Sustainable Water Resources Roundtable

Urban Issues
Kent Thornton, FTN
5 April 2005
Urban Issue Identification

1. WERF Project on Sustainable Water Resources Management
2. FTN Internal Discussion on Urban Issues
3. Other Engineering Firm Consultation
4. Current Issues In Arkansas
Urban Issues

● Some Are Black and White
  — Increased population
  — Altered land use
  — Pervious => Impervious area
  — Increased runoff
  — Increased pollutant loading
Urban Issues

● Some Different Shades
  — Developers
  — Property Owners
  — Regulators
  — Utilities
  — Public
  — Civil Society Institutions
Drivers of Urban Issues

- **Population Increase**
  - Increased water demand
  - Increased wastewater discharge
  - Increased stormwater discharge
  - Increased use conflicts
  - Human health

- **Population Increase**
  - Increased infrastructure
    - Transportation
    - Water/wastewater
    - Electricity/Gas, etc.
  - Increased regulation
  - Increased sprawl
  - Increased demand for services
Drivers of Urban Issues

• Altered Land Use
  – Increased impervious area
  – Flooding
  – Heat islands
  – Altered rainfall patterns
  – Streambank erosion, instability

• Altered Land Use
  – Increased sedimentation
  – Increased nutrient loading
  – Increased contaminant loading
  – Decreased biotic diversity
Contributors to Urban Issues

• Lack of:
  — Planning
  — Funding
  — Implementation
  — Quantified results (e.g., BMP effect.)
  — Quantified costs and benefits

• Lack of:
  — Education
  — Conflict Resolution
  — Forums for Coop. & Collaboration
  — Political Will
  — Perspective
Long-Term Urban Issues

- Regional Planning/Management
- Infrastructure Replacement
- Sustaining Water Demand vs Supply Management
- Reservoir Storage Reallocation
  - Quantity
  - Cost
Long-Term Urban Issues

- Water Rights, Uses, & Conflicts
- Reuse, Recycling, and Conservation
- Integrated Water Management
- Mental Models and Social Mindscapes
- Estimating True Value and Costs of Water
- Climate Change
Primary Issue: No Integration
Integration Perspective

1. Humans part of, not apart from, environment.

2. Water essential for life; every policy, regulation, practice, law, or activity directly/indirectly affects water.
   - e.g., TEA-21, Inner City Enterprise Zones, Urban Revitalization, Brownfields all contribute to resolving water issues.

3. Every sector benefits from sustainable water
Integrated Outcomes

Sustainable Water ⇒ Multiple Benefits

- **Actions:**
  - Stream Restoration
  - Economic Incentives
  - Pollutant Reduction
  - Urban Revitalization
  - Infrastructure Replace.
  - LID/ESD
  - Permeable Repavement
  - Urban Forests Mgt.
  - Energy & Water Conserv.
  - Institutional Educational Programs

- **Benefits:**
  - Restoration Industry & Jobs - Entrepreneurs
  - Efficient Q Allocation
  - Water Quality Improve.
  - Economic Develop.
  - Conflict Resolution
  - Urban Replumbing
  - Regionally Competitive
  - Water Reuse, Recycling
  - Social Amenities
Bottom Line

• Much of information needed to resolve urban water issues already exists.
• Has not been synthesized, integrated and used.
• Greatest Needs:
  – Systems Perspective
  – Integration
  – Education and Awareness
  – Adaptive Management
America’s Pathway to Sustainable Water Utility Management

Steve Allbee
Sustainable Water Resources
Roundtable, April 5-6, 2005
The Organization of This Presentation

- Glancing in the rear-view mirror.
- The state of play in asset management.
- The sustainable systems paradigm.
The Gap Report Released - -
WEFTEC 2002

- Purpose -- To reach a common quantitative understanding of the potential magnitude of investment needed to:
  - Address growing population and economic needs, and
  - Renew our existing aging infrastructure.

- The data is comparable, at order of magnitude level, with WIN & CBO reports.

http://www.epa.gov/owm/gapreport.pdf

Steve Allbee
Sustainable Water Resources
Roundtable, April 5-6, 2005
The Report Is Intended to Provide - - Transparent Numbers

- Estimates are made for water and wastewater, investment, cost and payments (2000-2019).
- Gap = Needs (-) Spending.
- The “gap” is not inevitable.
  - It is a starting point.
  - The impact can be somewhat mitigated.
  - Changes are needed to avoid it’s implications.
The Findings For The 20 Years - - (2000-2019)

<table>
<thead>
<tr>
<th></th>
<th>Clean Water</th>
<th>Drinking Water</th>
</tr>
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<tbody>
<tr>
<td>Capital</td>
<td>$122</td>
<td>$102</td>
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<tr>
<td>O&amp;M</td>
<td>$148</td>
<td>$161</td>
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<tr>
<td>Total</td>
<td>$271</td>
<td>$263</td>
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</table>

<table>
<thead>
<tr>
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<th>Clean Water</th>
<th>Drinking Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital</td>
<td>$21</td>
<td>$45</td>
</tr>
<tr>
<td>O&amp;M</td>
<td>$10</td>
<td>$0</td>
</tr>
<tr>
<td>Total</td>
<td>$31</td>
<td>$45</td>
</tr>
</tbody>
</table>

(Annual Rate of Increase - 3% Real)

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Sustainable Water Resources
Roundtable, April 5-6, 2005
The Primary Drivers of the Gap

- Another round of new investments to deal with a growing population & economy.
- For the first time, substantially adjusting financial approaches, to meet increasing demands for maintenance, repair, renewal and replacement associated with aging systems.
For The Last Several Decades
The Focus

Serving More People (In Millions)

<table>
<thead>
<tr>
<th>Year</th>
<th>1968</th>
<th>1972</th>
<th>1978</th>
<th>1996</th>
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</thead>
<tbody>
<tr>
<td>Total Plants</td>
<td>19,355</td>
<td>15,662</td>
<td>15,613</td>
<td>16,024</td>
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<tr>
<td>Less than Secondary</td>
<td>13.4%</td>
<td>19.9%</td>
<td>5.6%</td>
<td>1.1%</td>
</tr>
<tr>
<td>Secondary</td>
<td>48.7%</td>
<td>50.7%</td>
<td>58.2%</td>
<td>58.6%</td>
</tr>
<tr>
<td>More than Secondary</td>
<td>2.4%</td>
<td>17.6%</td>
<td>23.6%</td>
<td>27.6%</td>
</tr>
<tr>
<td>No Discharge</td>
<td>2.4%</td>
<td>10.2%</td>
<td>12.7%</td>
<td>12.7%</td>
</tr>
</tbody>
</table>

The Emerging Challenge

Additional Served Population
1996 to 2025 (In Millions)

Leveling Off of BODₚ Removal Efficiencies

The Additional Growth, Could Produce by 2016, BOD Loading to the Waters Similar to the Mid-1970s

A projection of increasing $\text{BOD}_u$ (Metric Tons Per Day)

The Network Reflects the Demographics of Urbanization
All Physical Assets Deteriorate

A projected deterioration pattern for 100 year pipe

Condition Classification

Excellent
Good
Fair
Poor
Very Poor

Percentage of Effective Life Elapsed

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The Average Age of the Pipe Network Will Increase Until 2050
More Pipe in Lower Condition Levels Will Impact Costs and Performance

- Excellent
- Good
- Fair
- Poor
- Very Poor
- Life Elapsed

1980

2000

2020

Approximately 2 - 2.5 Million Miles
Water / Wastewater: Public / Private
The Challenge Peaks After “2000 - 2019”
This Is Not A “All Broke Crisis”
But, Well on the Way to a
Systemic Problem

- Our systems are aging.

- The status quo will result in increased public health and environment risk.

- Failure to manage the assets based on life cycle costs will require more revenues over the long term to meet service objectives.

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EPA Has Identified Priority Target Areas

- Better management
- Water efficiency
- Full cost pricing
- Watershed approach
EPA Is An Important, But, Not the Primary Player

The One Thing That Is Critical To Sustainability Is That Utilities Are Able to Do Their Work Expertly
The Vast Majority of the Resources Come From Local Sources

Sources of funds from 1956 to 1994

Water Capital Federal
1.6%

Wastewater O&M
27.2%

Wastewater Capital Local
9.9%

Water Capital Local
19.0%

Water O&M
31.1%

Wastewater Capital Federal
11.2%
Bottom Line: Emergent Industry Profile

- Increasing aggregate demand – water and wastewater
- Diminishing available water resources
- Leveling of “production efficiencies”
- Increasing output restrictions
- Aging infrastructure

> **Result:** Increasingly expensive treatment options

- Aging customer base – more and more on fixed income
- Diminishing technical labor pool running larger and more sophisticated plants and facilities
- Outflow of knowledge with retiring labor base
- Increasing resistance to rate increases

> **Result:** Increasingly complex management environment
Becoming Expert at Maintenance, Repair, Renewal or Replacement Is the Heart of Managing a Successful Water or Wastewater Service
Least Cost Management of the Asset
Is About The Total Life Cycle Cost of Ownership

“A Dollar Spent is A Dollar Spent”

Operate  Acquire  Maintain  Renew

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Utilities Face Three Fundamental Management Decisions

- What are my work crews doing and where are they doing it?
- What Capital Improvements Projects (CIP) should be done and when?
- When to repair, when to renew and when to replace?

These decisions typically account for at least 80% of a utility’s annual expenditures!
The Focus Of Advanced Asset Management

Core Questions, Process & Life Cycle Cost
# The Five Core AM Questions

<table>
<thead>
<tr>
<th>Core Questions</th>
<th>1. What is the current state of my assets?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>What do I own?</td>
</tr>
<tr>
<td></td>
<td>Where is it?</td>
</tr>
<tr>
<td></td>
<td>What condition is it in?</td>
</tr>
<tr>
<td></td>
<td>What is its remaining useful life?</td>
</tr>
<tr>
<td></td>
<td>What is its economic value?</td>
</tr>
<tr>
<td></td>
<td>2. What is my required sustained Level Of Service?</td>
</tr>
<tr>
<td></td>
<td>What is the demand for my services by my stakeholders?</td>
</tr>
<tr>
<td></td>
<td>What do regulators require?</td>
</tr>
<tr>
<td></td>
<td>What is my actual performance?</td>
</tr>
<tr>
<td></td>
<td>3. Given my system, which assets are critical to sustained performance?</td>
</tr>
<tr>
<td></td>
<td>• How does it fail? How can it fail?</td>
</tr>
<tr>
<td></td>
<td>• What is the likelihood of failure?</td>
</tr>
<tr>
<td></td>
<td>• What does it cost to repair?</td>
</tr>
<tr>
<td></td>
<td>• What are the consequences of failure?</td>
</tr>
<tr>
<td></td>
<td>4. What are my best “minimum life-cycle-cost” CIP and O&amp;M strategies?</td>
</tr>
<tr>
<td></td>
<td>• What alternative management options exist?</td>
</tr>
<tr>
<td></td>
<td>• Which are most feasible?</td>
</tr>
<tr>
<td></td>
<td>5. Given the above, what is my best long-term funding strategy?</td>
</tr>
</tbody>
</table>

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The Asset Management Program Process

- Inventory Assets
- Assess Condition
- Determine Residual Life
- Determine Replacement $ & Date
- Set Target LOS

- What’s Critical
- Determine Appropriate Maintenance
- Determine Appropriate CIP
- Fund Your Strategy

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Core AAM Program Process Tools

System Layout; Data Hierarchy; Data Standards; Data Inventory

Condition Assessment, Rating Methodologies

Expected Life Tables; Decay Curves

Valuation; Life Cycle Costing

Demand Analysis; Balanced Scorecard; Performance Metrics

Inventory Assets

Assess Condition

Determine Residual Life

Determine Replacement $ & Date

Set Target LOS

Assign BRE Rating (Criticality)

Determine Appropriate Maintenance

Determine Appropriate CIP

Fund Your Strategy

Build the AMP

FMECA; Business Risk Exp; Delphi Technique

Root Cause; RCM; PdM; ORDM

Confidence Level Rating; Strategic Validation; ORDM

Renewal Annuity

Asset Mgt Plan, Policies & Strategy, Annual Budget

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The Pathway to Success In AAM Is Through Adoption of The Framework and Structure

1 Awareness
2 Systematic Application
3 Competence
4 Excellence
5 Sustainability

Time Is Required to Become Expert at the Content and Process
The Emerging Paradigm
Sustainable Management
“A Systems Approach to the Whole of What a Water Utility Does”
The Holistic View Of Sustainable Management Systems

Ecologically Sustainable Development (ESD)

- Public Accountability
- Environmental Management Systems (EMS)
- Business Management

OUTCOMES

- Compliance Management
- Asset Management (AM)
Emulate The Key Characteristics of Sustainable Utilities

- Sustainable Objectives Set for Economic, Social & Environmental
- Right Sized To Professionally Manage Task
- Stewardship of the Total Water Cycle
- Business Focus On Efficiency & Customer Service
- Excellence in Demand Management / Asset Management
- Highly Developed Risk Management Skills & Techniques
- Robust Regulatory Framework Rewards Best Practice
- A Structured Set Of Policies, Procedures & Practices Externally Audited

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Additional Skills Will Be Required to Become a Sustainable Business

The Focus of Our Current Competencies

- Leadership Skills
- Governance Skills
- Business System & Data Skills
- Asset Management Skills

Existing Core Knowledge

The Opportunity For Growth On The Pathway to Excellence

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Have A Great Day!
Sustainable Water Resources: Drinking Water Issues

Janice Skadsen
Water Quality Manager
City of Ann Arbor
Key Issues for Drinking Water

- Quantity
- Quality
- Cost
Quantity

Ground and Surface Waters

- “Great Lakes” unlimited supply
- Local impacts can limit surface and ground waters availability
- Ground and surface systems are integrally linked
Drinking Water Systems

- Over 2500 drinking water systems in Michigan rely on Groundwater
- Approximately 75 rely on surface waters
Droughts

- Decreased lake levels, river flows, water table levels impact utilities ability to withdraw sufficient water
- Droughts occur at same time as highest water demands
Competition for Resources

- Multiple water users
- Run of river & pond level requirements
- Recreational usage
- Environmental needs
Quality

- Contamination
- Point & Non-Point Discharges
- Eutrophication
- Invasive species
- Natural constituents
- Emerging issues
- Climate change
Contamination

- Persistent
- Increased loading
- New
- New detection methods
- Lower detection limits
Point & Non-Point Discharges

- Distance between wastewater discharge and drinking water intake typically <5 miles
- Increasing population
- Manufacturing
- Changing land use
Figure 3. Critical assessment zone (CAZ) for the Ann Arbor water supply, Ann Arbor, MI.
Eutrophication

- Increasing nutrients concentrations
- Land use changes
- Increasing population
Natural Constituents

- Arsenic
- Iron
- hardness
Emerging Issues

- Pharmaceuticals
- Endocrine disruptors
- Personal care products

- Medical applications
- NDMA, perchlorate, MTBE

Study to trace new chemicals in city water

U.S. study found chemicals in 80% of sampled streams
Huron River:
PPCPs

<table>
<thead>
<tr>
<th>Concentration (ppb)</th>
<th>February</th>
<th>April</th>
<th>June</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfamethoxazole</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trimethoprim</td>
<td></td>
<td>0.010</td>
<td></td>
</tr>
<tr>
<td>Acetaminophen</td>
<td>0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbamazepine</td>
<td>0.001</td>
<td>0.010</td>
<td></td>
</tr>
<tr>
<td>Ibuprofen</td>
<td>0.010</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>Caffeine</td>
<td>0.100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Climate Change

- Rainfall & snowfall
- Recharge
- Storm impacts
  - Turbidity
  - Microbial degradation
  - Chemical changes
Cost

• Protection of watersheds
• Increasing costs of treatment
• Increasing regulations
• Increasing O&M costs
• Affordability essential
Aging Infrastructure

- Estimated that over $1 trillion dollars needed to repair replace decaying water/wastewater infrastructure
Research needs: quantity

• Interrelationship between ground and surface waters
• Impacts of climate change
• Water conservation
  – Methods for the Midwest
  – Public acceptance
• Impacts of land use
• Protection of water resources
  – Communication
  – Commitment
  – Priority
  – Effectiveness
Research needs: quality

- Disconnect between point/nonpoint sources versus drinking water supply
- Nutrient reduction
- New contaminants
- Health effects of contaminants
- Spill detection and response
- Source tracking
Conclusions

• Quantity and quality are critical for the production of drinking water
• The more reliable the quantity and the higher quality of the source, the better the quantity and quality of the drinking water
• Goal is to protect public health
• Cost: must be affordable
Risks in Urban Water Management: Current and Future Water Needs

Peter Adriaens, Ph.D.
Environmental and Water Resources Engineering and Natural Resources and Environment
Contents

- Framing the question: “Urban water risk and risk management in 21st century”
- Challenges I: Infrastructure report card
- Challenges II: Waterborne diseases
- Challenges III: Emerging contaminants
- Challenges IV: Vulnerability of water supply systems
- Conclusions
Urban Water Challenges: 20\textsuperscript{th} vs 21\textsuperscript{st} century

- Acute problems
- Short-term impacts
- Technical probability certain
- High cost/benefit ratio
- Public perception of risk clear

- Chronic problems
- Long-term benefits?
- Technical probability uncertain
- Cost/benefit ratio uncertain
- Public perception of risk unclear
Society no longer has the luxury of using water only once.
Urban Use: Stretching the water supply through recycling

The introduction of wastewater into drinking water aquifers and surface water has become an important element in water resource planning to stretch a scarce resource.

The potential health and ecological effects of exposure to recycled water are not well understood.
Urban Water Challenges: I. Water-Borne Diseases

- Widespread contamination of surface waters and shallow wells by multiple pathogens (e.g. *Giardia* or *Cryptosporidium* in 5-50% of well and springs)
- From 6-40% of gastrointestinal illness is water related
- Need for disinfection complicates picture due to emerging evidence of disinfection by-products
- Limited effectiveness of disinfection to control most common pathogens
- Re-emerging pathogens and antibiotics
- Transfer of molecular detection methods for target pathogens and their infectivity from the research laboratory to the field
### Major Infectious Agents in Contaminated Drinking Water

<table>
<thead>
<tr>
<th>Organism</th>
<th>Disease</th>
<th>Primary sources</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bacteria</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Campylobacter</em></td>
<td>Gastroenteritis</td>
<td>Human feces</td>
</tr>
<tr>
<td>Enteropathogenic <em>E. coli</em></td>
<td>Gastroenteritis</td>
<td>Human feces</td>
</tr>
<tr>
<td><em>Salmonella</em> (1700 spp.)</td>
<td>Typhoid fever/salmonellosis</td>
<td>Human/animal feces</td>
</tr>
<tr>
<td><em>Shigella</em> (4 spp.)</td>
<td>Bacillary dysentery</td>
<td>Human feces</td>
</tr>
<tr>
<td><em>Vibrio cholerae</em></td>
<td>Cholera</td>
<td>Human feces</td>
</tr>
<tr>
<td><em>Yersinia enterocolitica</em></td>
<td>Gastroenteritis</td>
<td>Human/animal feces</td>
</tr>
<tr>
<td><em>Legionella pneumonophila</em></td>
<td>Acute respiratory illness</td>
<td>Thermally enriched waters</td>
</tr>
<tr>
<td><strong>Viruses</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adenovirus</td>
<td>Upper respiratory and gastrointestinal illness</td>
<td>Human feces</td>
</tr>
<tr>
<td>Enteroviruses (71 types)</td>
<td>Aseptic meningitis poliomyelitis</td>
<td>Human feces</td>
</tr>
<tr>
<td>Hepatitis A</td>
<td>Infectious hepatitis</td>
<td>Human feces</td>
</tr>
<tr>
<td>Norwalk virus</td>
<td>Gastroenteritis</td>
<td>Human feces</td>
</tr>
<tr>
<td>Reovirus</td>
<td>Mild upper respiratory and gastrointestinal illness</td>
<td>Human/animal feces</td>
</tr>
<tr>
<td>Rotavirus</td>
<td>Gastroenteritis</td>
<td>Human feces</td>
</tr>
<tr>
<td>Coxackie virus</td>
<td>Aseptic meningitis</td>
<td>Human feces</td>
</tr>
<tr>
<td><strong>Protozoans</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Balantium coli</em></td>
<td>Balantidiasis (dysentery)</td>
<td>Human feces</td>
</tr>
<tr>
<td><em>Cryptosporidium entamoeba</em></td>
<td>Amoebic dysentery</td>
<td>Human feces</td>
</tr>
<tr>
<td><em>histolytica</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Giardia lamblia</em></td>
<td>Giardiasis (gastroenteritis)</td>
<td>Human feces</td>
</tr>
</tbody>
</table>
Waterborne Disease Outbreaks Associated with Drinking Water (n=17)

- Chemical poisoning
- Infectious or suspected infectious etiology

Chart showing the number of outbreaks from January 1997 to December 1998.
## Disease Outbreaks: Etiology and Type of Water System

<table>
<thead>
<tr>
<th>Etiologic agent</th>
<th>Community</th>
<th>Noncommunity</th>
<th>Individual</th>
<th>Total</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Outbreaks</td>
<td>Outbreaks</td>
<td>Outbreaks</td>
<td>Outbreaks</td>
</tr>
<tr>
<td>AGI</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Copper</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cryptosporidium parvum</td>
<td>1</td>
<td>1,400</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Escherichia coli O157:H7</td>
<td>1</td>
<td>157</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Giardia intestinalis</td>
<td>2</td>
<td>57</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Shigella sonnei</td>
<td>1</td>
<td>83</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total (%)</td>
<td>8</td>
<td>1,744</td>
<td>5</td>
<td>252</td>
</tr>
</tbody>
</table>

*Community and noncommunity water systems are public water systems that serve ≥15 service connections or an average of ≥25 residents for ≥60 days/year. A community water system serves year-round residents of a community, subdivision, or mobile home park with ≥15 service connections or an average of ≥25 residents. A noncommunity water system can be nontransient or transient. Nontransient systems serve ≥25 of the same persons for >6 months of the year (e.g., factories or schools), whereas transient systems do not (e.g., restaurants, highway rest stations, or parks). Individual water systems are small systems not owned or operated by a water utility that serve <15 connections or <25 persons.

*Acute gastrointestinal illness of unknown etiology.
# Type of Deficiency

<table>
<thead>
<tr>
<th>Type of deficiency*</th>
<th>Community</th>
<th>Noncommunity</th>
<th>Individual</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Outbreaks</td>
<td>(%)</td>
<td>Outbreaks</td>
<td>(%)</td>
</tr>
<tr>
<td>Untreated surface water</td>
<td>0</td>
<td>(0.0)</td>
<td>0</td>
<td>(0.0)</td>
</tr>
<tr>
<td>Untreated groundwater</td>
<td>2</td>
<td>(25.0)</td>
<td>0</td>
<td>(0.0)</td>
</tr>
<tr>
<td>Inadequate treatment</td>
<td>3</td>
<td>(37.5)</td>
<td>3</td>
<td>(60.0)</td>
</tr>
<tr>
<td>Distribution system</td>
<td>3</td>
<td>(37.5)</td>
<td>2</td>
<td>(40.0)</td>
</tr>
<tr>
<td>Miscellaneous or unknown</td>
<td>0</td>
<td>(0.0)</td>
<td>0</td>
<td>(0.0)</td>
</tr>
<tr>
<td>Total</td>
<td>8</td>
<td>(100.0)</td>
<td>5</td>
<td>(100.0)</td>
</tr>
</tbody>
</table>

*Community and noncommunity water systems are public water systems that serve ≥15 service connections or an average of ≥25 residents for ≥60 days/year. A community water system serves year-round residents of a community, subdivision, or mobile home park with ≥15 service connections or an average of ≥25 residents. A noncommunity water system can be nontransient or transient. Nontransient systems serve ≥25 of the same persons for ≤6 months of the year (e.g., factories or schools), whereas transient systems do not (e.g., restaurants, highway rest stations, or parks). Individual water systems are small systems not owned or operated by a water utility that serve <15 connections or <25 persons.

*1-untreated surface water; 2-untreated groundwater; 3-treatment deficiency (e.g., temporary interruption of disinfection, chronically inadequate disinfection, and inadequate or no filtration); 4-distribution system deficiency (e.g., cross-connection, contamination of water mains during construction or repair, and contamination of a storage facility); and 5-unknown or miscellaneous deficiency (e.g., contaminated bottled...
• The median duration of illness was 9 days (range, 1 to 55).
• Among 285 people surveyed who had laboratory-confirmed cryptosporidiosis, the clinical manifestations included watery diarrhea (93 %), abdominal cramps (84 %), fever (57 %), and vomiting (48 %).
• Estimated 403,000 people had watery diarrhea attributable to this outbreak.

Mac Kenzie et al., NEJM (1994)
Impacts of Global Warming

- Increased algal blooms in inland systems (odor, taste, biotoxins)
- Higher microbial and nutrient loadings
- Increased heavy rains and flooding associated with waterborne disease outbreaks
- Increased urban water consumption (irrigation, lawn watering, drinking water, etc…)
Waterborne Disease Outbreaks and Extreme Precipitation Events
Although pharmaceuticals and industrial chemicals have dramatically improved quality of life worldwide, the presence of residual materials and byproducts in reclaimed water has introduced new challenges to the engineering community.

As new types of chemicals are introduced into the waste stream, the water reclamation community finds itself fighting an elusive battle to address new and emerging contaminants of concern.

Currently, a gap exists between what analytical methodology can detect and the composition of reclaimed water, particularly with respect to analytes that could pose uncertain and potentially long-term health risks.
Most Frequently Detected 'Emerging Contaminants' in the Nation's Streams

Based on 139 streams in 30 states:
Hormones, personal care products, pharmaceuticals, antibiotics, flame retardants, insect repellants...
Analytical Challenges for Sensing/Monitoring Networks

Analytical methods for trace organic compounds and endocrine disrupters

Various chemical and biological assays can detect trace organic compounds in water, but each method’s detection limits and reliability differ. In lieu of exhaustive chemical monitoring, enzyme-linked immunosorbent assays (ELISAs) and in vivo and in vitro bioassays can detect the low-level effective ranges required to detect endocrine disrupters.
Urban Water Challenges: III. Vulnerability of Water Supply Systems

- Infrastructure
  - ASCE Report card (March 2005): E
  - Need to invest $151 bn. over next two decades to maintain water infrastructure and ensure safe and healthy community water supplies
  - Need to increase current wastewater infrastructure investment by $19 bn. per year
Chlorine tolerance of biological weapons agents considered water threats:
- Anthrax – spores resistant
- Brucellosis – unknown
- C. perfringens – resistant
- Tularemia – inactivated (1 ppm, 5 min)
- Shigellosis – inactivated (0.05 ppm, 10 min.)
- Cholera – ‘Easily killed’
- Plague – unknown
- Botulinum toxins – inactivated (6 ppm, 20 min)
- T-2 mycotoxin – resistant
- ...

Need for water infrastructure ‘hardening’ (access, monitoring, etc...)
Contaminant Propagation in Water Systems

- Water distribution systems are far flung and made up of different hydraulic elements
- Complex contaminant dispersion
- Near impossible source tracking
- Simulation North Penn Water Authority: complete dispersion after 24 hrs; disappearance after 34 hrs.
Conclusions

- The state of public water infrastructure is inadequate to even meet current needs; future needs include hardening of public water infrastructure
- Land-use pressures will challenge watershed sharing
- Short-circuiting of water cycle results in increased recycling of water, exhibiting health implications
- Needs for increased monitoring for emerging target pathogens
- Balance disinfection needs and DBP exposure
- Needs for methodology to monitor emerging contaminants and biology