

**Water Reuse**

水の再利用

**Dick Kuchenrither, Black & Veatch Corporation, US**

ブラック・アンド・ヴィーチ社 ディック・クチェンライザー

## Water Reuse

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## Japan and the USA share a common interest in Water Reuse

Japan - U.S. Governmental Conference  
Drinking Water Quality Management  
and Wastewater Control  
October, 2002



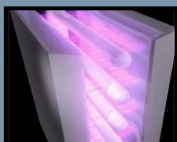
## Water Reuse Research Drivers



Attention focused on conserving and reusing existing water sources

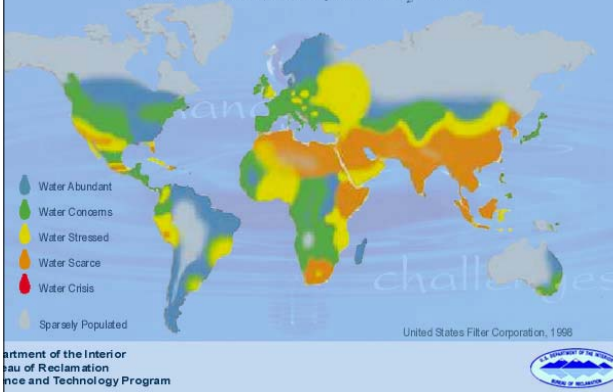
Non-potable uses already occurring

Potable reuse will have to meet regulatory standards



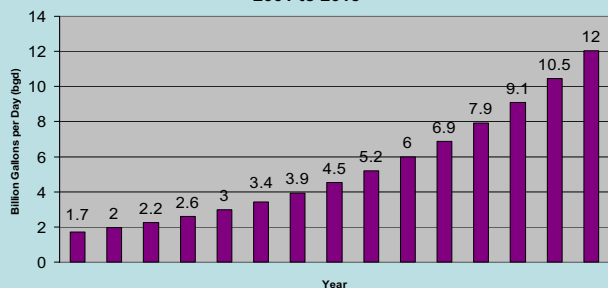
## Areas of Water Stress in 2020

Worldwide Fresh Water Availability in 2020



## Projected Growth in Water Reuse (15% per year)

Projected Water Reuse (WaterReuse Association, 2002)  
2001 to 2015



## Water Reuse Not Just for Irrigation



## Sources of Water for Reuse

- Municipal wastewater effluent
  - Industrial wastewater effluent
  - Household graywater
  - Stormwater
  - Brackish water
  - Poor quality ground water
  - Agriculture return flows
  - Oceans
- Beneficial reuse will require reclamation and treatment -



## Potential To Do Much More Reuse

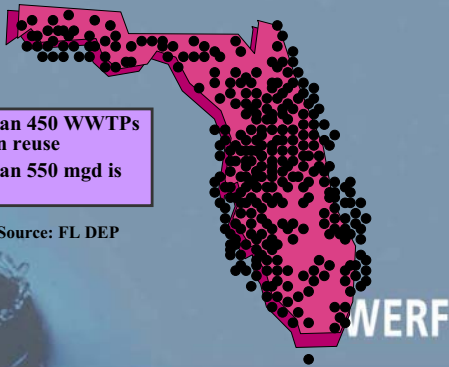
- Approximately 1,500 water reuse facilities in U.S.
- Only 5% of municipal wastewater is currently "reused"



## Florida Non-potable Reuse Projects

- More than 450 WWTPs involved in reuse
- More than 550 mgd is reclaimed

Source: FL DEP



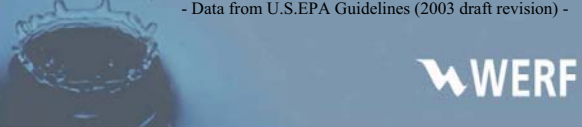
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## State Water Reuse Regulations/Guidelines

- Regulations 25 states
- Guidelines 16 states
- No regulations/guidelines 9 states
- Regulations/guidelines for uses other than irrigation 14 states

(Numbers include land application regulations or guidelines)

- Data from U.S.EPA Guidelines (2003 draft revision) -



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## Regulations and Guidelines Vary Depending on Type of Reuse

- Indirect Potable Reuse
- Agricultural Reuse on Food Crops
- Unrestricted Recreational Reuse
- Unrestricted Urban Irrigation Reuse
- Restricted Urban Irrigation Reuse
- Restricted Recreational Reuse
- Industrial Reuse
- Environmental Reuse
- Agricultural Reuse on Non-food Crops

More Stringent Regulations



Less Stringent Regulations

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## Water Reuse Research Areas

Treatment for Reuse



Microbial Detection and Risk Assessment

Chemical Contaminants



Communication and Public Acceptance

## Issue 1 – Treatment Processes

How can wastewater treatment processes be modified or developed to yield water for subsequent use?

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## Membrane Technology



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## Membrane Technology Research

- Impacts of process residuals on w/w treatment
- Zero liquid discharge & volume minimization
- Medialess microfiltration for pre-filtration
- Membranes for autotrophic denitrification
- Membrane-aerated bioreactors

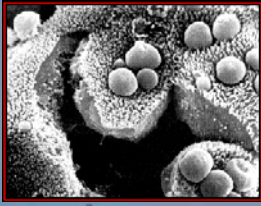
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## Issue 2 – Microbial Monitoring

What tools can be developed for on-line monitoring of viable microbes?

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## Issue 2 – Microbial Monitoring



1. Indicator organisms – including bacteria, viruses, protozoa
2. Detection technologies and removal/disinfection



## Microbial Monitoring Research

- DNA microarray and real-time PCR technologies
- Pathogen inactivation demonstration project
- Fiber optic sensors for real-time detection
- Innovative methods for rapid detection of *Cryptosporidium*



## Issue 3 – Chemical Contaminants

What chemical contaminants are of concern in reclaimed water and how do we monitor them?



## Heavy Metal Contamination



## Chemical Contaminant Research

- Chemicals in household graywater
- Fate of pharmaceuticals and personal care product chemicals
- Bioassays for pharmaceuticals in reclaimed water
- Online toxicology methods for potable reuse
- Bioassays and chemical measurements for EDCs in water reclamation



## Issue 4 – Public Acceptance

What information is needed to help the public view reclaimed water as a resource?



## Public Acceptance Research

- Public partnering in practice (pilot program)
- Sustainable water resource mgmt. strategies
- Microbial risk assessment in water reclamation
- Understanding public perception and participation



## Water Reuse Research Projects<sup>1</sup>

- 45 projects<sup>2</sup> totaling over \$10 million (U.S.)
  - 22 completed
  - 3 in report production
  - 15 ongoing
  - 5 requests for proposal available

<sup>1</sup> WERF (including cooperative projects with partners)

<sup>2</sup> detailed in handout



# WERF's Water Reuse Partners

- U.S. Environmental Protection Agency
- Joint Water Reuse Task Force
  - American Water Works Research Foundation
  - WatReuse Foundation
  - National Water Reuse Institute
  - Water Environment Research Foundation
- Global Water Research Coalition
  - 14 organizations (international representation)
  - www.globalwaterresearchcoalition.net



## RESEARCH PROJECTS ON MEMBRANES, SALINITY AND OTHER WATER REUSE RESEARCH

Project #	Title Description	Principal Investigator/Organization	Actual or Anticipated Start / Completion Year	WERF Cost	Total Cost
<b>MEMBRANES AND SALINITY</b>					
97-CTS-10 (Co-funded by EPRI)	<b>Innovative High-Rate Biologic Treatment Using Membranes</b> Provides a preliminary assessment of the technical and economic feasibility of using biologic (rather than permeable membrane) as a means of both supplying oxygen and supporting biomass in waste treatment applications.	Michael Semmens University of Minnesota	Completed	\$85,500	\$102,000
98-CTS-5	<b>Feasibility and Application of Membrane Bioreactor Technology for Water Reclamation</b> Will explore the feasibility and application of membrane bioreactor (MBR) technology to reduce costs and increase practicality of water reclamation for various uses. Will be a pilot study at the San Diego North City Water Reclamation Plant. Report will summarize the advantages and limitations of MBR process, and address the potential of MBRs for water reclamation, configuration problems for full-scale development, and regulatory compliance and preliminary cost estimates.	Sameer Adham Montgomery Watson Americas	Completed	\$150,000	\$235,000
00-CTS-8	<b>Membrane Technology: Feasibility of Solid-Liquid Separation in Wastewater Treatment</b> Provides a comprehensive assessment of membrane applications and identifies a method to evaluate the use of membrane technologies for specific treatment applications. Results from this research will allow for a direct comparison of membrane technologies with more conventional methods of solid-liquid separation.	Clm Dajger UTC-Hill	Completed	\$125,000	\$435,000
00-CTS-11 (Follow-on project to 97-CTS-10)	<b>Membrane Technology: Pilot Studies of Membrane-Aerated Bioreactors</b> Evaluates membrane-aerated bioreactors (MABR) as a means of wastewater treatment. MABR has the potential to significantly reduce operating costs of treatment in activated sludge processes.	Michael Semmens University of Minnesota	In Production	\$300,000	\$312,000

Project #	Title Description	Principal Investigator/Organization	Actual or Anticipated Start / Completion Year	WERF Cost	Total Cost
00-CTS-14-E1	<b>A Novel Membrane Process for Autotrophic Denitrification</b> Will determine the feasibility of treating nitrate-nitrogen from wastewater using a novel process for autotrophic denitrification that supplies hydrogen gas through microprocess, below-membrane treatment. This process could provide significant operational cost savings for wastewater treatment facilities.	Kauser Jahan Ruman University	Completed	\$58,000	\$73,000
01-CTS-6	<b>Membrane Treatment of Secondary Wastewater Effluent for Subsequent Use</b> Will survey a number of membrane technologies and applications currently in use in wastewater facilities to determine the relationship between effectiveness and operating variables. Will also conduct pilot tests of selected membranes.	Roderick D. Reardon Camp Dresser & McKee, Inc.	Completed	\$300,000	\$508,000
01-CTS-19-AR	<b>Effects of Biosolids Properties on Membrane Bioreactors and Solids Processing</b> Will lead to a better understanding of membrane bioreactor (MBR) processes and a fundamental understanding of biology-membrane interactions. Will help the industry engineer MBRs for optimal treatment performance.	Shay Hermanowicz University of California at Berkeley	Completed	\$200,000	\$385,000
01-CTS-14-E1	<b>Dynamic Membrane Microfiltration for Membrane Pre-filtration</b> Will develop a dynamic membrane pre-filtration capable of removing micro-sized particles from a liquid flow stream. Will address the potential improvement in the operation of wastewater treatment facilities by improving efficiency, reliability, and longevity of downstream conventional filtration media.	Steve R. Wright Innovatech, Inc.	Completed	\$75,000	\$82,000
To be assigned	<b>Zero Liquid Discharge and Volume Minimization for Water Utility Applications - cooperative project with Joint Water Reuse Task Force</b>	RFP Issued		\$140,000	TBD
To be assigned	<b>Beneficial and Non-Traditional Uses of Concentrate - cooperative project with Joint Water Reuse Task Force</b>	RFP Issued		\$80,000	TBD
To be assigned	<b>Impacts of Membrane Process Residuals on Wastewater Treatment - cooperative project with Joint Water Reuse Task Force</b>	RFP Issued		\$95,000	TBD
To be assigned	<b>Investigation of Regional Solutions for Disposal of Concentrate - cooperative project with Joint Water Reuse Task Force</b>	RFP Issued		\$70,000	TBD
To be assigned	<b>Development of Indicators and Surrogates for Chemical Contaminant Removal during Wastewater Treatment and Reclamation - cooperative project with Joint Water Reuse Task Force</b>	RFP Issued		\$300,000	TBD
Subtotal				\$1,979,500	\$2,181,000
<b>WATER REUSE</b>					
92-WRE-1	<b>Water Reuse Assessment</b> Evaluates existing technologies, examines planning and management issues, and reviews standards and guidelines for a wide variety of water reuse applications.	Camp Dresser & M.C.Roe, Inc.	Completed	\$45,000	\$65,000

Project #	Title Description	Principal Investigator/Organization	Actual or Anticipated Start / Completion Year	WERF Cost	Total Cost
96-HIE-1-CD	<b>Issues in Potable Reuse</b> This NRC study assessed the public health implications of using reclaimed water as a component of the potable water supply.	National Academy of Science	Completed	\$10,000	\$250,000
97-IRX-6	<b>Nonpotable Water Reuse Management Practices</b> Will survey and report experiences of reuse programs. Will document models for planning and management, assess costs of reclamation, and the financing used to develop and operate reclaimed water systems. Will report various site structures, and legal and liability issues, and define the level of treatment required for different uses. Can help new planning efforts to better address public perception issues and effectively involve stakeholders.	Per Mattavoa McEair and Eddy (Vivendi)	Completed	\$98,000	\$210,000
98-CTS-5 (See Above Section)	<b>Feasibility and Application of Membrane Bioreactor Technology for Water Reclamation</b> Will explore the feasibility and application of membrane bioreactor (MBR) technology to reduce costs and increase practicality of water reclamation for various uses. Will be a pilot study at the San Diego North City Water Reclamation Plant. Report will summarize the advantages and limitations of MBR process, and address the potential of MBRs for water reclamation, configuration problems for full-scale development, and regulatory compliance and preliminary cost estimates.	Sameer Adham Montgomery Watson Americas	Completed	\$150,000	\$285,000
98-FUM-1C0 (Cooperative with AWWARF)	<b>A Comparative Study of the Psychophysical Properties and Filtration of Several Human and Bacteria Viruses: Implications for Groundwater Recharge</b> Will characterize the surface electrostatic properties and filtration behavior of viruses. Will elucidate the scientific principles that regulate virus filtration in groundwater and provide support for the selection of bioassays as indicators of pathogenic disease.	Stanley Grant UC-Irvine	Completed	\$50,000	\$144,000
99-PXSL-4	<b>Impact of Surface Storage on Reclaimed Water: Seasonal and Long Term</b> Will provide understanding of which water quality computer modeling tools will effectively address water quality issues for seasonal and long-term surface storage of reclaimed water. Information on use and applicability of models to determine reclaimed water storage design, water quality and operation for specific storage facilities will maximize the effective use of existing resources for reclaimed water applications, and allow for improvement of design and management of facilities.	Gerry Miller Black & Veatch	Completed	\$100,000	\$129,000

Project #	Title Description	Principal Investigator/Organization	Actual or Anticipated Start / Completion Year	WERF Cost	Total Cost
00-FUM-1T (Cooperative with NWRRI, AWWARF, and WaterReuse Foundation)	<b>Water Reuse: Understanding Public Perception and Participation</b> Will provide guidance for water reuse professionals to successfully incorporate stakeholder priorities in water reclamation programs. Will help members of the water industry address the social & political complexity of adapting potable and nonpotable water reuse and recycling as part of a sustainable community strategy.	Tracy Hartley Revo, Inc.	Completed	\$104,000	\$108,000
00-FUM-3	<b>Evaluation of Microbial Risk Assessment Techniques and Applications in Water Reclamation</b> Will evaluate existing microbial risk assessment models for nonpotable uses of reclaimed water and will advance one of the models. Will help provide a basis for future regulations and reformulating for nonpotable use of reclaimed water.	Adam O'Brien EPA, Inc.	Completed	\$200,000	\$245,000
00-WSM-6	<b>Strategies for Sustainable Water Resource Management</b> Sustainable management of a resource on allow its use to meet current needs yet not diminish the resource's potential use for future generations. This project will develop a comprehensive, integrative framework for developing and implementing sustainable water resource management plans that will set the national context for practitioners at the local and regional levels.	Ken Thornton The Associates	Completed	\$300,000	\$327,000
01-HIE-4	<b>Online Technology Methods for Evaluating Potential Chemical Risks Associated with Potable Reuse - Project</b> Workshop will evaluate state-of-the-art toxicologic techniques for on-line monitoring of reclaimed water quality. Will determine the most appropriate approach to use for the development of an effective online method.	WERF	Completed	\$50,000	\$50,000
01-HIE-4A	<b>Online Technology Methods for Evaluating Potential Chemical Risks Associated with Potable Reuse - Project</b> Following the workshop, the selected method will be developed, evaluated, and validated for its effectiveness as an appropriate monitoring tool for reclaimed water. This method will provide a scientifically sound tool to monitor the water quality of reclaimed water and thus increase its acceptability by the regulatory and user communities.	Daniel Schick U.C. Riverside	Completed	\$250,000	\$440,000
01-HIE-20T (Joint Water Reuse Task Force, CWWA)	<b>The Use of Biosensors and Chemical Measurements to Assess the Removal of Endocrine Disrupting Compounds in Water Reclamation Systems</b> Will apply endocrine disruption biosensors and chemical analysis to evaluate water reclamation treatment processes that will be employed to prevent endocrine disruption in the aquatic environment.	William Sonzogni Wisconsin State Hygiene Lab	Completed	\$100,000	\$522,000

Project #	Title Description	Principal Investigator/Organization	Actual or Anticipated Start / Completion Year	WERF Cost	Total Cost
01-HIE-21T (Joint Water Reuse Task Force, CWWA)	<b>Evaluation and Testing of Biosensors for Pharmaceuticals in Reclaimed Water</b> Will address the use of biosensors for one or more major classes of pharmaceutical contaminants. This approach will serve as a model for developing assays for other classes of pharmaceuticals that have potential health risks for aquatic ecosystems and humans.	Sech Kulkarni UCI University	Completed	\$75,000	\$219,000
03-CTS-21-AR	<b>Contributions of Household Chemicals to Sewage and their Relevance to Municipal Wastewater Systems and the Environment</b> Will select a short list of High Volume Production (HVP) chemicals for analysis of removal efficiencies through different wastewater treatment processes.	Jorg Drewes Colorado School of Mines	Completed	\$124,242	\$202,242
03-CTS-22-AR	<b>Fate of Pharmaceuticals and Personal Care Products through Wastewater Treatment Processes</b> Will assess the fate of PCPs through conventional secondary and tertiary wastewater treatment facilities.	Roger Stephenson MWH	Completed	\$124,970	\$189,875
03-CTS-18C0	<b>Long-term Study on Landscape Irrigation using Household Greywater</b> Will provide quantitative evidence regarding the safety of household grey water for landscape irrigation, focusing on assessing consumer product usage and disposal recommendations in greywater reuse systems. This first project will be a workshop which will be followed by field evaluation.	Under contract negotiations	Completed	\$75,000	TBD
04-HIE-1C0	<b>Development of Indicators and Surrogates for Chemical Contaminant Removal during Wastewater Treatment and Reclamation (Coop with and managed by WaterReuse)</b> Will develop a list of potential indicators and/or surrogates used to validate their suitability of wastewater and recycled water treatment methods for various water reuse applications and beneficial uses of recycling water.	RFP Stage		\$150,000	\$400,000
Subtotal				\$2,006,512	\$3,782,417
<b>WATER/WASTEWATER PATHOGEN DETECTION</b>					
97-HIE-4ET	<b>Innovative Methods for Rapid Detection of Cryptosporidium</b> Will evaluate a new ITP analysis using UV-visible spectroscopy for rapid identification of Cryptosporidium in wastewater.	Joan Rose University of South Florida	Completed	\$75,000	\$75,000
98-HIE-1	<b>Modification of Existing and Emerging Methods to Survey Cryptosporidium Removal and Disinfection in Wastewater Treatment Systems</b> Will modify existing and emerging methods to survey Cryptosporidium removal from wastewater and demonstrate the ability of proposed methods to detect and	Jeanine Clancy Cyanic Environmental Constraints, Inc.	Completed	\$500,000	\$679,000

Project #	Title Description	Principal Investigator/Organization	Actual or Anticipated Start / Completion Year	WERF Cost	Total Cost
	quantity Cryptosporidium in unit processes of representative wastewater plants. Will also determine the effectiveness of Cryptosporidium removal and disinfection in treatment processes and allow facilities to adjust treatment efforts to ensure effective removal/inactivation of Cryptosporidium.	In Production			
99-HIE-4ET	<b>BANNA for Waterborne Pathogen Detection</b> Will evaluate the use of a novel hand-held instrument for the rapid detection and identification of pathogens such as Cryptosporidium and E. coli O157:H7. This technology could provide PCR detection in a portable, easy-to-use format for a wide variety of end uses.	James Higgins USDA-ARS	Completed	\$75,000	\$82,000
99-HIE-5-AR	<b>Development of Molecular Methods for Detecting Infectious Viruses in Treated Wastewater</b> Will develop a sensitive and specific assay for the detection of viruses in treated wastewater.	Theresa Cressman University of North Carolina	Completed	\$193,000	\$249,000
00-HIE-2A	<b>Overcoming Molecular Sample Processing Limitations: New Platform Technologies</b> To take advantage of new molecular techniques for the detection of pathogens and indicator organisms, this research will evaluate novel technologies for the automated, rapid detection of bacteria, viruses, and protozoa. Will provide alternatives to conventional measurements of water quality.	James Higgins USDA-ARS	Completed	\$125,000	\$143,000
00-HIE-2B	<b>Overcoming Molecular Sample Processing Limitations: Quantitative PCR</b> To take advantage of new molecular techniques for the detection of pathogens and indicator organisms, this research will develop simple, standardized protocols for rapid quantitative PCR detection of total and viable Cryptosporidium and infectious coliforms in wastewater. Will provide alternatives to conventional measurements of water quality.	George DiGiovanni AWWARF	Completed	\$125,000	\$319,000
00-HIE-2C	<b>Overcoming Molecular Sample Processing Limitations: Fiber-Optic Biosensors</b> To take advantage of new molecular techniques for the detection of pathogens and indicator organisms, this research will test the sensitivity and specificity of a fiber-optic biosensor for real-time detection of bacterial pathogens. Will provide alternatives to conventional measurements of water quality.	Valerie J. Harwood University of South Florida	Completed	\$125,000	\$135,000
00-FUM-2T (ICR project with City of St.	<b>Pathogen Removal and Inactivation in Water Reclamation for Nonpotable Uses</b> Will provide a characterization of unit process performance, under defined	Joan Rose University of South Florida	Completed	\$150,000	\$475,000

Project #	Title Description	Principal Investigator/Organization	Actual or Anticipated Start / Completion Year	WERF Cost	Total Cost
96-IRX-2	<b>Effects of Multiple Stressors on Aquatic Ecosystems</b> Will provide a scientific tool for assessing the effects of multiple stressors on aquatic ecosystems. Includes a review of existing data that will provide a comprehensive resource document and annotated bibliography of valuable information for both managerial and technical water quality professionals on the application of multiple stressor concepts to the risk assessment process.	Jerome Gerritsen Etna Tech, Inc.	In Production	\$292,000	\$334,000
01-HIE-2A	<b>Detection of Pathogens and Indicators: Real-Time PCR</b> Will facilitate molecular monitoring methods for pathogen and indicator organisms in the environment. This development of more rapid and specific detection methods for these organisms will lead to near on-line analysis of human health risk.	Robert Brousseau Biotechnology Research Institute	Completed	\$200,000	\$320,000
01-HIE-2B	<b>Detection of Pathogens and Indicators: Microarray Technology</b> Will facilitate molecular monitoring methods for pathogen and indicator organisms in the environment. This development of more rapid and specific detection methods for these organisms will lead to near on-line analysis of human health risk.	Sunny Jung University of California-Irvine	Completed	\$400,000	\$482,000
01-HIE-2B	<b>Detection of Pathogens and Indicators: Microarray Technology</b> Will facilitate molecular monitoring methods for pathogen and indicator organisms in the environment. This development of more rapid and specific detection methods for these organisms will lead to near on-line analysis of human health risk.	Darrell P. Chandler Battelle	Completed	\$400,000	\$400,000
Subtotal				\$2,368,000	\$3,359,000
<b>WATERSHED SOURCE PROTECTION</b>					
99-IRX-2	<b>Effects of Multiple Stressors on Aquatic Ecosystems</b> Will provide a scientific tool for assessing the effects of multiple stressors on aquatic ecosystems. Includes a review of existing data that will provide a comprehensive resource document and annotated bibliography of valuable information for both managerial and technical water quality professionals on the application of multiple stressor concepts to the risk assessment process.	Jerome Gerritsen Etna Tech, Inc.	In Production	\$292,000	\$334,000
99-HIE-2	<b>Sources of Cryptosporidium in Watersheds</b> Will improve watershed management applications and help mitigate public health risks. May improve sampling procedures for monitoring, and evaluate priorities for wastewater treatment facilities for long term control planning and compliance. Should enhance our ability to proactively improve the protection of public health.	Jon H. Staudacher Wisconsin State Laboratory of Hygiene, University of Wisconsin-Madison	Completed	\$300,000	\$494,000
99-ECD-3	<b>An Assessment of the Occurrence and Ecological Significance of Endocrine Disrupting Chemicals in Watersheds</b>	Patricia V. Cline EcoSider Associates, Inc.	Completed	\$480,000	\$480,000

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		Actual or Anticipated Start / Completion Year		
	Will provide information on presence of chemicals and biomarkers related to endocrine modulation in surface waters. Will identify how risks can be controlled.	Completed		
00-HHE-7-CO (Cooperative with AWAREF and WaterSense Foundation)	<b>Workshop on Endocrine Disruptors and Pharmaceutically-active Chemicals in Drinking Water</b> A workshop to examine the implications of pharmaceutically-active compounds and endocrine disruptors to the water and wastewater supply community with respect to occurrence, environmental and potential human health effects, and treatment. Priority research needs will be identified.	Peter Weyer University of Iowa	\$25,000	\$81,000
		Completed		
Subtotal			\$1,077,000	\$1,396,000
<b>TOTAL</b>			<b>\$7,461,012</b>	<b>\$8,738,017</b>

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