Boil Water Notification**

## Boil Water Notice!

The City of Ann Arbor has issued a boil water notice for the following affected ar

\*\* [insert affected area](#) \*\*

If you are experiencing low water pressure, or have no water at all, please call (734) 994-XXXX.

If you are a Comcast Cable subscriber, please tune your TV to channel 16 for further information regarding the incident.

- Response

# Detection Focus: Objectives

- Develop drinking water quality models for distribution systems that allow prediction and evaluation of multiple potential chemical and biological threats
- Determine spatial and temporal resolutions necessary for *in situ* data collection sensor networks for real-time decision-making
- Improve methods for handling and interpreting real-time streaming data from *in situ* sensor networks.

# Detection: Current Distribution System Monitoring



24-48 hours for  
microbiological



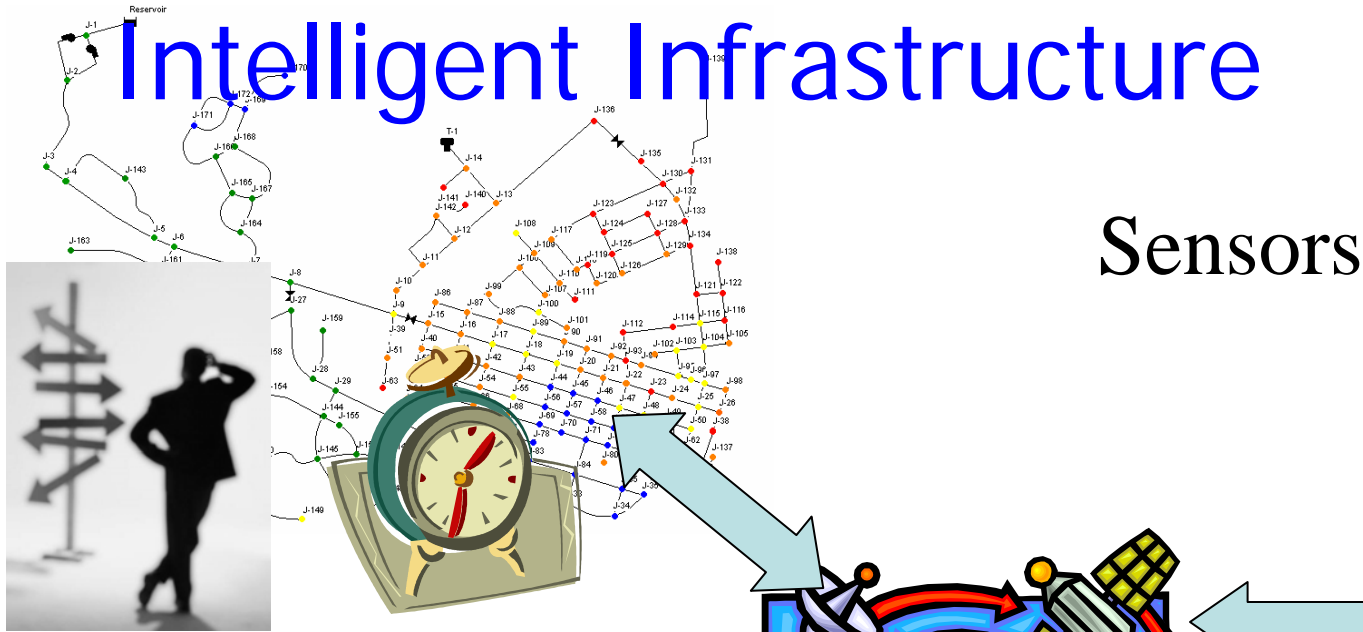
Minutes for  
chlorine

# Detection: What about Real-time?



Is detection sufficient?

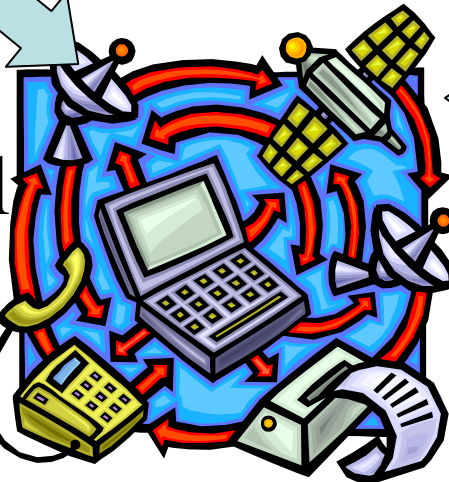
# Intelligent Infrastructure



Sensors



Application or model



Data Store

# Drinking Water Sensor Networks: what are the issues?

- Hardware – expensive, uses consumables, power requirements, cannot have 100% network coverage.
- Handling Data – too much data, sorting through what it all means in real-time, finding patterns
- Data Quality – false positives and false negatives, surrogates and undetectable contaminants
- Response – short term alerts, shifting to other water sources, bringing the system back on line, re-establishing consumer trust.

## Domain Knowledge



Top ranked Environmental Engineering Program with significant expertise in environmental modeling and water quality

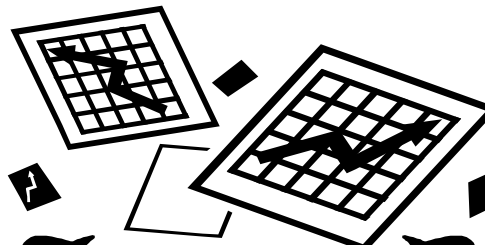
## Database Expertise



Top ranked Computer Science School with significant expertise in data handling and advanced knowledge discovery tools

## Managing Environmental Data Sensing

## Decision-Making

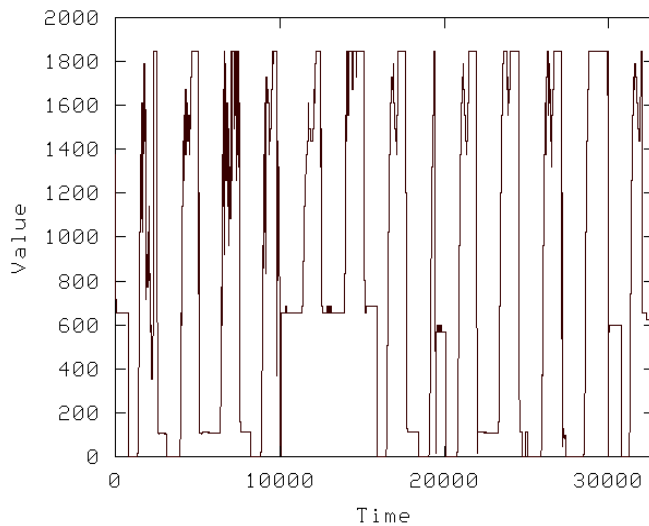
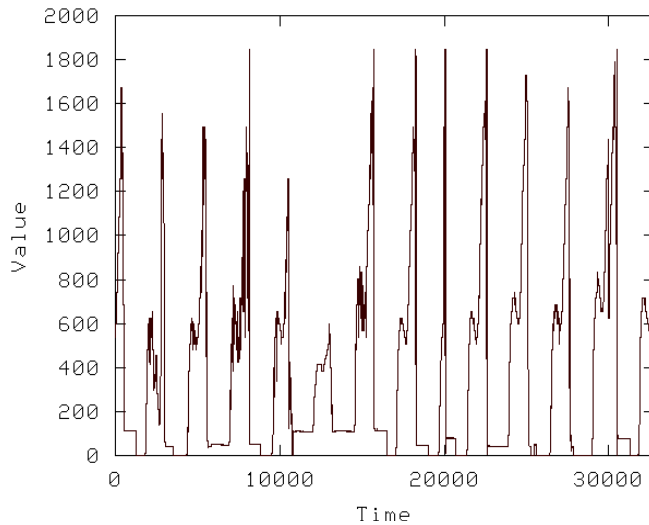


Unique Engineering and Public Policy Department that integrates social science expertise with engineering problems routinely and successfully

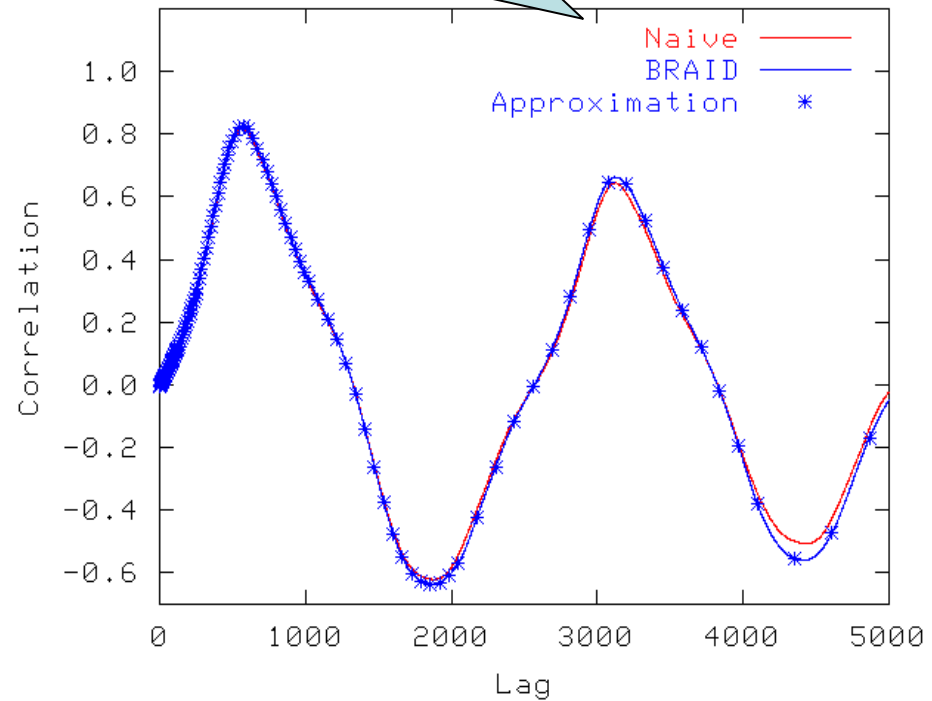
# Approach

- Coupling system modeling with data base development and data mining
- Evaluating methods to store data and predict future data streams from previous relationships among different sensors
- Coupling decision-support models with water distribution models

# Preliminary Results: sensor correlations



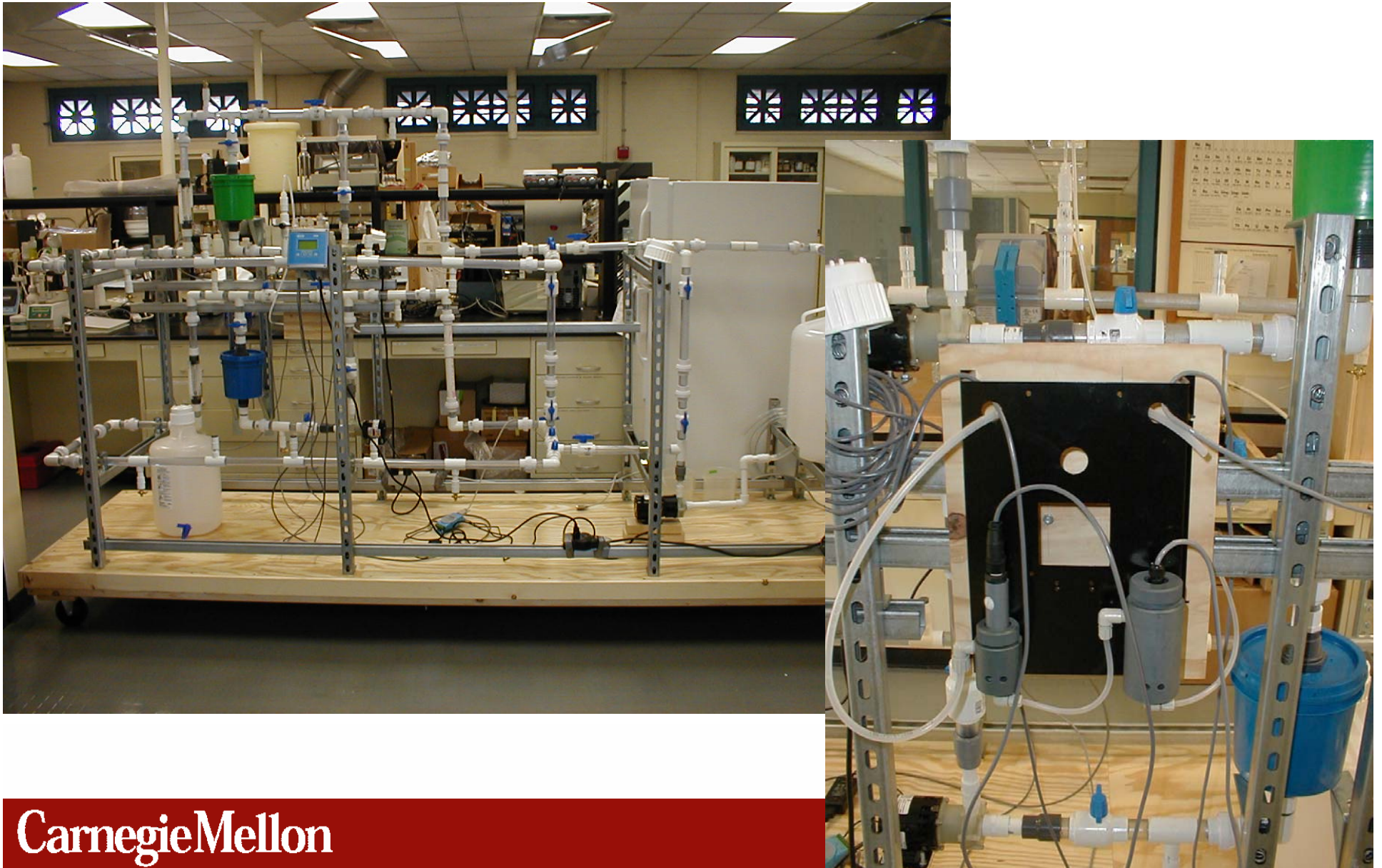
BRAID closely estimates the correlation coefficients



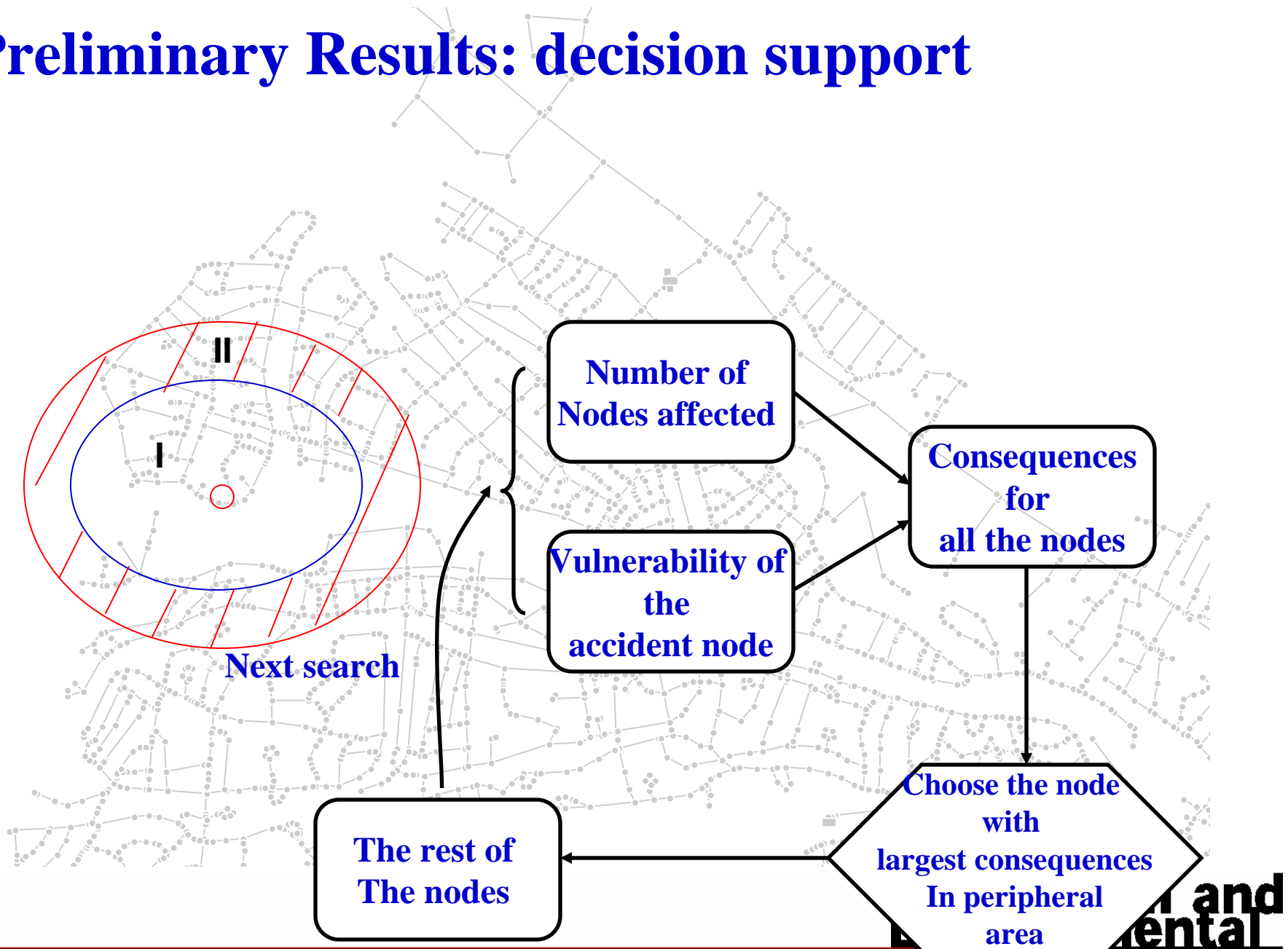
CCF (Cross-Correlation Function)



# Preliminary Results: chlorine surrogate



# Preliminary Results: decision support



# Acknowledgements

**Domain Knowledge**



Dr. Mitchell Small

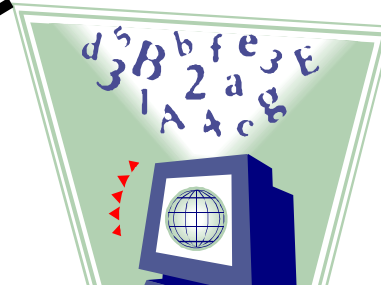
Dr. Jeanne VanBriesen

Damian Helbling

Shannon Isovitsch

Royce Francis

**Database Expertise**



Dr. Christos Faloutsos

Dr. Anastassia Ailamaki

Dr. Carlos Guestrin

Stratos Papadomanolakis

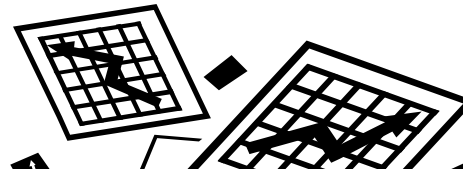
Jimeng Sun

Spiros Papadimitriou

**Managing Environmental  
Data Sensing**



**Decision-Making**



Dr. Paul Fischbeck

Stacia Thompson

Jianhua Xu

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## QUESTIONS?

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# Research Issues

- **Sensor Development:**
  - Detection of specific pathogens
  - Detection of viability of pathogens
  - Lower cost sensors
  - Sensors requiring no reagents
  - Multi-analyte sensors.
- **Data acquisition:**
  - Data that can be acquired are surrogates, not direct measure.
  - Some data are time-delayed. We collect today, have results of analyses in two days, so we know the state of the system two days ago.
  - Data from sensors are often related- understanding time lagged data streams.
  - May need query schedule for sensors with limited number of uses; how to know when to turn on sensor and when to turn off.
  - Event is low probability; need to work with data that are almost always ZEROs; how to evaluate when a change is significant and sound an alarm.
  - False Positive/ False Negative issues.

# Research Issues

- **Model generation:**
  - Flow models are very good, chemical/biological interaction models are still under development.
  - Models are limited by uncertainty in the physical infrastructure and the nature of the interactions among chemical/biological agents and infrastructure
  - Models are limited by uncertainty in the effect of chemical/biological agents and human agents. When do people stop drinking the water and why? When do people stop swimming in natural waters and why?
- **Decision support:**
  - Real time adjustments based on sensed data is currently done ad-hoc in systems, based generally on flow and presumption of quality or on limited quality data.
  - Human decision processes regarding water quality data are not well understood. See above: when and why do people stop using a recreational bathing beach?