Water Reuse: Potential for Expanding the Nation's Water Supply Through Reuse of Municipal Wastewater

Committee on the Assessment of Water Reuse as an Approach to Meeting Future Water Supply Needs

National Research Council

Rhodes Trussell, Committee Chair

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NRC Staff:
Stephanie Johnson (Study Director), Sarah Brennan, and Steven Russell

Study Charge

1. **Contributing to the nation's water supplies**. What are the potential benefits of expanded water reuse and reclamation? What is the suitability of processed wastewaters for various purposes?
   - *Focused on municipal wastewater*.
2. **Assessing the state of technology**. What is the current state-of-the-technology in wastewater treatment and production of reclaimed water? What are the current technology challenges and limitations?
3. **Assessing risks**. What are the human health risks of using reclaimed water? What are the risks of using reclaimed water for environmental purposes? How effective are monitoring, control systems, and the existing regulatory framework in assuring the safety and reliability of wastewater reclamation practices?

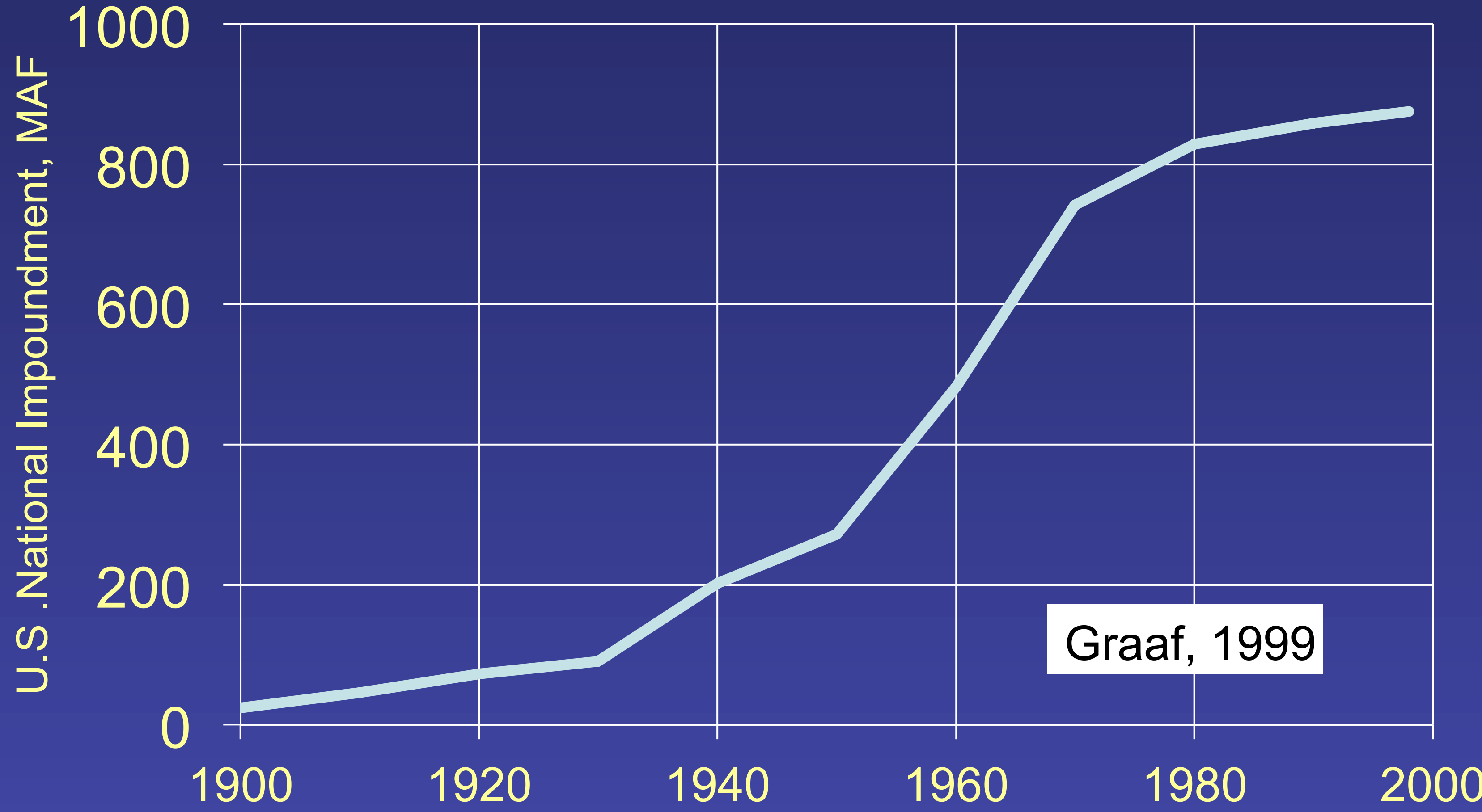
Study Charge (cont.)

4. **Costs**. How do the costs (including environmental costs) and benefits of water reclamation and reuse generally compare with other supply alternatives?
5. **Barriers to implementation**. What implementation issues limit the applicability of water reuse to help meet the nation's water needs and what, if appropriate, are means to overcome these challenges?
6. **Research needs**. What research is needed to advance the safe, reliable, and cost-effective reuse of municipal wastewater where traditional sources of water are inadequate? What are appropriate roles for governmental and non-governmental entities?

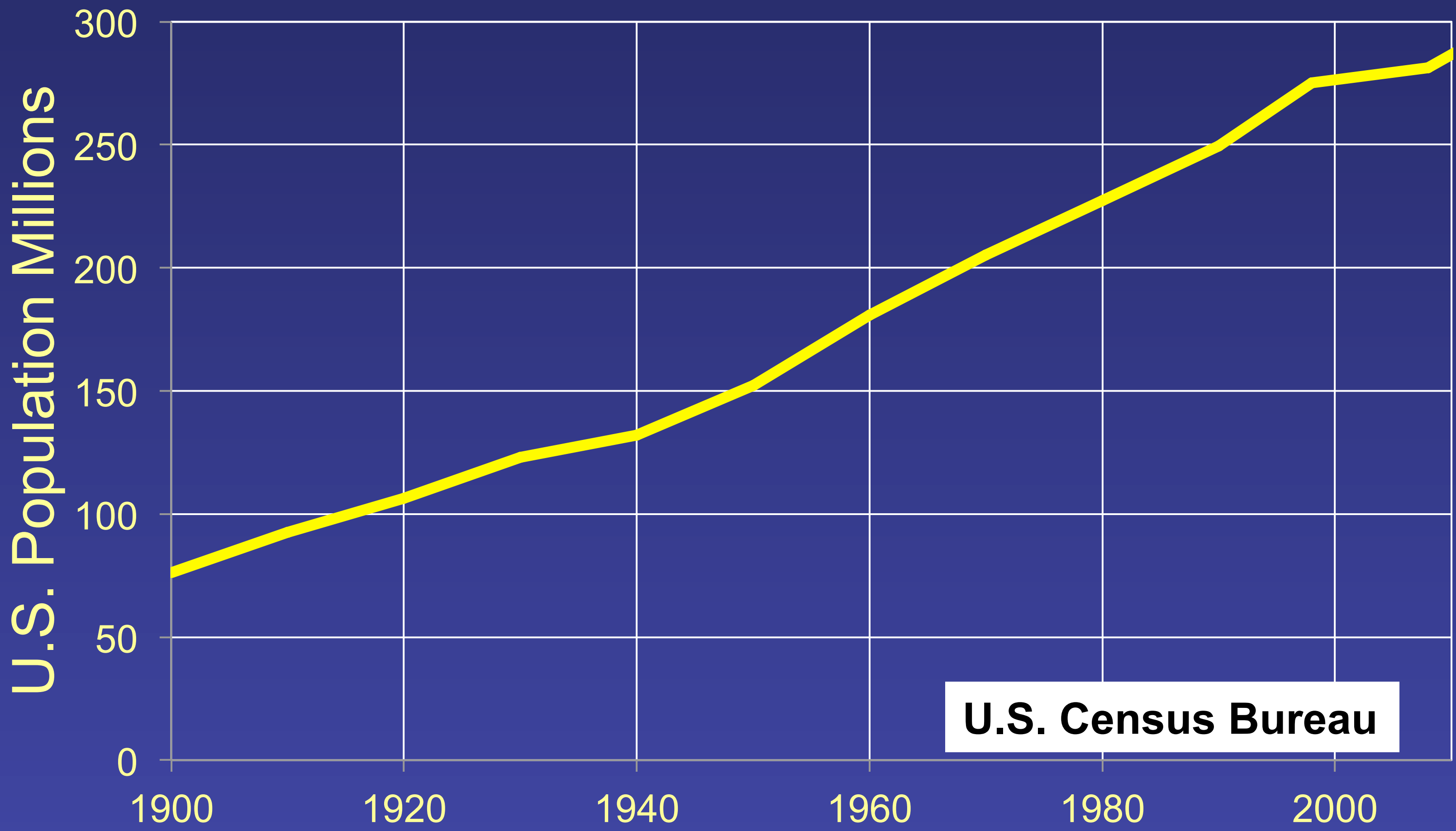
Study Process

- 8 meetings (5 information gathering):
    1. Irvine, CA - Dec. 2008
    2. San Francisco, CA - Jun. 2009
    3. Golden, CO - Jul. 2009
    4. Orlando, FL - Oct. 2009
    5. Washington, D.C. - Jan. 2010
    6. Woods Hole, MA - Jun. 2010
    7. Irvine, CA - Sept. 2010
    8. Dallas/Ft. Worth, TX - Jan. 2011
- Briefings/presentations from many individuals, agencies and organizations
- Included original data analysis and survey of utilities for reuse costs
- Peer-reviewed consensus report

In The 20th Century, The U.S. Saw The Construction of Major Water Infrastructure



There Was Also Major Population Growth During That Period



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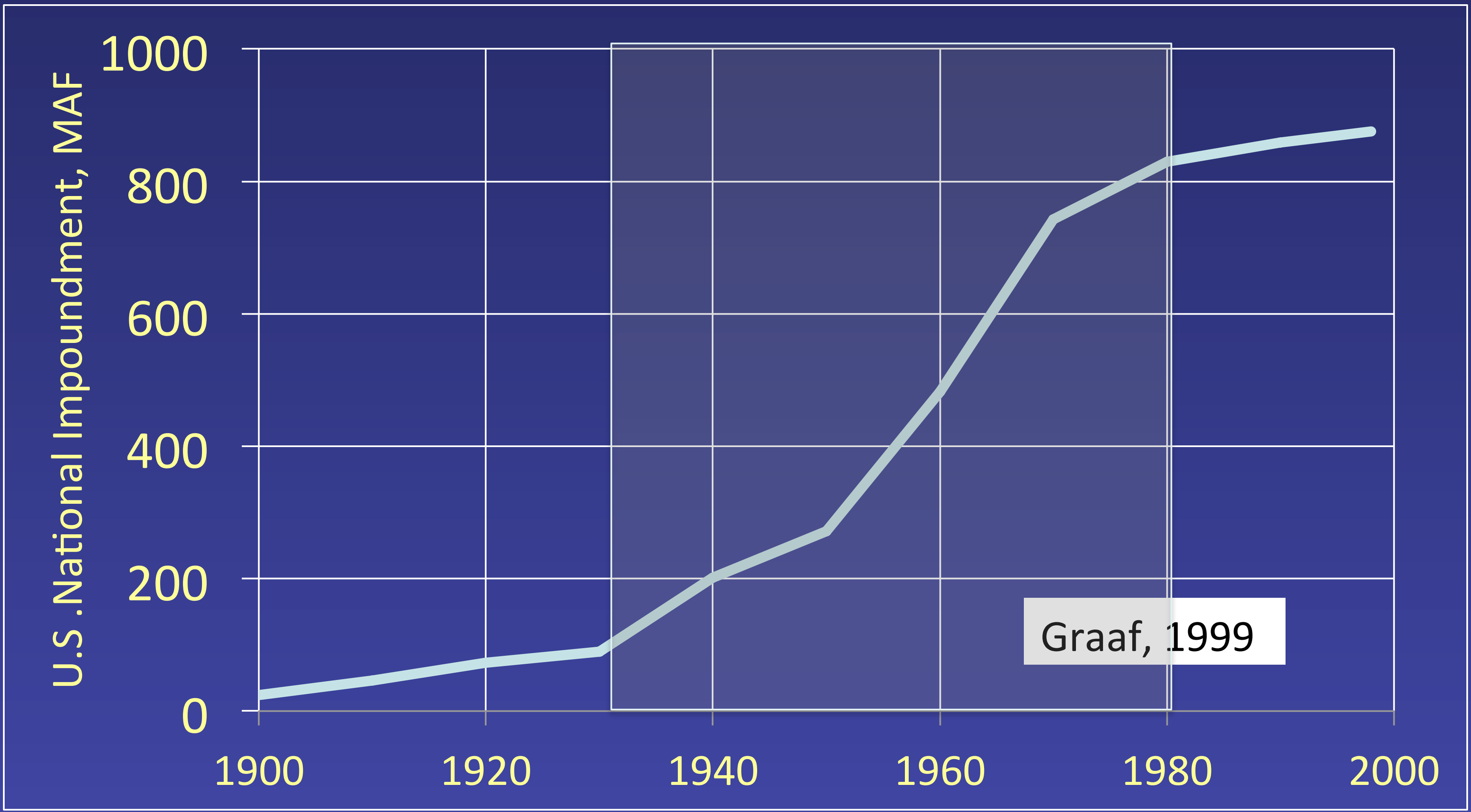
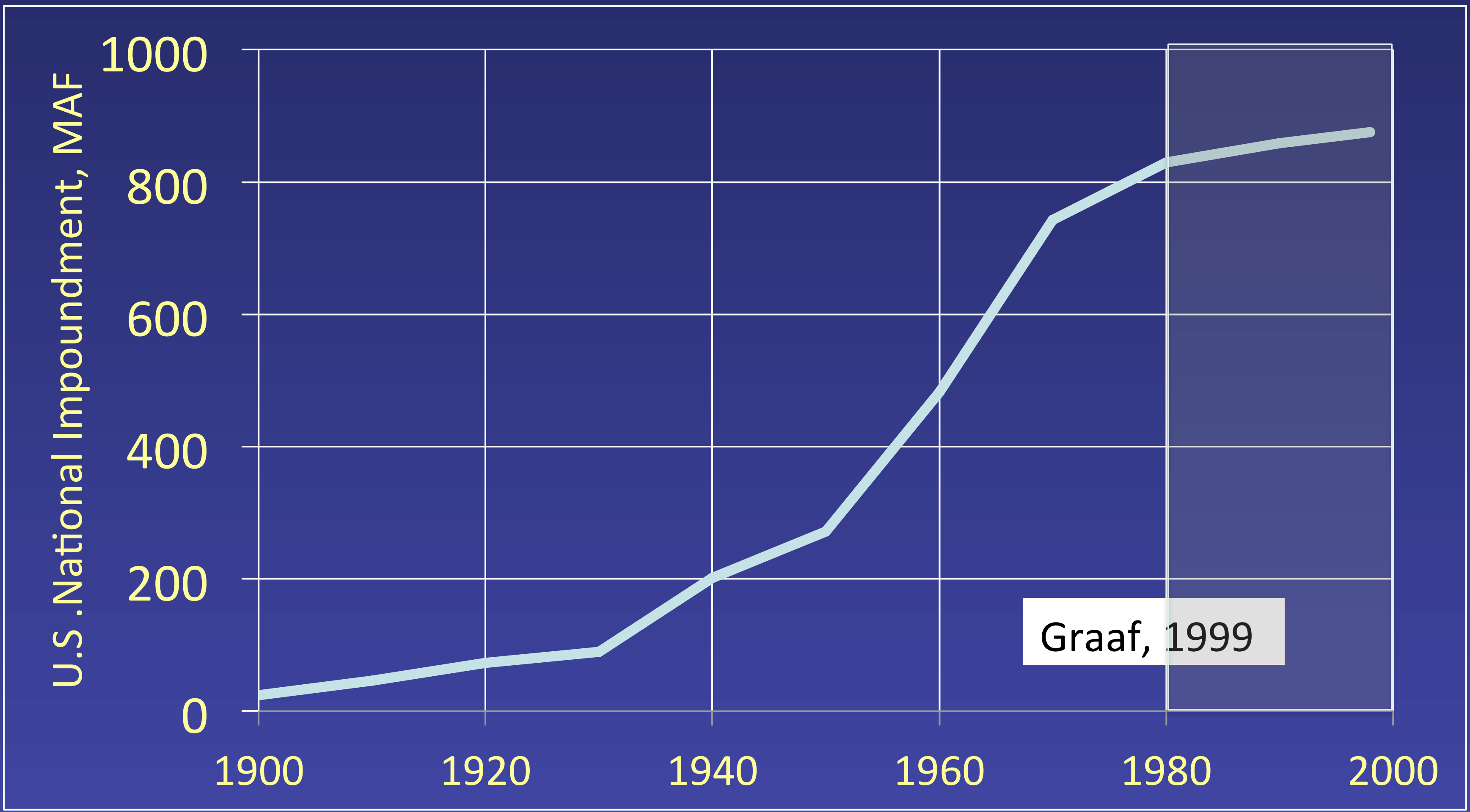
Most of That Infrastructure Was Built Between 1930 & 1980



Since 1980, Construction Has Been Pretty Flat



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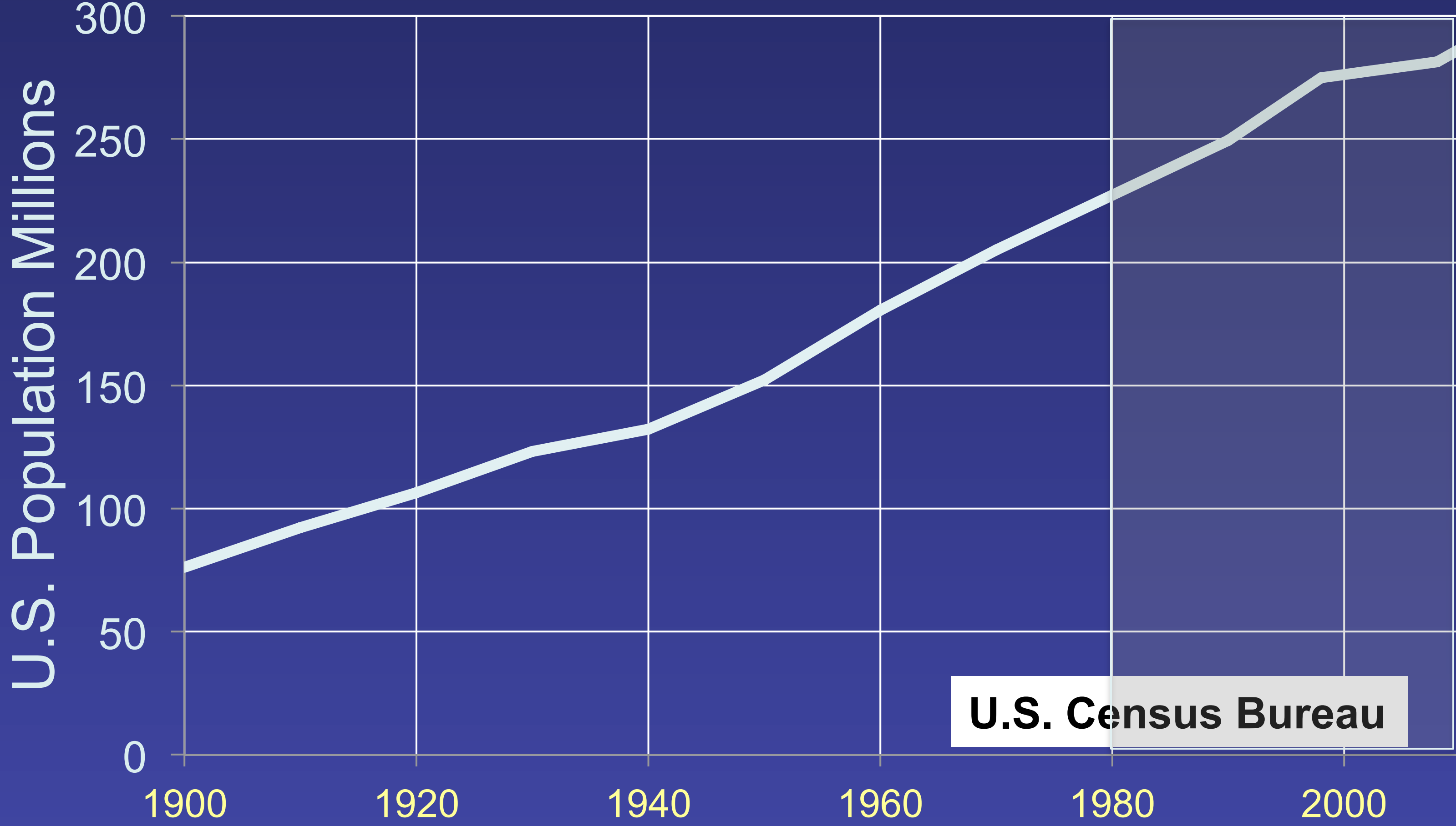
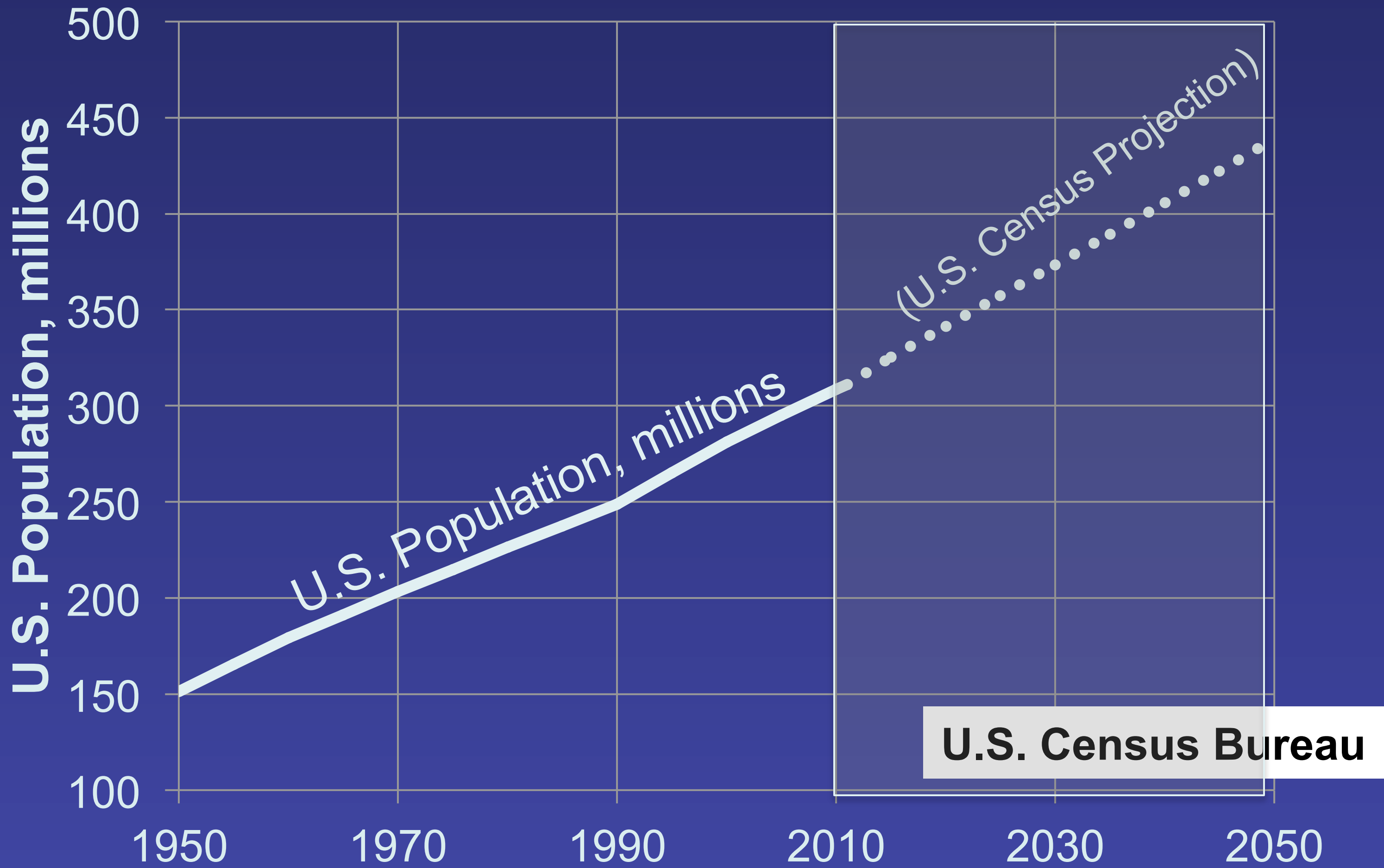
But The Population Has Grown 35% Since 1980



The U.S. Census Predicts that the Population Will Continue to Grow



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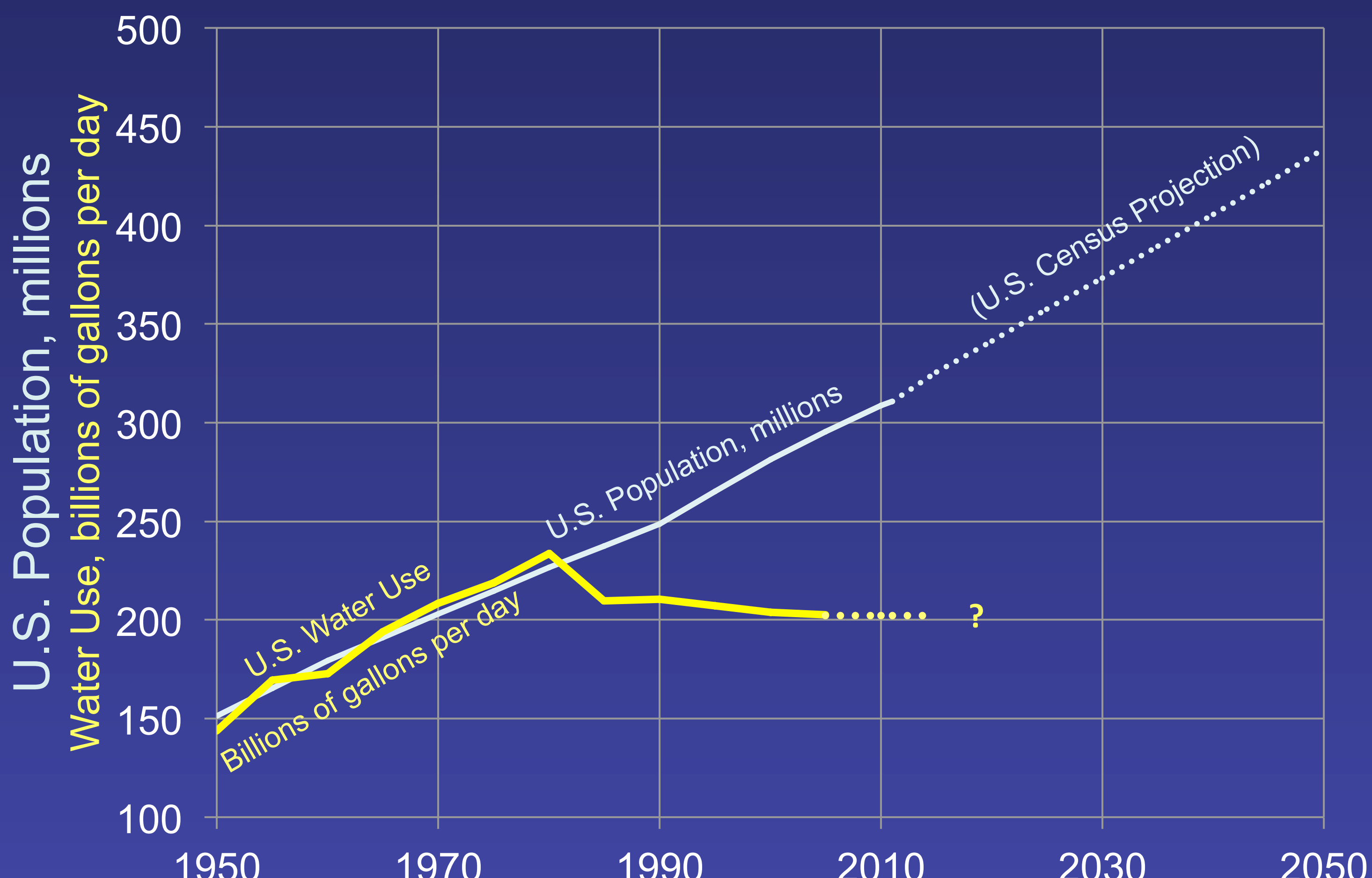
Total Water Use Also Leveled Off in 1980



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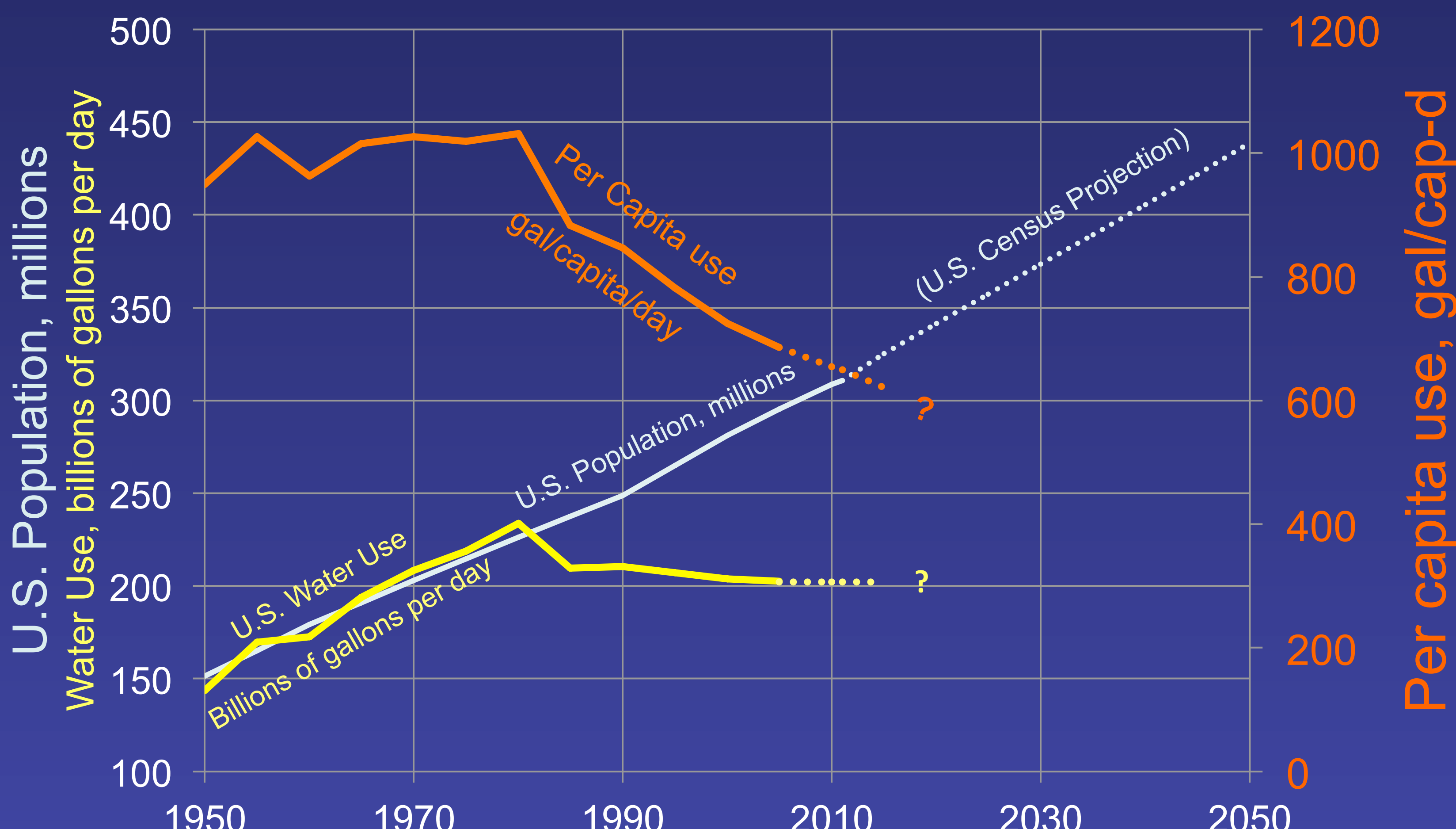
Per Capita Use Dropped 37%



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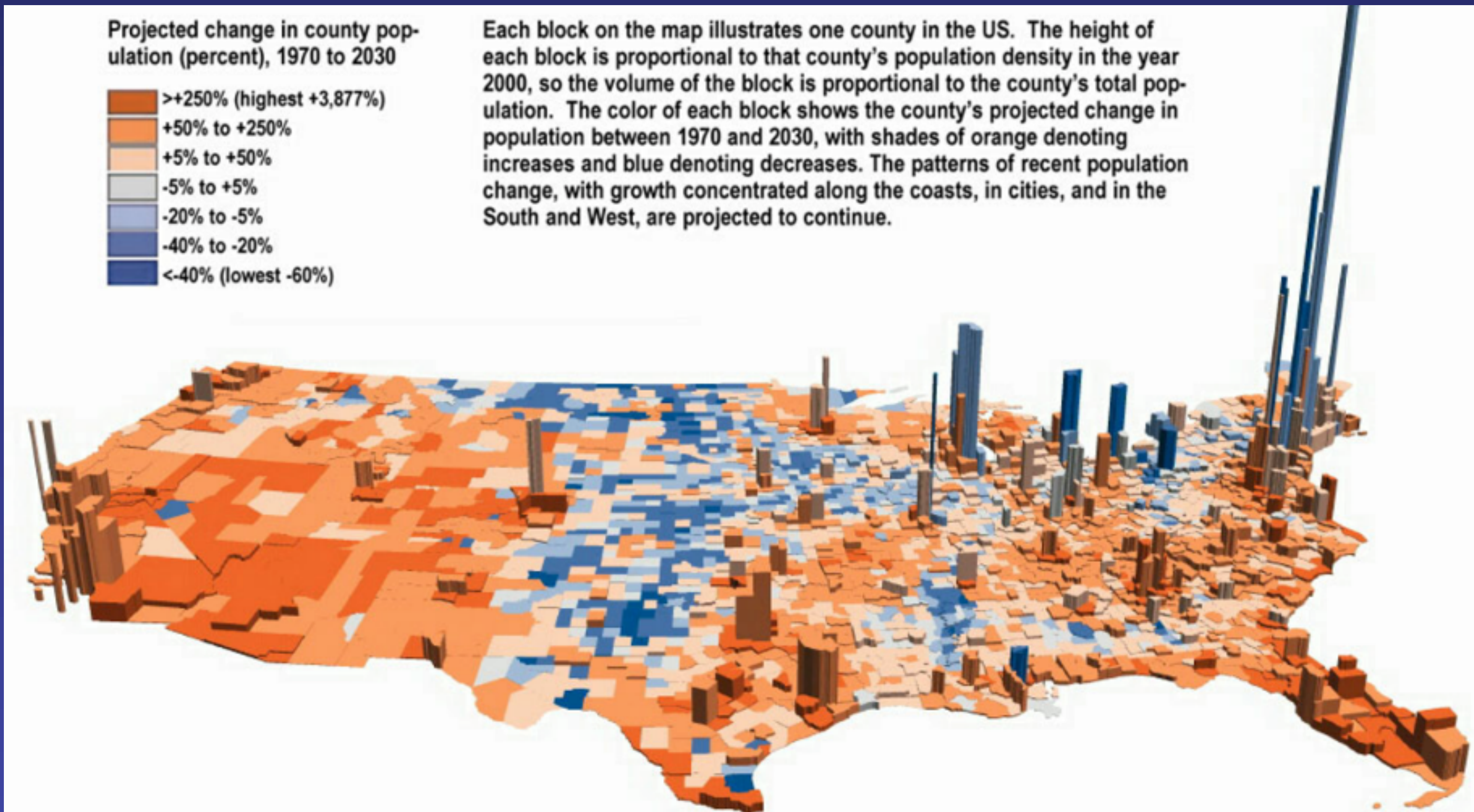
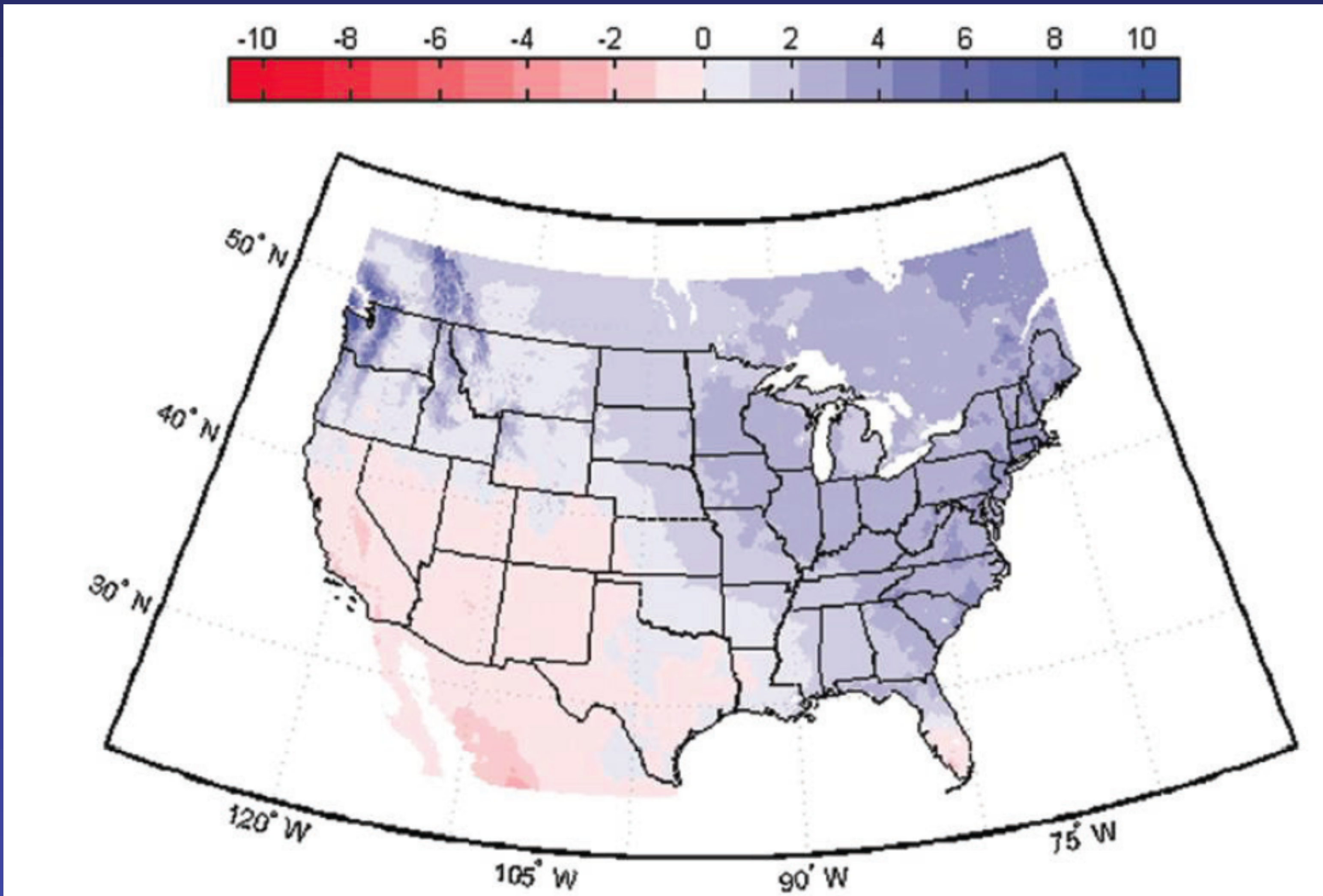
In the Meantime Our Population is Moving From the Northeast to the South



We Estimate Global Warming Will Reduce Rainfall in the Southwest



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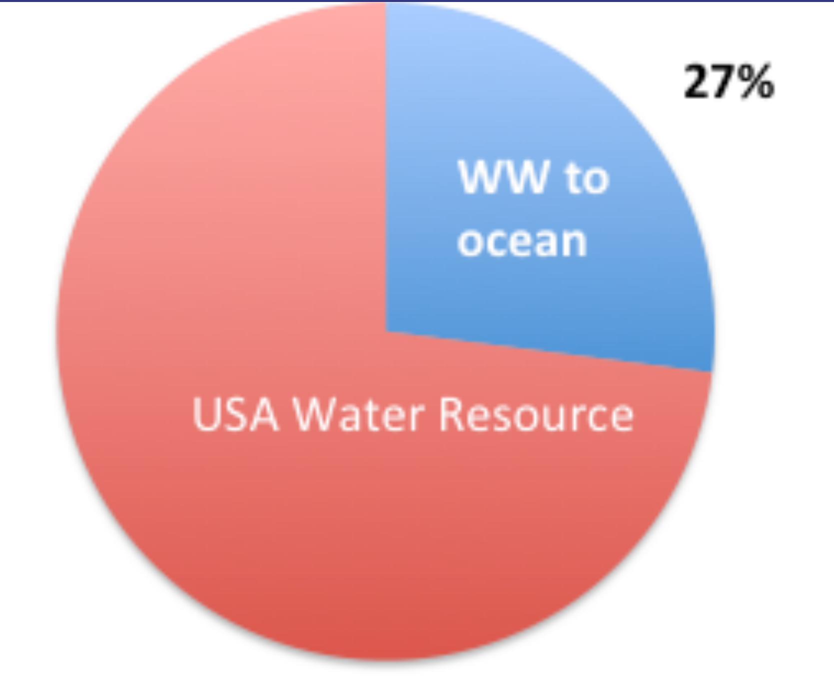
Wastewater Reuse Potential

- New water supplies and improved efficiency needed to meet demands of shifting populations and changing climate
- **In 2008 the US produced** 32 BGD wastewater effluent
- **Only 5 to 6% was reclaimed**
- **But** 12 BGD discharged directly to ocean or estuary in U.S. and that represents 27% of municipal water use



Wastewater Reuse Potential

- New water supplies and improved efficiency needed to meet demands of shifting populations and changing climate
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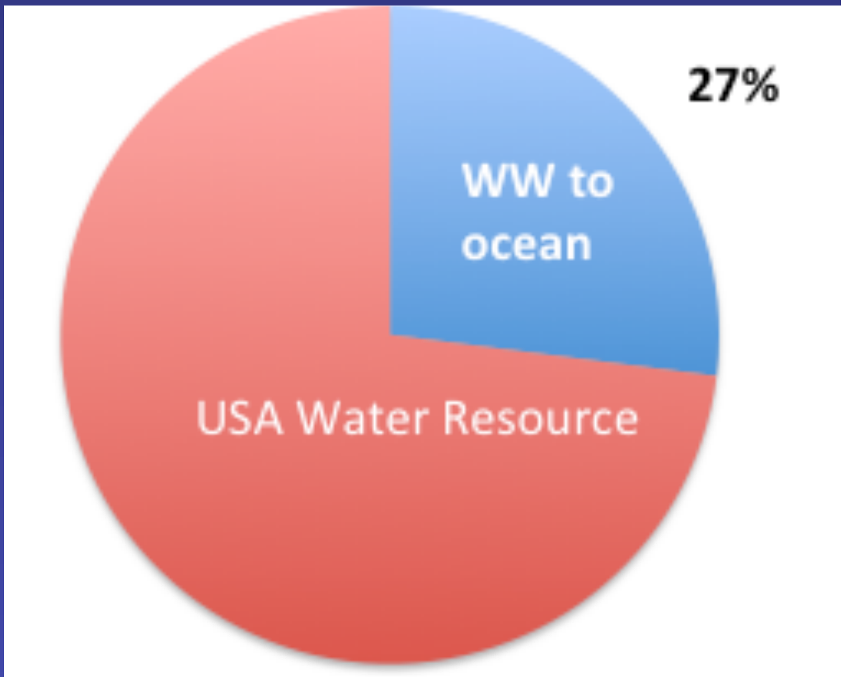
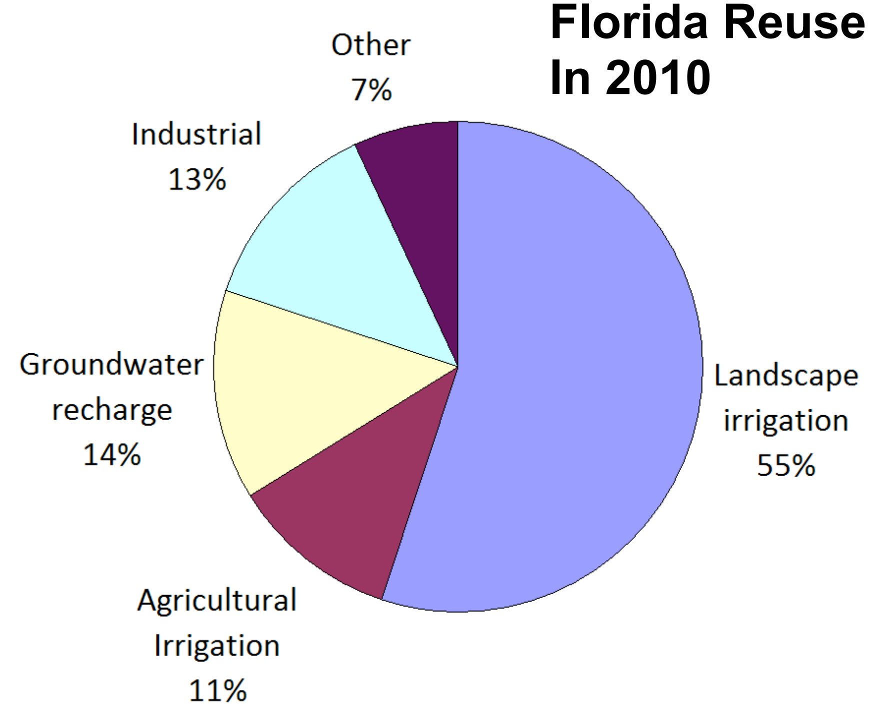
Thus, reuse of municipal WW does offer significant potential to increase the national water resource.



Water Reuse in Context

- Reuse projects are estimated to be <1% of total U.S. water use
- Nonpotable reuse well established, generally accepted.
- Potable reuse projects represent a fraction of all reuse

Florida Reuse In 2010



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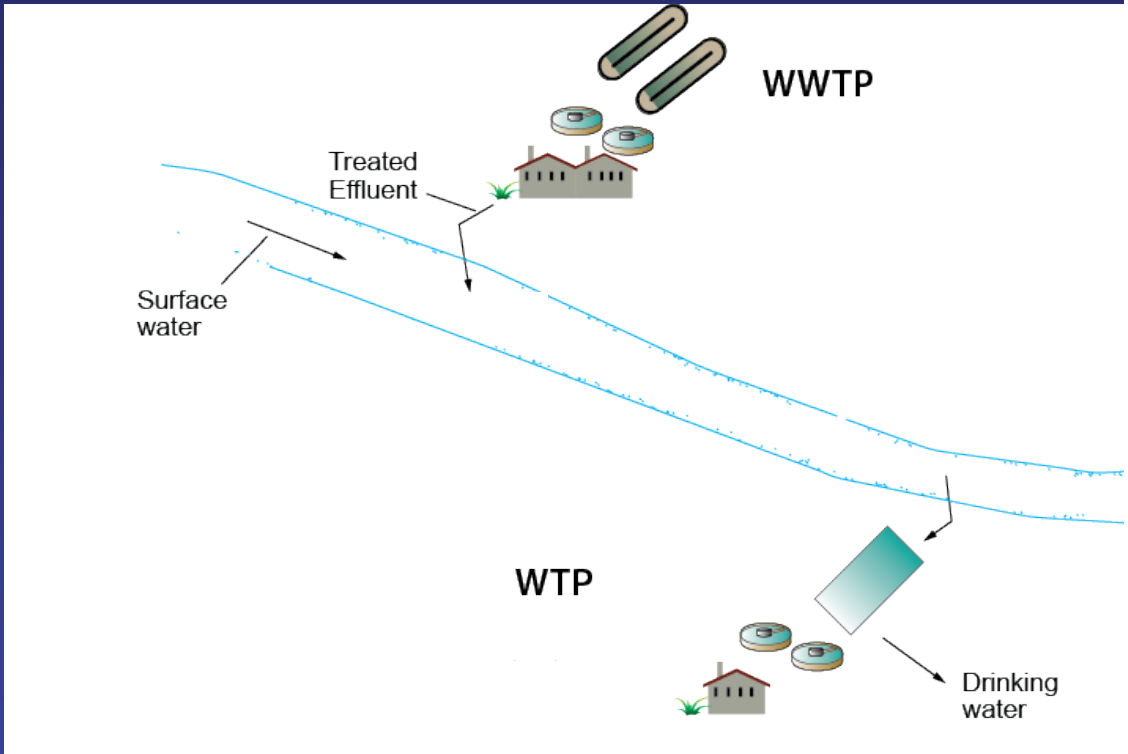
Water Reuse in Context

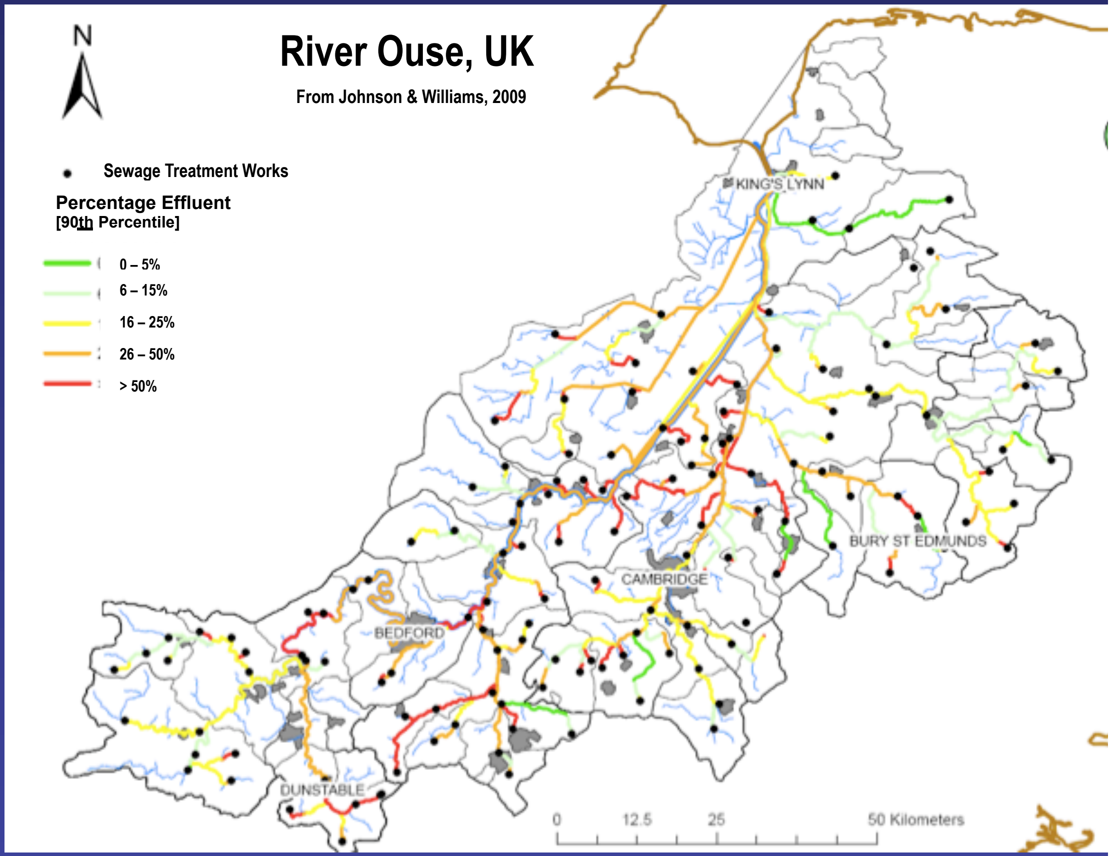
- De facto reuse* is common



* Where reuse is practiced but not officially recognized or permitted as a reuse project.

Water Reuse in Context

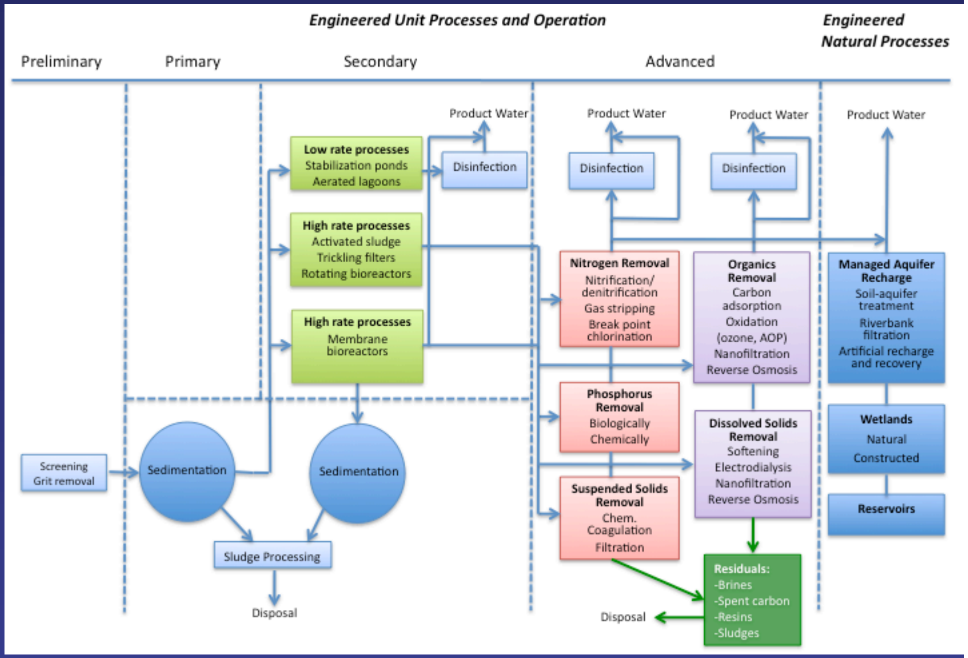
- De facto reuse* is common
- Updated analysis of extent of de facto reuse needed



* Where reuse is practiced but not officially recognized or permitted as a reuse project.

Water Reuse Treatment Technology

A portfolio of treatment options exists to mitigate microbial and chemical contaminants in reclaimed water.

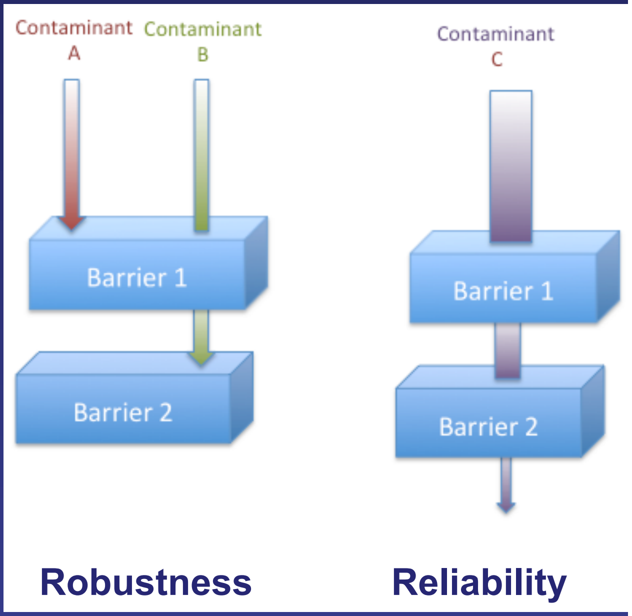


– Includes engineered treatment and natural processes

– The lack of guidance for design and operation of natural processes is the biggest deterrent to their expanded use in engineered reuse systems.

Quality Assurance

- Reuse treatment trains should be designed to include robustness and reliability.
- Reclamation facilities should develop monitoring and operational plans to respond to variability, equipment malfunctions, and operator error.



- Retention and blending requirements for quality assurance are expected to become less significant as monitoring and attenuation technologies improve.

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Environmental Buffers

- Natural systems are employed in most potable water reuse systems to provide an environmental buffer.
  - May provide: (1) retention time, (2) attenuation of contaminants, and (3) blending (or dilution)
  - But, the science required to design for uniform protection from one environmental buffer to the next is not available.
- Engineered processes can be designed to achieve these same functions.
  - It cannot be demonstrated that such “natural” barriers provide public health protection that is not also available by other engineered processes.
- The potable reuse of highly treated reclaimed water without an environmental buffer is worthy of consideration, if adequate protection is engineered within the system.
- The distinction between *indirect* and *direct* potable reuse is not scientifically meaningful to product water quality.

Understanding the Risks

- Health risks remain difficult to fully characterize and quantify through epidemiological or toxicological studies
- However, well-established methods exist for estimating the risks of various water reuse applications.
  - The occurrence of a contaminant at a detectable level does not necessarily indicate a significant risk.
  - Risk assessment screening methods can be used to estimate human health effects where dose-response data are lacking.

Evaluating the Risks in Context

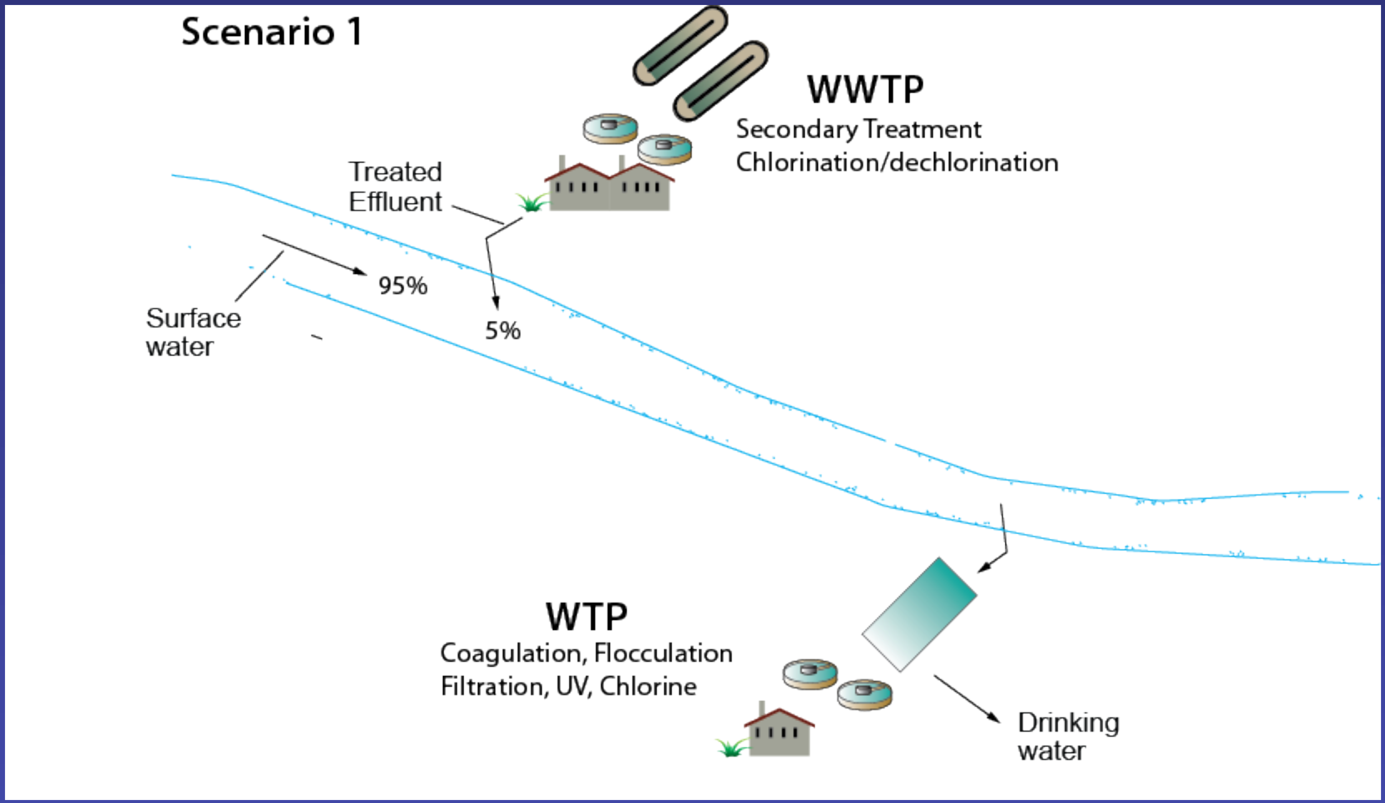
- It is appropriate to compare the risk from water produced by potable reuse projects with the risk associated with the water supplies that are presently in use.

- Committee's Risk Exemplar:
  - Original comparative analysis of 3 potable reuse scenarios
  - Estimate risk from 4 pathogens and 24 chemical contaminants

Risk Exemplar Scenarios

Scenario 1: De facto reuse

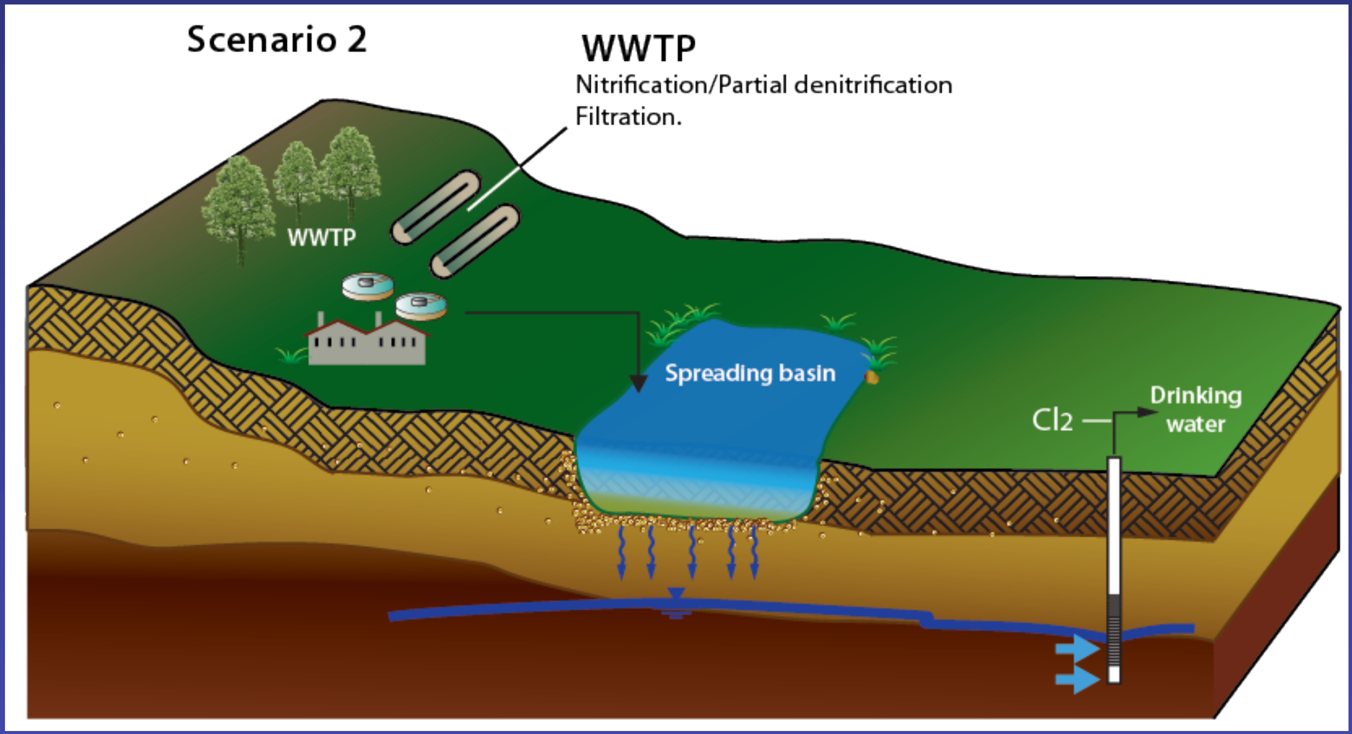
5% effluent in pristine surface water, no degradation in stream



Risk Exemplar Scenarios

Scenario 2: Soil-Aquifer Treatment (SAT)

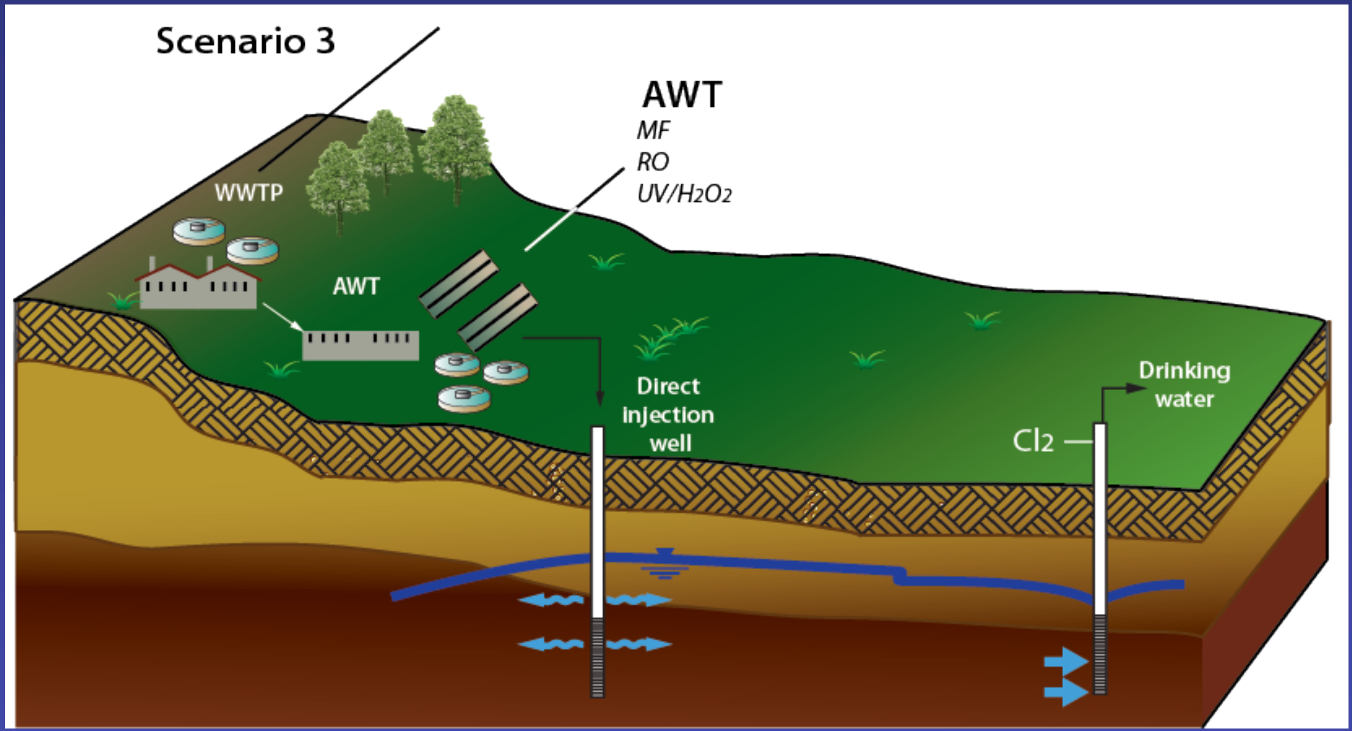
Secondary treatment, filtration, no disinfection, SAT, 6 mo retention in subsurface, no dilution, wellhead Cl_2 disinfection.



Risk Exemplar Scenarios

Scenario 3: Advanced Water Treatment

Secondary treatment, chloramination, MF, RO, UV/AOP, direct injection, 6 mo retention in subsurface, no dilution, wellhead Cl_2 disinfection.



Risk Exemplar Contaminants

Pathogens:
- Adenovirus
- Norovirus
- *Salmonella*
- *Cryptosporidium*

Disinfection Byproducts
- Bromate
- Bromoform
- Chloroform
- Dibromoacetic acid (DBCA)
- Dibromoacetonitrile (DBAN)
- Dibromochloromethane (DBCM)
- Dichloroacetic acid (DCAA)
- Dichloroacetonitrile (DCAN)
- Haloacetic acid (HAA5)
- Trihalomethanes (THMs)
- *N*-Nitrosodimethylamine (NDMA)

Hormones and Pharmaceuticals
- 17β-Estradiol
- Acetaminophen (paracetamol)
- Ibuprofen
- Caffeine
- Carbamazepine
- Gemfibrozil
- Sulfamethoxazole
- Meprobamate
- Primidone

Others
- Triclosan
- Tris(2-chloroethyl)phosphate (TCEP)
- Perfluorooctanesulfonic acid (PFOS)
- Perfluorooctanoic acid (PFOA)

Risk Exemplar Methods
(Detailed in Appendix A)

Contaminant concentrations:

- Estimated initial concentration of contaminants in source waters based on literature review
- Estimated removal efficiencies and fate assumptions for steps in 3 scenarios (based on literature review)

Microbial Risk Assessment:

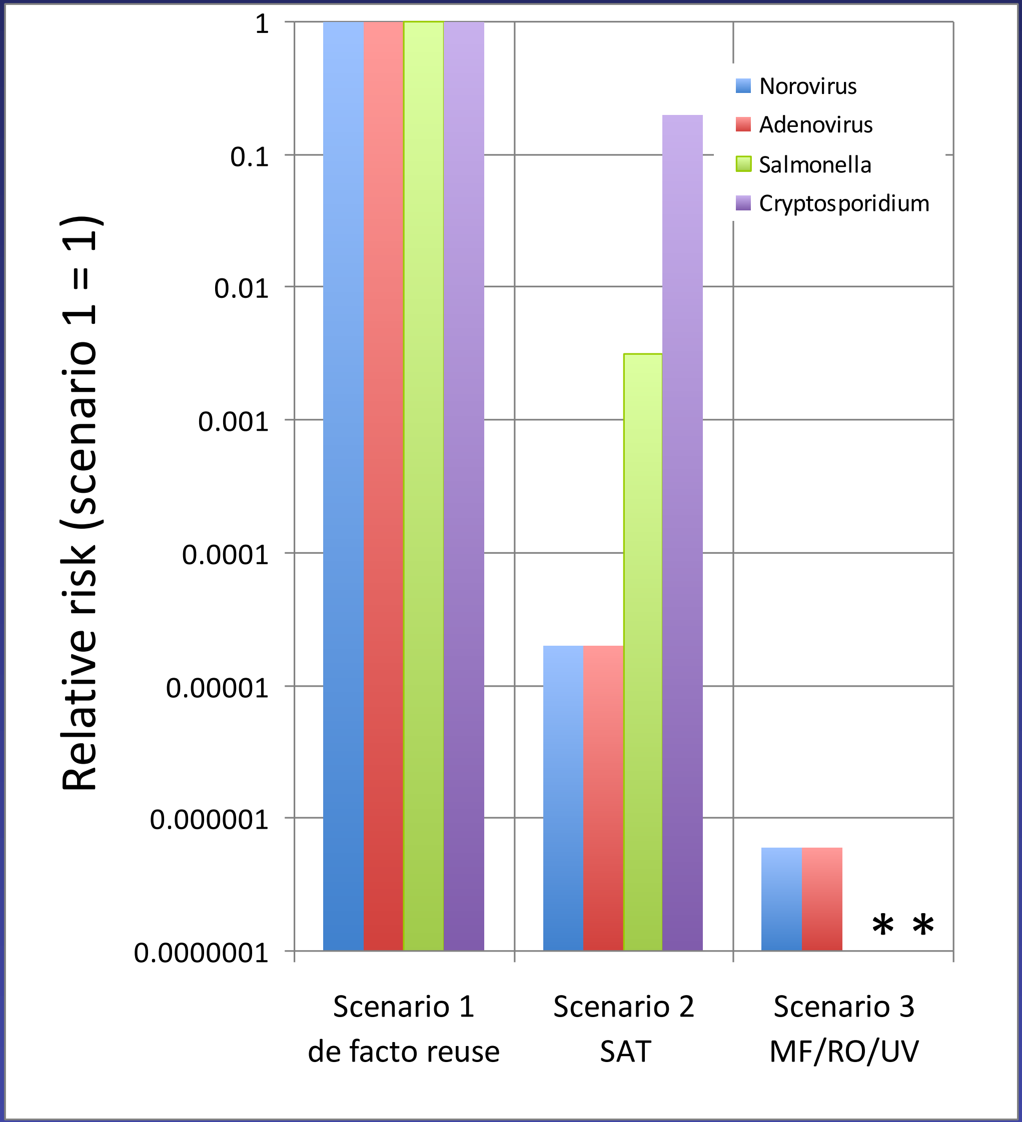
- Used dose response equations shown in App. A. Assumed 1 L/d water consumption (unboiled).

Chemical risk assessment:

- Risk based action levels (RBALs) determined for chemicals based on 2 L/d consumption (Table A-12)
- Margin of Safety = RBAL / drinking water conc.
- MOS < 1 not considered to be a significant health risk

Verification

Risk Exemplar Results: Pathogens



* The risks for *Salmonella* and *Cryptosporidium* in Scenario 3 were below the limits that could be assessed by the model.

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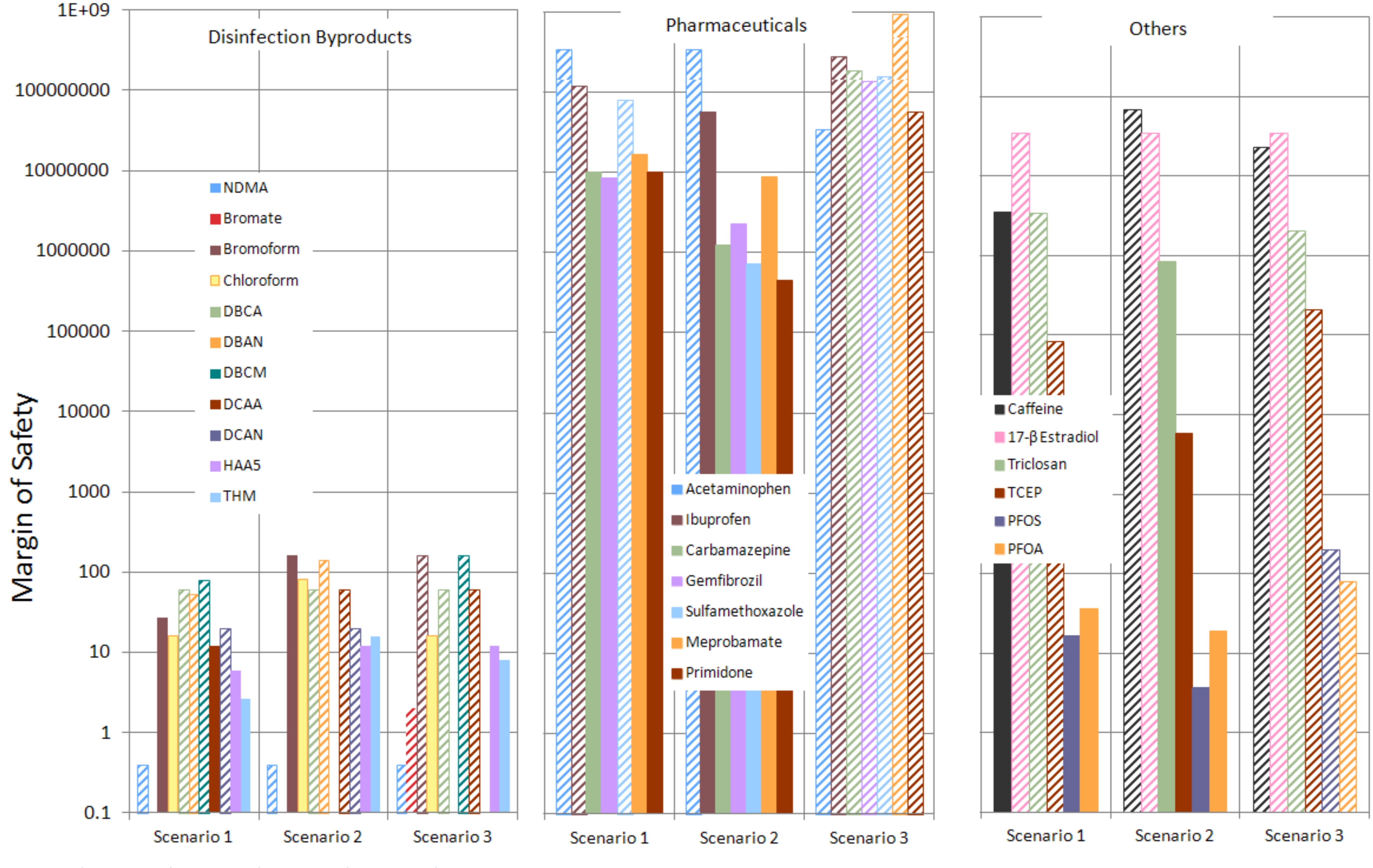
Risk Exemplar Results: Chemicals



Risk Exemplar Conclusions

- The risk from 24 selected chemical contaminants in the two potable reuse scenarios does not appear to exceed the risk in common existing water supplies.
- With respect to pathogens, although there is a great degree of uncertainty, the committee's analysis suggests the risk from potable reuse does not appear to be any higher, and may be orders of magnitude lower than currently experienced in at least some current (and approved) drinking water treatment systems (i.e., de facto reuse).

Ecological Enhancement Via Reuse

- Few studies have documented the environmental risks associated with the purposeful use of reclaimed water for ecological enhancement.
  - risk issues not expected to exceed those encountered with the normal surface water discharge of wastewater.
- Trace organic chemicals have raised some concerns, because aquatic organisms can be more sensitive to trace organic chemicals than humans.
- Sensitive ecosystems may necessitate more rigorous analysis of ecological risks before proceeding with ecological enhancement projects with reclaimed water.

Costs

- Financial costs of water reuse are widely variable and dependent on site-specific factors
  - Distribution system costs can be the most significant component of costs for nonpotable reuse systems.
- To determine the most socially, environmentally, and economically feasible alternative, water managers and planners should consider nonmonetized costs and benefits of reuse projects in their comparative cost analyses of water supply alternatives.

  Example benefits:
  - Improved supply reliability
  - Reduce dependence on imported water.

  Example costs:
  - Reuse projects may have a larger (or smaller) carbon footprint than existing supply alternatives.
  - Can reduce water flows to downstream users and ecosystems.

Social, Legal, and Regulatory Issues

- Water rights laws, which vary by state, affect the ability of water authorities to reuse wastewater.
- Enhanced public knowledge of water supply and treatment are important to informed decision making.
  - The public, decision makers, and media need access to credible scientific and technical materials on water reuse to help them evaluate proposals and frame the issues.
  - Public debate on water reuse is evolving and maturing as more projects are implemented.

Social, Legal, and Regulatory Issues

- Risk-based federal regulations for *nonpotable* reuse would provide uniform nationwide minimum acceptable standards of health protection
  - could facilitate broader implementation of reuse.
- Modifications to the structure or implementation of the SDWA would increase public confidence in the *potable* water supply and ensure the presence of appropriate controls in potable reuse projects.
  - SDWA does not include specific requirements for treatment or monitoring when source water consists mainly of municipal wastewater effluent.
  - Such requirements could enhance public health protection and provide nationwide consistency when planned *or* de facto potable reuse is practiced.

Social, Legal, and Regulatory Issues

- EPA should fully consider the advantages and disadvantages of federal reuse regulations to the future application of water reuse to address the nation's water needs while appropriately protecting public health.
- Application of legislative tools to effluent-impacted water supplies could improve the protection of public health. These could include:
  – Updates to the National Pretreatment Program's list of priority pollutants.
  – Increased designated use of surface waters for public water supplies.

Research Needs

Health, Social, and Environmental Issues

1. Quantify the extent of de facto reuse in the U.S.
2. Address critical gaps in the understanding of health impacts of human exposure to constituents in reclaimed water.
3. Enhance methods for assessing the human health effects of chemical mixtures and unknowns.
4. Strengthen waterborne disease surveillance, investigation methods, governmental response infrastructure, and epidemiological research tools and capacity.
5. Assess the potential impacts of environmental applications of reclaimed water in sensitive ecological communities.
6. Quantify the nonmonetized costs and benefits of potable and nonpotable water reuse compared with other water supply sources to enhance water management decision making.
7. Examine the public acceptability of engineered multiple barriers compared with environmental buffers for potable reuse.

Research Needs

Treatment Efficiency and Quality Assurance

- Develop a better understanding of contaminant attenuation in environmental buffers.
- Develop a better understanding of the formation of hazardous transformation products during water treatment for reuse and ways to minimize or remove them.
- Develop a better understanding of pathogen removal efficiencies and the variability of performance in various unit processes and multibarrier treatment and develop ways to optimize these processes.
- Quantify the relationships between polymerase chain reaction (PCR) detections and viable organisms in samples at intermediate and final stages.
- Develop improved techniques and data to consider hazardous events or system failures in risk assessment of water reuse.
- Identify better indicators and surrogates that can be used to monitor process performance in reuse scenarios and develop online real-time or near real-time analytical monitoring techniques for their measurement.
- Analyze the need for new reuse approaches and technology in future water management.

Federal and Nonfederal Roles in Research

- Addressing the research needs will require the involvement of several federal agencies as well as support from nongovernmental research organizations.
  - Improved coordination is needed.
- If national water reuse regulations are developed, a more robust research effort will be needed with enhanced coordination among federal and nonfederal entities.
  - Such an effort would benefit from the leadership of a single federal agency.

Overall Summary

- Expanding water reuse could significantly increase the nation's water resource, particularly in coastal communities.
- Available technology can reduce chemical and microbial contaminants to levels comparable to or lower than those present in many current drinking water supplies.
- Modifications to the CWA and SDWA could ensure public health protection for both reuse projects and *de facto* reuse while increasing public confidence in water reuse.
- Improved coordination among federal and nonfederal entities could more effectively address key research needs.

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