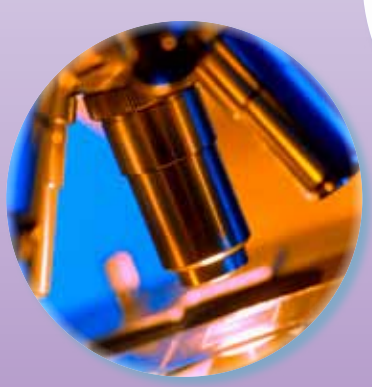
WATER REUSE RESEARCH AGENDA



FEBRUARY 2011

ALAN PLUMMER ASSOCIATES, INC.
ENVIRONMENTAL ENGINEERS AND SCIENTISTS

February 2011

Dear Valued Stakeholder,

Water reuse, the practice of using water that has already been used, is currently considered a key component of the water supply portfolio in Texas. This fact is demonstrated by regional water planning recommendations for water reuse strategies in state water plans. There is a growing recognition that, to achieve the expected supply goals for water reuse strategies, a common agenda focusing on the science, technology, and public awareness aspects of water reuse needs to be developed.

The Texas Water Development Board, through the project "Advancing Water Reuse in Texas," has produced a series of documents to address public awareness of water reuse in Texas. This document, "Water Reuse Research Agenda," identifies and prioritizes water reuse research topics to advance water reuse in Texas. The document discusses available resources and opportunities for partnerships and will serve as a reference for guiding future water reuse research investments in Texas.

Please take the opportunity to review this document. With your support and cooperation, we can protect and advance the state's most valuable resource and serve as a model for communities around the world.

J. Kevin Ward
Executive Administrator

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1. INTRODUCTION

Over the next several decades as Texas grows in population, it will be critical to ensure that a safe and sustainable water supply is available. The importance of efficiently using existing water supplies is becoming increasingly evident as sources of new supply become more difficult to acquire. Water reuse, the practice of taking water that has already been used and using it again for a beneficial purpose, is a key component of the state's water supply portfolio. Typically this practice uses reclaimed water (or reclaimed wastewater), which is domestic or municipal wastewater that has been treated to a quality that makes it suitable for a beneficial use.

When talking about water reuse, it is important to make the distinction between *direct reuse* and *indirect reuse*. Consistent with Texas law, *direct reuse* is the use of reclaimed water that is piped directly from the wastewater treatment plant to the place where it is used. *Indirect reuse* is the use of reclaimed water that is placed back into a river, stream or aquifer and then diverted downstream to be used again. Within these two broad categories of water reuse there are a number of specific non-potable and potable uses that can be applied. *Potable reuse* refers to the planned use of reclaimed water to augment drinking water supplies while *non-potable reuse* refers to the planned use of reclaimed water for purposes other than to augment drinking water supplies. Reclaimed water is not the same as graywater, which is untreated household water from sinks, showers, and baths.

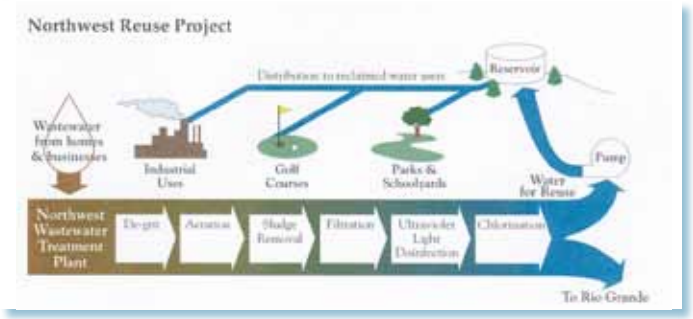
1.1. IMPORTANCE OF WATER REUSE TO WATER SUPPLY IN TEXAS

Planned water reuse has been practiced in Texas since the late 1800s. While initial uses were primarily for irrigation of agriculture, today reclaimed water is used for a wide range of beneficial purposes, including power plant cooling water, commercial and municipal irrigation, river and stream flow enhancement, natural gas exploration activities, and augmentation of drinking water supplies.

One of the primary advantages of reclaimed water is that wastewater treatment plants are usually located in or near the communities where the water is needed. To support projected population growth, water suppliers in Texas will have to look further away from the population centers to find additional water supplies. These new supplies will be expensive to develop and will require new infrastructure and more energy to transport the water to where it is needed in contrast to the use of local supplies. Water reuse provides an opportunity to take advantage of a reliable supply that is local to the communities it serves.

A number of communities and water providers in Texas provide reclaimed water for direct and indirect reuse. Although wastewater can be treated to achieve compliance with federal and state drinking water standards, currently no entity in Texas distributes reclaimed water directly for drinking water purposes. Examples of a direct and indirect reuse project include:

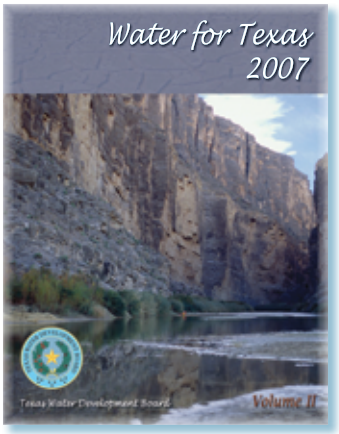
- **DIRECT REUSE (NON-POTABLE)** - El Paso's Northwest Reclaimed Water Project provides more than 300 million gallons of reclaimed water per year to schools, parks, a golf course, multifamily housing developments, and residential customers for irrigation.



El Paso's Northwest Reclaimed Water Project provides over 300 million gallons of reclaimed water per year for direct reuse.

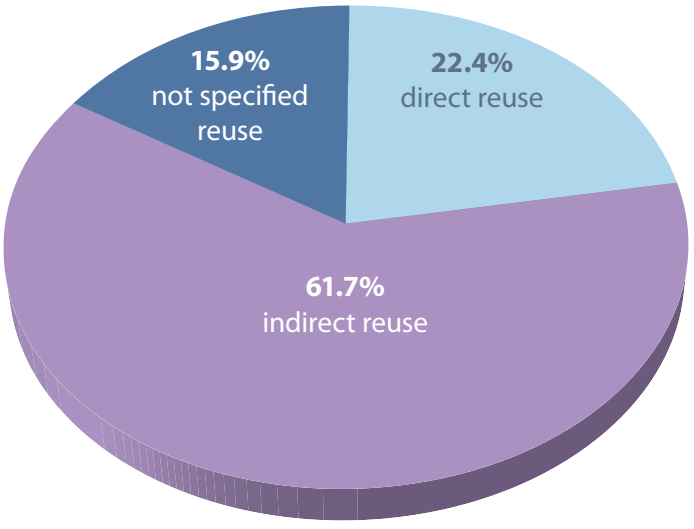
Tarrant Regional Water District uses constructed wetlands to further "polish" wastewater-dominated river water withdrawn from the Trinity River as a method of indirect reuse.

- **INDIRECT REUSE (POTABLE)** - Tarrant Regional Water District uses constructed wetlands[A] to further "polish" wastewater-dominated river water withdrawn from the Trinity River. This project provides an additional 20 billion gallons per year to the Richland-Chambers Reservoir. A second planned project will yield an additional 17 billion gallons per year for the Cedar Creek Reservoir.



Every five years, the Texas Water Development Board prepares a comprehensive state water plan that is the culmination of regional water planning efforts conducted in 16 planning regions throughout the state to map out how to conserve water supplies, meet future water supply needs, and respond to future droughts. According to the most recent plan, *Water for Texas 2007*, water reuse will provide 800,000 acre-feet per year[B] of supply to Texans by 2010[C]. By the year 2060, the projected supply from water reuse is expected to grow to more than 1.6 million acre-feet per year, which is approximately 14 percent of new water supplies to be met by all recommended water management strategies. The majority of this supply will be for indirect reuse projects. Of the 16 planning regions, Region C (the Dallas/Fort Worth area) will be the most reliant on water reuse for its future water supply. By 2060, 27 percent of the new water supply in Region C is projected to be provided by reclaimed water.

PLANNED NEW REUSE WATER SUPPLIES IN 2060



[A] Constructed wetlands for water reuse are used to remove suspended sediment, and nutrients (nitrogen and phosphorus) from the water. In addition, research is ongoing to evaluate the effectiveness of wetlands in the removal of some trace organic compounds.

[B] An acre-foot is a unit of volume commonly used when describing large-scale water supply quantities in the United States. One acre-foot is the volume of water covering one acre of land, if the water were one foot deep. It is equivalent to approximately 326,000 gallons.

[C] Water for Texas 2007 *was the most recently published state water plan available at the time this report was prepared. An updated state water plan will be published in 2012. There is currently no statewide tracking of actual usage of reclaimed water to compare with the plan projections.*

1.2. PURPOSE AND SCOPE

The Texas Water Development Board, through the project "Advancing Water Reuse in Texas," has committed to developing a series of documents to record the history of reuse in Texas, summarize the state of technology with respect to water reuse, and prepare an agenda of priority research needs and funding mechanisms that will help advance the implementation of water reuse projects included in the 2007 State Water Plan. This document comprises the third in this series. Its purpose is to provide an overview of the key challenges that must be addressed to meet future water reuse needs in Texas. In many cases, additional research will be required to answer fundamental scientific and policy questions for specific water reuse applications to ensure that the use of reclaimed water continues to occur in a cost effective and sustainable manner to protect public health and the environment. This document presents information on the types of water reuse research currently being conducted throughout the United States and critical research topics to advance water reuse in Texas.

2. CHALLENGES TO ADVANCING REUSE IN TEXAS

There are a number of challenges to advancing water reuse in Texas. Addressing these challenges requires a deliberate, effective approach that will include addressing key research issues.

2.1. WATER RIGHTS

According to Texas law, treated wastewater that is not reused but rather discharged to a watercourse is return flow. Water reuse can ultimately reduce the amount of flow in the watercourse that is available to other water rights holders and the environment.[1] While significant quantities of reclaimed water have been permitted in recent years, the success of obtaining these permits has been largely due to coordination and collaboration between various water rights stakeholders potentially impacted by the issuance of the permits. It is critical that similar coordination and collaboration be emphasized in the future in order to continue the advancement of water reuse projects. Research that provides insight on advantageous institutional arrangements and partnering opportunities can facilitate water reuse implementation.

2.2. FUNDING

Water for Texas 2007 estimates that implementation of the water reuse projects identified to meet 2060 demands will cost nearly $4 billion dollars. A major challenge for implementing water reuse projects is funding for constructing the initial infrastructure. For direct non-potable reuse systems, the infrastructure needs typically are associated with building pipelines to bring the reclaimed water from the treatment plant to the reuse site. For indirect potable reuse systems, infrastructure can include diversion structures, pipelines, and supplementary reclaimed water purification systems.

Potential federal funding sources for water reuse projects include the Bureau of Reclamation and the Environmental Protection Agency. Research funding may also be available from organizations such as the WateReuse Foundation, the Water Research Foundation

or the Water Environment Research Foundation. The Texas Water Development Board has some funding programs in place that can be used for implementing water reuse projects. These include the State Revolving Funds, Water Infrastructure Fund, and State Participation Fund. Additionally, the Texas Water Development Board's Water Research Grant program provides funding for water resource-related projects. This program has generally been funded in an annual amount of about $600,000. Historically, some of the funds have been allocated to fund reuse research projects. However, there is a need to establish funding mechanisms that specifically address the challenges of starting up a new reclaimed water project. The use of cost-effective treatment schemes commensurate with specific reuse applications and better tools to evaluate the economic, ecological, and social value of water reuse projects are research needs that must be pursued to optimize funding resources.

2.3. BALANCE BETWEEN ECOLOGICAL AND HUMAN NEEDS

There is a need to balance the volume and quality of water required for agricultural, municipal, and industrial use with that needed to support a sound ecological environment. Decreases in wastewater discharges and/or diversions of in-stream flows can adversely affect the habitat of aquatic ecosystems. The quality of reclaimed water utilized for indirect reuse is also an important factor to ensure protection of aquatic life and wildlife. Recently, concerns have been raised about the use of reclaimed water for environmental and recreational uses due to the presence of constituents of emerging concern in reclaimed water, such as pharmaceuticals and ingredients in personal care products. These chemicals may have potential ecological health effects. As more reclaimed water is utilized for direct reuse applications, less reclaimed water will be discharged to the environment, thus reducing the ecosystem's exposure to constituents of emerging concern. Further research is needed to develop the scientific and technical principles necessary to better understand ecosystem sensitivity related to the continued safe use of reclaimed water.

2.4. WATER QUALITY

Significant research demonstrates that reclaimed water is safe for many non-potable uses, including those that involve potential public contact.[2] In addition, research has been and continues to be performed related to the use of reclaimed water for augmenting potable water supplies.[3][4][5] However, as Texas continues to develop additional potable reuse projects, it is critical that additional research be performed to improve our understanding of the quality and safety of reclaimed water.

2.5. PUBLIC EDUCATION AND AWARENESS

Advancement of water reuse in Texas will depend on support from the public, who ultimately will pay for and benefit from the projects. Public attitudes about water reuse vary depending on the water reuse application. Experience and research in the area of public acceptance has clearly shown that public perceptions and opinions can make the difference

between the success and failure of a reuse project for both non-potable and potable reuse applications,[6] and it is important to engage the public early in the planning of a project using effective communications and outreach tools. Therefore, in order to meet future reuse demands, it will be important to implement proactive public outreach and awareness programs on a local, regional and statewide basis. The programs need to inform the public and policy makers about the need for and value of reclaimed water and provide information about the safety of using reclaimed water. Research is needed to develop strategies and information that can enhance public education and awareness programs.

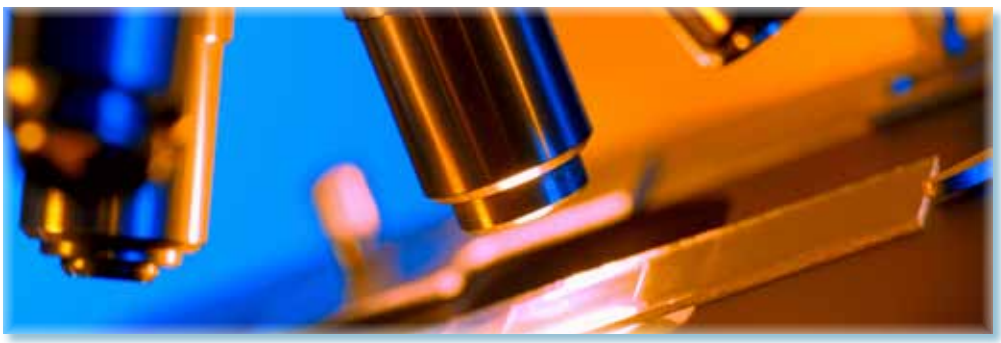
2.6. REGULATORY ISSUES

Regulations can have a significant impact both on public perception and the viability of water reuse projects. In some cases, compliance with regulatory standards (such as nutrient management requirements) can be a primary driver for implementing a water reuse project. As regulations continue to develop and evolve, it is important that impacts of regulatory decisions on future implementation of water reuse projects be evaluated and considered in the rule-making process.

3. PRIORITY RESEARCH TOPICS

The goal of this task was to identify and prioritize water reuse research topics specifically directed at the needs of advancing water reuse in Texas. It included three components:

- A summary of priorities of research entities and their applicability to water reuse in Texas.
- An expert workshop to develop a proposed water reuse research agenda for Texas.
- A description of potential research partnering/ funding mechanisms to support the Texas water reuse agenda.



3.1. SUMMARY OF RESEARCH PRIORITIES OF OTHER ORGANIZATIONS

In the United States, there are three prominent research foundations that support applied research on water reuse: the WateReuse Foundation, the Water Research Foundation, and the Water Environment Research Foundation. For this project, research priorities and recently completed research projects for each organization were identified and reviewed to determine whether the research is applicable to Texas. This information was used in developing the proposed water reuse agenda for Texas to avoid potential duplication of research and to identify specific research needed to meet the demand in the 2007 State Water Plan. A list of recently completed projects for the three foundations is presented in Appendix A.

3.1.1. WATEREUSE FOUNDATION

The WateReuse Foundation's primary mission is to conduct and promote applied research on water reuse and desalination. Water reuse research focuses on six primary topic areas:

- Defining and addressing emerging contaminants that may be present in reclaimed water such as pharmaceuticals and ingredients in personal care products;
- Public perceptions of the benefits and risks of water reuse;
- Management practices related to indirect potable reuse;
- The use of reclaimed water to augment groundwater (including groundwater recharge and aquifer storage and recovery);
- Evaluation and methods for managing salinity levels in reclaimed water; and
- Economics and marketing of water reuse.

The WateReuse Foundation uses three processes for identifying and prioritizing research:

- Workshops on assessing research needs;
- Recommendations from the Foundation's Research Advisory Committee; and
- Collaboration with research partners in developing and implementing research projects.

The most recent research needs assessment workshop was held in December 2009, which was facilitated by the development of white papers that defined the state of the science and identified knowledge gaps requiring further study. The workshop resulted in suggested research projects for the following topic areas:

- Policy, social sciences, and applications projects;
- Microbiology and disinfection;
- Chemistry and toxicology;
- Treatment technologies; and
- Desalination.

The project concepts resulting from the research needs workshop will be reviewed and prioritized on an annual basis by the Foundation's Research Advisory Committee and Board of Directors for funding and implementation.

Research organizations and other potential funding partners can approach the WateReuse Foundation on specific projects for funding under the Research Partnership program.

3.1.2. WATER RESEARCH FOUNDATION

The Water Research Foundation's primary focus is drinking water and the research program addresses four strategic goal areas:

- Infrastructure;
- Management and customer relations;
- Water quality; and
- Water resources and environmental sustainability.

Within these strategic goals, research projects focus on treatment, distribution, resources, monitoring and analysis, management, and health effects. Several projects specifically address water reuse or topics that encompass water reuse.

As part of its Partnership Program, the Water Research Foundation collaborates with organizations on research efforts that range from a single study to formalized multi-year cooperative agreements. For 2010, three projects have been approved for this program:

- Business continuity plans for water.
- Effective microbial control strategies in response to main breaks and depressurization.
- Identifying meaningful opportunities for health risk reduction.

The Water Research Foundation also has a multi-year strategic initiatives program that addresses critical issues that have long-term and broad importance to drinking water utilities and allows funding to be leveraged through partnerships. Currently, three initiative programs have been established:

- Climate change;
- Distribution water quality; and
- Endocrine disrupting compounds[D] and pharmaceuticals and personal care products.

Priority projects are identified annually by volunteer committees and the Water Research Foundation's Board of Trustees based on planning activities conducted under each of the strategic goal areas, including periodic topic-based planning workshops that define the state of the science and identify knowledge gaps requiring further study.

3.1.3. WATER ENVIRONMENT RESEARCH FOUNDATION

The Water Environment Research Foundation focuses on research dedicated to wastewater and stormwater issues. For several years, this effort has focused on 13 research challenges (challenge areas) designed to tackle pressing water quality issues. The challenge areas were developed with input from Foundation subscribers and the Water Environment Research Foundation Research Council:

- Biosolids;
- Climate change;

[D]Synthetic and natural compounds that mimic, block, stimulate or inhibit natural hormones in the endocrine systems of animals, humans, and aquatic life.

The North Texas Municipal Water District East Fork Raw Water Supply project provides water supply benefits as well as recreation and habitat enhancement.

- Decentralized wastewater treatment systems[E];
- Nutrients (such as phosphorus and nitrogen);
- Wastewater treatment operations optimization;
- Pathogens (such as viruses, bacteria, and parasites) and human health;
- Security and disaster response;
- Stormwater;
- Strategic asset management;
- Trace organic chemicals;
- Methods to evaluate the attainment of beneficial uses of surface waters (such as recreation, drinking, wildlife); and
- Water reuse.

A multiyear strategic research program is conducted for each challenge area. Issue area teams develop the research plans and specific projects goals, and provide technical oversight and peer review of individual projects to ensure that the challenge goals are achieved.

As the existing challenges have begun to wind down, six new challenges have been identified with input from Foundation subscribers and the Research Council. Exploratory teams are being formed to investigate the feasibility of these topics as potential research challenges:

- Next generation of used water: 1) define the new vision for more sustainable wastewater and stormwater systems; and 2) commission a series of demonstration projects for more sustainable ways to convey, treat, and reuse water.
- Energy management: develop methods that will allow a wastewater treatment plant to run solely on the energy it gets from wastewater.
- Wastewater as a resource: define and develop resource recovery options (exclusive of energy) that result in cost savings or income sources for wastewater operations and show a net environmental benefit.
- Trace organic chemicals in biosolids[F]: address recent U.S. Environmental Protection Agency

[E]This refers to treatment systems for the collection, treatment, and dispersal/reuse of wastewater from individual homes or clusters of homes at or near the point of waste generation, and includes septic systems.
[F]This refers to the solid or semisolid material obtained from treated wastewater.

findings that identify trace organic compounds in biosolids as an emerging issue and define the sources, fate, and transport of these contaminants.

- Managing receiving water quality impacts: determine the net environmental benefit from process and technology investments in order to evaluate relative cost versus benefit of environmental policy decisions (such as regulating and controlling nutrients).
- Enhanced sensor detection technology: identify real-time and process control sensors that minimize compliance violations and maintain or increase the efficiency of wastewater collection and treatment operations.

The Water Environment Research Foundation is seeking partners and collaborators for the six new research challenges to leverage resources (including funding, data, and facilities) to support the research.

3.2. OVERVIEW OF PROCESS TO SELECT PRIORITY TOPICS FOR TEXAS

The priority research topics for the Texas water agenda were identified using a three-step process.

1. Developed a preliminary list of 27 research themes using an expert panel comprised of the following individuals. Additional information on the panel members is included in Appendix B.

   Bryan W. Brooks, Ph.D., Professor, Baylor University

   James Crook, Ph.D., P.E., Environmental Engineering Consultant

   Jörg E. Drewes, Ph.D., Professor, Colorado School of Mines

   Sara Katz, Katz & Associates

   Ellen T. McDonald, Ph.D., P.E., Alan Plummer Associates, Inc.

   Margaret H. Nellor, P.E., Nellor Environmental Associates

   Alan H. Plummer, Jr., P.E., BCEE, Alan Plummer Associates, Inc.

   David L. Sedlak, Ph.D., Professor, University of California at Berkeley

   Shane A. Snyder, Ph.D., Professor, University of Arizona

2. Held a one-day workshop to further develop research topics and descriptions. The workshop was facilitated by Alan Plummer Associates, Inc., and included the expert panelists and the following additional contributors:

   Jorge Arroyo, P.E., Texas Water Development Board

   Collins Balcombe, Bureau of Reclamation

   Lann Bookout, Texas Water Development Board

   Louis C. Herrin III, Texas Commission on Environmental Quality

   Bob Jurenka, P.E., Bureau of Reclamation

   Saqib Shirazi, Ph.D., P.E., Texas Water Development Board

   Each of the preliminary 27 research themes was reviewed and discussed in terms of goals, objectives, and anticipated benefits to advancing water reuse. The themes were combined into 11 research topic areas:

   - Aquatic life impacts/water quality monitoring
   - Energy/water nexus
   - Environmental, financial, and social benefits
   - Reclaimed water monitoring (monitoring)

- Organizational and institutional issues
- Public awareness
- Risk assessment for non-potable reuse
- Risk assessment for potable reuse
- Treatment using natural systems (wetlands, riverbank filtration and soil aquifer treatment[G])
- Transport and fate of contaminants in natural systems
- Treatment optimization

3. Following the workshop, the expert panel members were assigned to prepare summaries for one or more of the research topics. Each summary addressed the following information areas:
   - General description
   - Approach
   - Benefits
   - Project duration
   - Budget
   - Opportunities for collaboration

   As a result of this effort, 14 potential research projects emerged. The draft summaries for the 14 potential projects were reviewed and finalized by the expert panel. Based on this information a final ranked list of research priorities was developed and endorsed by the expert panel. Of the 14 projects, seven projects were designated as specifically relevant for Texas and seven projects were deemed to be nationally relevant but with applicability to Texas. The complete list of projects and project summaries are presented in Appendix C and Appendix D.

3.3. SUMMARY OF PRIORITY RESEARCH TOPICS

The top seven water reuse research priorities for Texas are presented in Table 1. The rankings were predicated on the need for research 1) to facilitate implementation of indirect potable reuse, which represents the majority of future reuse planned for the state, and 2) to support current and future direct reuse efforts.

[G]Riverbank filtration occurs when water infiltrates into groundwater through the riverbed or banks of a river. Soil aquifer treatment occurs when water infiltrates into groundwater in earthen spreading basins.

TABLE 1. TOP SEVEN TEXAS WATER REUSE RESEARCH PRIORITIES			
Rank	Title	Category	Purpose
1	Understanding the role of environmental buffers in surface water indirect potable reuse projects	Indirect potable reuse: transport and fate in natural systems	Environmental buffers, such as wetlands, storage, and blending, can provide additional treatment, and/or reduce the concentrations of contaminants in reclaimed water used for indirect reuse projects, and serve as barriers between potential threats and the drinking water consumer. In Texas, specifications for project buffers are currently based on professional judgment and precedent rather than knowledge-based science. Research is needed to better quantify the performance and benefits of environmental buffers utilized for surface water augmentation with reclaimed water.
2	Effectiveness of treatment wetlands in improving reclaimed water quality	Indirect potable reuse: transport and fate in natural systems	Constructed wetlands provide treatment of wastewater-dominated river water, prior to delivering the water to water supply reservoirs. Research is needed to document the effectiveness of wetlands treatment for removing contaminants and to identify management approaches and operational strategies that assure the long-term performance of wetland systems. This research would strategically fill in information gaps that are specific to Texas conditions and water quality needs.
3	Use of managed aquifer recharge systems to facilitate water reclamation in Texas	Indirect potable reuse: treatment in natural systems (riverbank filtration and soil aquifer treatment)	Indirect potable reuse includes augmentation of groundwater with reclaimed water, which is called managed artificial recharge. Some types of managed aquifer recharge use natural treatment systems, such as riverbank filtration and soil aquifer treatment, and can provide significant advantages in combination with above ground engineered treatment systems for achieving a consistent high water quality at reduced costs and environmental impact. No managed artificial recharge projects using natural treatment systems have been implemented for indirect potable reuse in Texas. Research is needed to explore the feasibility of managed aquifer treatment in Texas and the suitability of soil aquifer treatment and riverbank filtration for producing potable water quality using reclaimed water or river water that is highly impacted by wastewater discharges.
4	Understanding the effectiveness of nutrient removal processes in reduction of constituents of concern relative to indirect potable reuse	Indirect potable reuse: treatment optimization	Based on nutrient control criteria in the 2010 Texas Surface Water Quality Standards[H], Texas wastewater utilities have a unique opportunity to jointly determine what types of wastewater technologies and operational protocols will meet the new regulations and provide a high quality reclaimed water that can be used for water supply augmentation. Research is needed to design and operate wastewater treatment facilities that will produce reclaimed water for indirect potable reuse in a manner that maximizes the reduction of nutrients as well as other potential constituents of concern and would strategically fill in information gaps that are specific to Texas conditions and water quality needs.

[H] *Texas Administrative Code, Title 30, Chapter 307*

Rank	Title	Category	Purpose
5	Understanding the potential for utilizing nanofiltration as a beneficial treatment process relative to reclaimed water in Texas	Indirect potable reuse: treatment optimization	One of the key parameters that can drive treatment requirements and costs for indirect potable reuse is the level of salt in reclaimed water and the need to prevent salt build-up in water supplies. There are specific treatment methods that remove salt from reclaimed water, but many of them have high energy requirements and produce brine wastes that are difficult to dispose of. Research is needed to select the most effective treatment schemes for salt removal and management to advance indirect potable reuse in Texas. In particular, research is needed on nanofiltration, which provides benefits in terms of removal of salt and lower energy usage, but may not be capable of removing other constituents that can impact water quality.
6	Organizational, institutional, and public awareness framework to advance water reuse in Texas	Direct and indirect reuse: organizational and institutional issues; public awareness	To meet the water reuse goals in *Water for Texas 2007*, research is needed to develop an integrated planning framework given the unique organizational, institutional, water rights and regulatory structures in Texas. This research is intended to develop a framework that includes public awareness and outreach strategies, reuse customer strategies (particularly for large volume users such as the electrical power industry), organizational/institutional models that can effectively implement reuse, and tools that allow utilities to make informed decisions in the selection of and investment in reuse options.
7	Development of integrated water quality models for the Trinity River System	Indirect potable reuse: transport and fate in natural systems	A significant amount of indirect potable water reuse, both planned and unplanned, occurs in the Trinity River system, with effluent accounting for the majority of the flow in the river in some seasons and approximately half of the water entering Lake Livingston on an annual basis. To assess the potential effects of water diversions and changes in water quality in the watershed, research is needed to modify existing models to include relevant constituents, such as trace organic contaminants and regulated drinking water contaminants. This information can be used to plan and implement new indirect reuse projects in conjunction with projected water management activities.

4. ADVANCING THE TEXAS WATER REUSE RESEARCH AGENDA

In order to advance the research agenda and the implementation of water reuse projects in Texas, there will need to be commitment and support from key stakeholders and policy-makers throughout the state.

4.1 TEXAS WATER DEVELOPMENT BOARD ROLE

The Texas Water Development Board Mission Statement is: ***To provide leadership, planning, financial assistance, information, and education for the conservation and responsible development of water for Texas.***

The Texas Water Development Board's main responsibilities are threefold:

- Collect and disseminate water-related data;
- Assist with regional water planning and preparing the State Water Plan for the development of the state's water resources; and
- Administer cost-effective financial programs for the construction of water supply, wastewater treatment, flood control, and agricultural water conservation projects.

Since 1957, the Texas Water Development Board has been charged with addressing the state's water needs. This goal has been accomplished through guiding, enabling and supporting the responsible development of the state's water resources to ensure that sufficient water will be available at a reasonable cost while protecting the state's agricultural and natural resources.

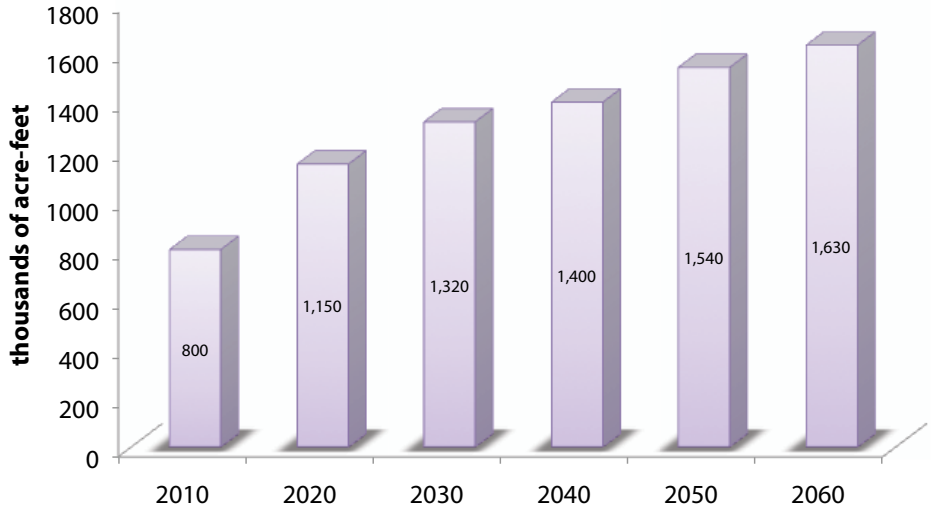
Based on its role to ensure that the water needs of the state are met and its historical role in water-related research, the Texas Water Development Board has the unique qualifications to serve as the lead agency in advancing the water reuse research agenda.

4.2 IMPORTANCE OF RESEARCH

As previously noted, *Water for Texas 2007* indicates that water reuse is expected to provide more than 1.6 million acre-feet per year by 2060. A large portion of this planned reuse is attributed to indirect potable reuse applications. Completion of the proposed research efforts will help develop the information needed to support the implementation and operation of indirect potable reuse projects throughout the state as well as support non-potable reuse projects. Furthermore, these research efforts could provide valuable information that could increase the number of water reuse projects implemented in the future, beyond those currently identified in the State Water Plan.

PROJECTED REUSE SUPPLIES IN TEXAS

(from *Water for Texas 2007*)



4.3 RESEARCH PERFORMANCE SUPPORT

It is critical that a broad base of support for carrying out the proposed research agenda be developed. Gaining the support of the Regional Planning Groups, major water providers, and key policymakers will be important in achieving that objective. Additionally, collaborating with other state agencies and professional and technical organizations will be very important.

Based on the estimates provided in Appendices C and D, support of the priority research projects will cost on the order of $1,850,000 for projects of specific Texas interest and $1,900,000 for other projects with Texas and national interest. In order to fund the research, there will be a need to gain legislative support and to partner with other potential funding participants.

4.4 POTENTIAL RESEARCH PARTNERING OPTIONS

Based on the proposed research agenda, there are a number of potential partnering opportunities that could be pursued to leverage state funding.

- WateReuse Foundation: under the Research Partnership program.
- Water Research Foundation: under the Partnership Program.
- Water Environment Research Foundation: under two of the new research challenges (next generation of used water and enhanced sensor detection technology) and under some of the ongoing challenges (for example trace organics).
- WateReuse Association, Texas
- Texas utilities and major water providers
- Federal agencies (Bureau of Reclamation, Environmental Protection Agency)

REFERENCES

(1) Reuse Committee of the Texas Water Conservation Association (2006) Texas Water Rights and Wastewater Reuse; Texas Water Conservation Association: Austin, Texas.

(2) Crook, J. *Irrigation of Parks, Playgrounds, and Schoolyards with Reclaimed Water: Extent and Safety.* WateReuse Foundation: Alexandria, VA, 2005.

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APPENDIX A - RECENTLY COMPLETED WATER REUSE RESEARCH PROJECTS

Project Identification	Description	Relevant to Texas
WateReuse Foundation		
WRF-01-007	**Removal of Endocrine Disrupting Compounds in Water Reclamation Processes** The goal of this research was to develop approaches combining bioassays with chemical analysis to study removal of endocrine disrupting chemicals (EDCs) by different reclamation treatment process.	Yes
WRF 02-008	**A Reconnaissance-Level Quantitative Comparison of Reclaimed Water, Surface Water, and Groundwater** This project investigated and documented the water quality associated with: 1) surface and groundwaters that have minimal or no direct influence from treated municipal wastewater and/or reclaimed water discharges; 2) surface and ground waters that are known to be influenced by treated municipal wastewater and/or reclaimed water discharges; and 3) reclaimed water.	Yes
WRF-03-014	**Development of Indicators and Surrogates for Chemical Contamination Removal During Wastewater Treatment** The objectives of this project were to identify surrogates and indicators for wastewater derived chemical contaminants that might be useful in the assessment of indirect potable reuse systems, to identify and assess the performance of analytical methods for the chosen surrogates and indicators, and to validate the ability of chosen surrogates and indicators to predict the occurrence and removal of wastewater derived contaminants in indirect potable water reuse systems.	Yes
WRF-04-008	**The Psychology of Water Reclamation and Reuse: Survey Findings and Research Road Map** The goal of this project is to provide a solid foundation with respect to how individuals regard potable water, water treatment, the history of water, water naturalness, and water quality. The project will also develop a three to five year research plan to direct future research initiatives.	Yes
WRF-04-010	**Extending the Integrated Resource Planning Process to Include Water Reuse and Other Nontraditional Water Sources** The focus of this report is to identify the opportunities and challenges for extending the Integrated Resource Planning (IRP) process to Nontraditional Water Sources (NTWS). NTWS options include reclamation (such as water recycling), desalination (coastal or groundwater), and stormwater use. The goal is to help local and regional water planners and utilities make (and implement) better informed decisions regarding their mix of NTWS and traditional water supply options.	Yes

Project Identification	Description	Relevant to Texas
WRF-04-011	**Application of Microbial Risk Assessment Techniques to Estimate Risk Due to Exposure to Reclaimed Waters** The objective of this investigation was to assess the relative risks associated with non-potable water reuse applications and provide water and wastewater utility managers with decision making tools for water reuse applications. The objective was to be realized by developing a matrix of relative microbial risks associated with the use of reclaimed water for non-potable reuse applications under a range of different conditions including: occurrence of various infectious agents in reclaimed water; treatment processes used to produce the reclaimed water; end-uses and use-specific exposure pathways; disease endpoints; and exposed population characteristics from healthy to sensitive subgroups. This approach can be use for indirect potable reuse projects.	Yes
WRF-04-12	**Collecting, Exploring, and Interpreting Microbiological Data Associated with Reclaimed Water Systems** The purpose of this project is to develop a guidance document for applying sound statistical approaches for microbiological characterization of reclaimed water including study design, sampling limitations, data management, data interpretation, and data communication.	Yes
WRF-04-017	**Reaction Rates and Mechanisms of Advanced Oxidation Processes for Water Reuse** This study develops an understanding of the water-based free radical chemistry in the destruction of organic microconstituents. The long-term goal of this type of research is to provide the data necessary to develop kinetic models that describe the underlying chemistry for advanced oxidation process applications.	Yes
WRF-04-021	**Selecting Treatment Trains for Seasonal Storage of Reclaimed Water Treatment of Influent to and Withdrawals from Storage: A Resource Guide** The goal of this study is to document water quality and cost tradeoffs associated with storage options of reclaimed water. A guidance manual has been produced to provide a decision-making framework for utilities and consulting engineers considering long-term or short-term storage of reclaimed water.	Yes
WRF-05-001	**Evaluating Pricing Levels and Structures to Support Reclaimed Water Systems** This study provides utility and agency managers with a clear and comprehensive discussion of issues and objectives to consider when developing pricing levels and structures for reclaimed water. This will result in better planned water reclamation projects, greater public acceptance, improved financial sufficiency, and successful implementation.	Yes

Project Identification	Description	Relevant to Texas
WRF-05-002	**Guidance Document on the Microbiological Quality and Biostability of Reclaimed Water Following Storage and Distribution** This study provides valuable data for understanding microbial community structure changes that occur during storage and distribution of reclaimed water. A comparison has been made to evaluate chemical and physical relationships with microbiological water quality parameters in order to establish the extent and magnitude of changes that occur during storage and distribution.	Yes
WRF-05-004	**Development of Surrogates to Determine the Efficacy of Soil Aquifer Treatment Systems for the Removal of Organic Chemicals** This is the second phase of WRF-03-014, which has been completed. The main objective of this project is to determine appropriate organic surrogates for groundwater recharge projects that use reclaimed water. The technical approach includes tasks to identify an appropriate surrogate or group of surrogates for recharge projects where biodegradation is the major removal mechanism, and to identify an appropriate surrogate or group of surrogates for direct injection projects where membrane treatment before injection is the major removal process.	Yes
WRF-05-005	**Identifying Hormonally Active Compounds, Pharmaceutical Ingredients, and Personal Care Product Ingredients of Most Health Concern From Their Potential Presence in Water Intended for Indirect Potable Reuse** This study consisted of a workshop held in November 2008, which was attended by regulators, scientists, and water industry professionals to discuss alternative methods to efficiently develop regulatory-based human health toxicity criteria for PPCPs and EDCs in wastewater. Case studies of methods for developing toxicity criteria were prepared for 22 PPCPs and 15 EDCs.	Yes
WRF-05-007	**Selection and Testing of Tracers for Measuring Travel Times in Groundwater Aquifers Augmented with Reclaimed Water** The objective of this study is to select, identify, and test environmentally acceptable tracers to cost effectively measure travel times of biophysicochemical constituents in natural water systems that are augmented with treated wastewater effluent.	Future
WRF-05-008	**The Effects of Salinity on the Removal of Contaminants of Concern during Biological Water Reclamation** This study evaluates the impact of salinity on the removal of target organic contaminants of concern during biological wastewater treatment.	Yes
WRF-05-009	**Dewatering Reverse Osmosis Concentrate from Water Reuse Applications Using Forward Osmosis** This study focuses on exploring innovative draw solutions, commercially available forward osmosis (FO) membranes, and the feasibility of applying FO to dewater reverse osmosis (RO) concentrate. This report summarizes initial feasibility data on the application of FO to minimize the concentrate from RO process.	Yes

Project Identification	Description	Relevant to Texas
WRF-05-010	**Oxidative Treatments of Organics in Membrane Concentrates** The goal of this study was to develop an oxidation process for removing organics present in the concentrate from reverse osmosis membrane treatment.	Yes
WRF-06-002	**Developing a Pragmatic Research Agenda for Examining the Value of Water Supply Reliability** Although "drought-proofing" is often cited as a major benefit of water reuse and desalination projects, the existing empirical information is limited, often dated, and not easily interpreted. This study evaluated empirical values that can be used to quantify the benefits of water reuse and desalination projects.	Yes
WRF-06-005	**Leaching of Metals from Aquifer Soils during Infiltration of Low-Ionic-Strength Reclaimed Water: Determination of Kinetics and Potential Mitigation Strategies** The objective of this study is to evaluate the potential for release of metals of public health concern from a surface spreading operation. Desorption kinetics calculated from experimental data have been used to create groundwater transport models that will predict potential plume structure and facilitate migration planning.	Future
WRF-06-008	**Low Cost Treatment Technologies for Small Scale Water Reclamation Plants** This study identifies and evaluates established and innovative technologies that provide treatment of flows of less than one million gallons per day. The report includes an extensive cost database, where the cost and operation data from existing small-scale wastewater treatment and water reuse facilities have been gathered and synthesized.	Yes
WRF-06-018	**Tools to Assess and Understand the Relative Risks of Indirect Potable Reuse and Aquifer Storage and Recovery Projects** The objective of this research is to use existing risk assessment tools that can be used by sponsors of indirect potable reuse projects to evaluate and explain the relative human health risks related to the use of reclaimed water. The study is comprised of three tasks: 1) conduct a quantitative relative risk assessment for two active groundwater recharge projects in California that use reclaimed water, based on chemicals that are currently regulated or under consideration for regulation the Montebello Forebay project and the Chino Basin project); 2) develop TDIs and DWELs for 43 CECs in reclaimed water; 3) predicting future chemicals of emerging concern (CECs) and their treatability.	Yes
WRF-06-019	**Monitoring for Microconstituents in an Advanced Wastewater Treatment Facility and Modeling Discharge of Reclaimed Water to Surface Canals for Indirect Potable Use** The project presents the results of a pilot advanced treatment study and the potential impact of microconstituents (also called constituents of emerging concern) to aquatic organisms using toxicological assays and chemical analyses. The project also examines the fate and transport of select microconstituents from a hypothetical canal discharge location in South Florida to a drinking water aquifer.	Yes

Project Identification	Description	Relevant to Texas
Water Research Foundation		
2968 (in collaboration with UKWIR and WateReuse Foundation)	**Framework for Developing Water Reuse Criteria With Reference to Drinking Water Supplies** Documents existing standards and their rationale/basis (such as, public health and/or other parameters), defines merits and weaknesses of existing approaches, identifies gaps in existing knowledge, and develops a rationale for setting standards/guidelines based upon pathway/risk end point.	Yes
2971 (in collaboration with WateReuse Foundation, Bureau of Reclamation, and Water Environment Research Foundation)	**Beneficial Uses and Non-Traditional Uses of Concentrate** Provides a comprehensive review and comparison of the full range of alternate uses of concentrate and assesses the feasibility of implementation, economic considerations, and environmental safety. Also evaluates both direct uses of concentrate and the potential for recovery and marketing of individual salts separated from concentrate.	Yes
3012 (in collaboration with the West Basin Municipal Water District)	**Comparing Nanofiltration and Reverse Osmosis for Treating Recycled Water** Evaluates the feasibility of nanofiltration (NF) and ultra-low-pressure reverse osmosis (ULPRO) membranes for rejecting total organic carbon, total nitrogen, and unregulated trace organic compounds under a range of experimental conditions at the laboratory-, pilot-, and full-scale to produce water suitable to augment drinking water supplies. Provides utilities with guidance on selecting membranes and predicting solute rejection during NF-ULPRO membrane treatment.	Yes
3056 (in collaboration with the California Energy Commission)	**Evaluation of Dynamic Energy Consumption of Advanced Water and Wastewater Treatment Systems** Documents the energy use, cost, and efficiency of water and wastewater unit operations. Includes a comparison with theoretical efficiencies and an identification of the largest energy usages. Conducts a comparison of 12 different plants to include a range of advanced water and wastewater treatment processes including desalination.	Yes
3085 (in collaboration with the WateReuse Foundation)	**Toxicological Relevance of Endocrine Disruptors and Pharmaceuticals in Drinking Water** This project addressed the fundamental issue of potential human health impacts from the trace concentrations of EDCs and pharmaceuticals and personal care products (PPCPs) detected in drinking waters from across the United States by combining toxicological literature reviews and analytical monitoring results. It compared the health risks of drinking water and reclaimed water with food products; it also developed Tolerable Daily Intakes (TDIs) and Drinking Water Equivalent Levels for 16 PPCPs and 13 EDCs.	Yes

Project Identification	Description	Relevant to Texas
3096 (in collaboration with Arizona State University National Science Foundation Water Quality Center, City of Phoenix Water Services Department, City of Goodyear, and City of Scottsdale	**Inland Membrane Concentrate Treatment Strategies for Water Reclamation Systems** Identifies and develops methods to manage brine streams from water reclamation systems (including agricultural drainage) so that the water may be recovered for potable or industrial purposes while the salts are converted into solid by-products. The study also determines the optimum combination of membrane, thermal, and solid-liquid separation processes for different brine solutions, and develops a computer model for optimizing unit processes for different water qualities. Provides a bench-scale testing protocol for simulating different brine concentration strategies.	Yes
3180 (in collaboration with the City of Aurora, CO)	**Removal of Bulk Organic Matter, Organic Micropollutants, and Nutrients During Riverbank Filtration** Identifies key removal mechanisms and conditions for emerging organic pollutants in river bank filtration (RBF) systems. Assesses the performance and potential limitations of RBF systems regarding removal of emerging micropollutants, TOC, and nutrients (ammonia, nitrate, and phosphorus). Develops a guidance document for design and operation of RBF systems.	Yes
91212 (in collaboration with the WateReuse Foundation)	**Comparing Nanofiltration and Reverse Osmosis for Treating Recycled Water** This project evaluated the feasibility of nanofiltration (NF) and ultra-low-pressure reverse osmosis (ULPRO) membranes for rejecting total organic carbon, total nitrogen, and unregulated trace organic compounds under a range of experimental conditions at the lab-, pilot-, and full-scale to produce water suitable to augment drinking water supplies.	Yes
Water Environment Research Foundation		
99-PUM-4	**Impact of Surface Storage on Reclaimed Water: Seasonal and Long Term** Storing reclaimed water in open reservoirs can impact its quality. In this study, the project team analyzed published literature and federal and state reclaimed water guidelines to develop a better understanding of the effects of storage on reclaimed water quality. The report includes 1) information on computer models that simulate water quality in reclaimed water reservoirs, 2) the water quality parameters that can change during storage and the physical, chemical, and biological processes that cause these changes, and 3) management strategies and tools to minimize water quality problems.	Yes

Project Identification	Description	Relevant to Texas
00-PUM-1 (in cooperation with the WateReuse Foundation)	**Understanding Public Perception and Participation** This study was a multidisciplinary analysis undertaken by a team of social scientists, engineers, and water professionals to develop a framework for water professionals that identifies the five underlying principles that contribute to shaping public perception and acts as a guide for public outreach, education, and participation activities.	Yes
00-PUM-2T	**Reduction of Pathogens, Indicator Bacteria, and Alternative Indicators in Wastewater Treatment** The increased implementation of wastewater reclamation systems requires adequate controls to protect users of reclaimed water from exposure to pathogens. This research report identifies the relative effectiveness of biological treatment systems, filtration, and disinfection for removal of these viral and protozoan pathogens. The report also is an effective guide for facilities interested in developing improved monitoring tools to assess microbiological water quality. This report is intended to help to catalyze discussions on a regulatory framework focused on reclaimed water quality for viruses, parasites, and bacteria.	Yes
01-CTS-6a	**Membrane Treatment of Secondary Effluent for Subsequent Use: Pilot Plant Comparisons of Tests of MF and UF for Pretreatment of High-Pressure Membranes** The literature review conducted in Phase 1 of this project (01CTS6) showed the need for direct comparisons between microfiltration (MF) and ultrafiltration (UF) as pretreatment for high pressure membranes in water reclamation systems. Two reverse osmosis (RO) and one nanofiltration (NF) membrane systems were placed in two parallel treatment trains of a large pilot plant, one set receiving MF and the other UF filtrate. An extensive database was provided to decide between these pretreatment systems for either retrofitting existing or designing new facilities. UF pretreatment produced less fouling of the high-pressure membranes and required less energy, while either pretreatment produced excellent removal of both organic and inorganic compounds. Autopsies showed less accumulation of polysaccharides and organic carbon on high-pressure membranes receiving UF than MF pretreatment.	Yes
01-HHE-4a	**Online Methods for Evaluating the Safety of Reclaimed Water** The objective of this research was to develop an online bioassessment platform (such as Japanese medaka) to evaluate the safety of reclaimed water. Evidence exists that indicates the presence of unregulated organic contaminants (such as pharmaceuticals and personal care products) in municipal wastewater effluents, surface waters, groundwater, and drinking water sources are at concentrations that adversely affect endocrine and reproductive systems of fish.	Yes

Project Identification	Description	Relevant to Texas
03-CTS-17d (in collaboration with Water Research Foundation, WateReuse Research Foundation)	**Investigation of Regional Solutions for Disposing of Concentrate** Provides an overview of concentrate disposal and management practices and includes a decision methodology that can be used to assess not only what concentrate disposal options are technically feasible but also what options are viable. The decision methodology is provided in the form of interactive software included on a CD-ROM that allows users to enter site-specific data and assess options.	Yes
03-CTS-21UR (in cooperation with the WateReuse Foundation)	**Contributions of Household Chemicals to Sewage and their Relevance to Municipal Wastewater Systems and the Environment** This study identified high-volume production (HVP) chemicals and organic compounds from household products, and provided information on the occurrence and fate of HVP chemicals in wastewater systems and the environment.	Yes
CEC2C08	**Communication Principles and Practices, Public Perception and Message Effectiveness** Water and wastewater utilities communicate with customers, the media, and other stakeholders about the presence of trace organic compounds in water supplies and the potential risks to human health and the environment. This project reviewed previously published communications research and analyzed media reports about trace organic compounds. Ten utilities share their perspectives and describe their outreach programs, communication methods, key messages, and thoughts about communication deficiencies or needs. The researchers developed a framework to help utilities as they present and monitor the effectiveness of communication strategies and materials.	Yes

APPENDIX B – TEXAS WATER REUSE AGENDA EXPERT PANEL

BRYAN W. BROOKS, PH.D.

Department of Environmental Science, Baylor University

Dr. Brooks' research interests include understanding how anthropogenic activities and stressors influence various levels of biological organization. Students and postdoctoral fellows working in his group are engaged in interdisciplinary projects that often incorporate laboratory and field studies in environmental toxicology and risk assessment, applied aquatic ecology, and water quality research. Because of the complex nature of environmental science and environmental health, students receive an interdisciplinary training that balances formational coursework with applied problem solving experiences. His current research focuses on water quality dynamics of rapidly urbanizing regions, developing approaches to define contaminants of emerging concern (such as pharmaceuticals, personal care products, and endocrine active substances), water reuse, and the ecology and environmental toxicology of harmful algae blooms. Dr. Brooks has given over 60 invited presentations and lectures in the United States, United Kingdom, France, Poland, Portugal and Australia.

JAMES CROOK, PH.D., P.E.

Environmental Engineering Consultant

Jim Crook is an environmental engineer with more than 37 years of experience in state government and consulting engineering arenas, serving public and private sectors in the U.S. and abroad. He has authored more than 100 publications and is an internationally recognized expert in water reclamation and reuse. He has been involved in numerous projects and research activities involving public health, regulations and permitting, water quality, risk assessment, treatment technology, and all facets of water reuse. Crook spent 15 years directing the California Department of Public Health's water reuse program, during which time he developed California's first comprehensive water reuse criteria. He also spent 15 years with consulting firms overseeing water reuse activities and is now an independent consultant specializing in water reuse. He has served on several advisory panels and committees convened by the National Academy of Sciences, NWRI, and others. Among his honors, he was selected as the American Academy of Environmental Engineers' 2002 Kappe Lecturer and the WateReuse Association's 2005 Person of the Year. Crook received a B.S. in Civil Engineering from the University of Massachusetts and both an M.S. and Ph.D. in Environmental Engineering from the University of Cincinnati. He is a registered professional engineer in California and Florida.

JÖRG E. DREWES, PH.D.

Professor and Director, Advanced Water Technology Center, Environmental Science and Engineering Division, Colorado School of Mines; Drewes Environmental, LLC, President

Dr. Drewes has been actively involved in research in the area of water treatment and non-potable and potable water reuse for more than 18 years. For the last 14 years, Dr. Drewes has been conducting research on indirect potable reuse projects in Arizona, California, Colorado, Nevada, and Florida including surface spreading as well as direct injection projects. The main focus of these studies has been the fate and transport of trace organic chemicals in these systems. He has led research as the principal investigator (PI) or Co-PI to better understand the rejection of trace organic chemicals during high-pressure membrane treatment (nanofiltration, reverse osmosis) as well as the fate and transport of micropollutants in soil-aquifer treatment systems. A common theme in all these projects was to identify meaningful trace organic compounds that can serve as indicator compounds for system performance assessments. He has also conducted tailored studies to further develop this concept for multiple treatment processes commonly employed in indirect potable reuse followed by more focused efforts for surface spreading and direct injection projects. This indicator

concept has been adopted in the Australian Water Recycling Guidelines for Drinking Water Augmentation in 2008. In addition, he has been involved in several studies addressing the occurrence of emerging contaminants in recycled water and to provide guidance to the water industry regarding occurrence, fate and transport, health effects, analytical methods and communication. Dr. Drewes research group is currently working on developing more predictive tools for the fate of trace organic chemicals in various reuse schemes using quantitative structural property relationships (QSPRs) coupled with process models. Dr. Drewes has published more than 250 journal papers, book contributions, and conference proceedings. He was awarded the 2007 AWWA Rocky Mountain Section Outstanding Research Award, the 2003 Dr. Nevis Cook Excellent in Teaching Award, the Quentin Mees Research Award in 1999, and the Willy-Hager Award in 1997. In 2008, he was appointed to the National Research Council Committee on Water Reuse as an Approach for Meeting Future Water Supply Needs. Since 2007, Dr. Drewes holds Visiting Professor appointments at the University of New South Wales, Sydney, Australia and the King Abdullah University of Science and Technology in Saudi Arabia/.

SARA KATZ

President, Katz & Associates

During her 25 years of public affairs experience, Sara has developed a recognized specialty in developing communication programs for local, state and federal public agencies. Her experience includes public outreach and involvement programs for major public works projects, social awareness programs and controversial public policy issues. Sara's experience with water and wastewater programs includes work in California, Nevada, Texas, Georgia, Florida and Sydney, Australia. Other areas of expertise include air transportation, land use planning, redevelopment, mass transit, energy, schools and consumer protection. Sara's wealth of experience ranges from issues management, coalition building and facilitation to strategic planning, media strategy and crisis management. Recent client experience includes the Port of San Diego, Southern Nevada Water Authority, the US Army Corps of Engineers – Omaha and Kansas City Divisions, San Francisco Public Utilities Commission (Water Department) and the El Paso Water Utilities. Under Sara's supervision, the firm has grown to more than 45 employees while maintaining a solid track record of personalized service, the hallmark of her boutique-size firm. A frequent conference speaker and published writer, Sara is past chair of the AWWA Public Involvement Committee. Sara earned a Bachelor of Science degree in economics with a minor in political science from San Diego State University. She has completed coursework in facilitation and public involvement/process negotiations.

ELLEN T. MCDONALD, PH.D., P.E.

Principal, Alan Plummer Associates, Inc.

Dr. McDonald is a registered professional engineer in Texas and currently leads the water resources planning group at Alan Plummer Associates, Inc. She has more than 20 years of experience working in the areas of water resources planning, water reuse, water quality modeling and water and wastewater system modeling and planning. Dr. McDonald's experience in water reuse includes project management and technical direction on numerous projects within the state of Texas. These include reclaimed water implementation plans for the City of Dallas, City of Fort Worth, City of Irving, White River Municipal Water District and North Texas Municipal Water District. In addition to developing plans for these entities, she has assisted a number of entities with associated water rights permitting and obtaining reclaimed water authorizations for their projects. She has also facilitated workshops to assist entities starting

a new reclaimed water utility with the development of policies and procedures, rates and ordinances for their systems. Dr. McDonald currently serves as a trustee for the Texas section of the WateReuse Association and is a member of the Water Environment Association of Texas water reuse committee. Prior to joining Alan Plummer Associates, Inc., Dr. McDonald was an assistant professor at The Ohio State University where she taught and performed research in the area of environmental fluid mechanics. She holds a Bachelor of Science degree in Civil Engineering from Bucknell University and a Master of Science and Ph.D. in Water Resources Engineering from Stanford University.

MARGARET H. NELLOR, P.E.

President, Nellor Environmental Associates

Ms. Nellor has over 30 years of professional experience in the environmental field including water and wastewater quality management, research, regulatory and legislative policy development and analysis, water recycling, groundwater replenishment, source control and pollution prevention. She is also very active in professional activities related to the environmental profession. She currently is the President of Nellor Environmental Associates, Inc., an environmental engineering consulting firm that provides technical services and assistance related to wastewater management, water recycling, regulations, legislation and policies. She previously was the Assistant Department Head of Technical Services for the County Sanitation Districts of Los Angeles County, which provides for the wastewater and solid waste management needs of over five million people in Los Angeles County, California. In that capacity, she was responsible for the overall administration of the agency's wastewater quality, compliance, water reclamation, and laboratory and research programs. Ms. Nellor has a Masters Degree in Environmental Health Engineering and a Bachelors Degree in Civil Engineering from the University of Texas at Austin and is a member of the University of Texas Civil and Architectural Engineering Academy of Distinguished Alumni. She is a registered civil engineer in California and Texas. She served on the University of Texas Engineering Foundation Advisory Council of the College of Engineering. She was the past President of the WateReuse Association and served on the Association's Board of Directors. She also served as the Vice-President of the WateReuse Foundation's Board of Directors and currently serves on the Foundation's Research Advisory Committee. She also serves on the Water Environment Federation's Water Reuse Committee and the Water Environment Research Foundation's Trace Organics Issue Area Team. She served on the Board of Directors for the National Association of Clean Water Agencies (NACWA), and chaired NACWA's Regulatory Policy Committee and Mercury Workgroup. She was the Co-Chair of the Environmental Protection Agency's Effluent Guidelines Task Force, and was the past Chair of Tri-TAC. She is the author and/or co-author of over 20 technical publications, papers, and has also contributed to books and manuals of practice.

ALAN H. PLUMMER, JR., P.E., BCEE

Chairman of the Board, Alan Plummer Associates, Inc.

Alan Plummer, founder of Alan Plummer Associates, Inc., has a wealth of water resources planning and system design experience. His expertise in problem assessment and solution development, both from technical and project management perspectives, has provided invaluable insight to water districts, river authorities, and municipalities. Mr. Plummer's 45 years of experience includes water quality studies and analyses, water reclamation and reuse planning, and natural and constructed wetlands water treatment. He served on a Technical Advisory Committee to develop state rules for water reclamation use for irrigation purposes and was an active participant on the

Texas Section AWWA Water Conservation and Reuse Committee (Chair of Strategic Planning Subcommittee), the WEAT Reuse Committee (Committee Chair), the AWWA Reuse Committee, the WEF Reuse Committee, and the Governor's Water Conservation Task Force. Mr. Plummer is a Board Member of the Texas Water Conservation Association (TWCA) and serves on the TWCA Water Reuse Committee. He was elected the first president of the Texas Section of the WateReuse Association and currently serves on the WateReuse Foundation's Board of Directors. He was the 2008 recipient of the WateReuse Foundation's Award of Merit for significant contributions to the advancement of water reuse. He received a Bachelor of Science degree in civil engineering from Lamar University and a Master's degree in environmental health engineering at the University of Texas at Austin and is a member of the University of Texas Civil and Architectural Engineering Academy of Distinguished Alumni.

DAVID L. SEDLAK, PH.D.

Department of Civil and Environmental Engineering, University of California at Berkeley

David Sedlak is a Professor in the Department of Civil and Environmental Engineering at the University of California at Berkeley. His research addresses water quality engineering with a focus on trace contaminants and their fate in natural and engineered systems. Prior to joining the faculty at UC Berkeley, Sedlak was a postdoctoral researcher at the Swiss Federal Institute for Environmental Science & Technology (EAWAG). He received a B.S. degree from Cornell University in 1986 and a Ph.D. from the University of Wisconsin-Madison in 1992. Dr. Sedlak has served on the Executive Committee of the UC Toxic Substances Research & Teaching Program and is on the editorial boards of Environmental Science & Technology and Water Research. He is a recipient of the NSF CAREER award, WERF's Paul L. Busch Award and a Fulbright Senior Scholar Fellowship.

SHANE A. SNYDER, PH.D.

Department of Chemical and Environmental Engineering, University of Arizona

Shane Snyder is a Professor of Chemical and Environmental Engineering at the University of Arizona. He also is the Co-Director of an NSF funded center dedicated to the analysis and characterization of emerging contaminants, the Arizona Laboratory for Emerging Contaminants.

Dr. Snyder is an internationally renowned expert on emerging water quality issues with over 15 years of experience in the evaluation of occurrence and fate of trace contaminants in water. He joined the Southern Nevada Water Authority in 2000 as the first Research and Development staff and was instrumental in the founding of the Authority's Applied Research and Development Center.Through Dr. Snyder's leadership, this research center has been awarded over $5,000,000 of competitive research funding from a variety of government and private sector agencies. He has served two terms on the U.S. Environmental Protection Agency Federal Advisory Committee for the Endocrine Disruptor Screening Program and has served on two expert panels for the U.S. Environmental Protection Agency's Candidate Contaminant List III. He is a member of the Research Advisory Council for the WateReuse Foundation and is a member of the American Water Works Association's Water Science & Research Division Board of Trustees. In April 2008, Dr. Snyder testified before the U.S. Senate Committee on Environment and Public Works for a subcommittee hearing entitled "Pharmaceuticals in the Nation's Water: Assessing Potential Risks and Actions to Address the Issue." He has published more than 100 peer-reviewed manuscripts and book chapters on the detection, treatment, and health impacts of endocrine disruptors and pharmaceuticals in water.

APPENDIX C – RANKED LIST OF POTENTIAL PRIORITY RESEARCH PROJECTS

Title	Category	Funding category	Rank	Estimated Budget
Understanding the role of environmental buffers in surface water indirect potable reuse projects	Indirect potable reuse: transport and fate in natural systems	T	1	$200,000
Effectiveness of treatment wetlands in improving reclaimed water quality	Indirect potable reuse: transport and fate in natural systems	T	2	$400,000
Use of managed aquifer recharge systems to facilitate water reclamation in Texas	Indirect potable reuse: natural treatment systems (riverbank filtration and soil aquifer treatment)	T	3	$150,000
Understanding the effectiveness of nutrient removal processes in reduction of constituents of concern relative to indirect potable reuse	Indirect potable reuse: treatment optimization	T	4	$250,000
Understanding the potential for utilizing nanofiltration as a beneficial treatment process relative to reclaimed water in Texas	Indirect potable reuse: treatment optimization	T	5	$250,000
Organizational, institutional, and public awareness framework to advance water reuse in Texas	Direct and indirect reuse: organizational and institutional issues; public awareness	T	6	$250,000
Development of integrated water quality models for the Trinity River System	Indirect potable reuse: transport and fate in natural systems	T	7	$350,000
Subtotal Projects Texas Interest				**$1,850,000**
Comparative and relative human health risk assessment of indirect potable reuse in Texas	Indirect potable reuse: risk assessment	N	1	$200,000
Selection of appropriate chemical indicators and surrogates for indirect potable reuse projects in Texas	Indirect potable reuse: monitoring	N	2	$150,000
Environmental quality of water reuse projects in Texas	Indirect potable reuse: aquatic life impacts/monitoring	N	3	$300,000
Development and validation of real-time monitoring methodology	Indirect potable reuse: monitoring	N	4	$300,000
Development of quantitative molecular methods for evaluating the viability and concentration of microorganisms	Direct and indirect reuse: monitoring	N	5	$250,000
Safety of reclaimed water used for irrigation of public lands and residential areas in Texas	Direct reuse: risk assessment	N	6	$350,000
Tools to evaluate the environmental, financial and social benefits of water reuse in Texas	Direct reuse: environmental, financial and social benefits	N	7	$350,000
Subtotal Projects National Interest				**$1,900,000**
Total				**$3,750,000**

T – Specific Texas interest

N – National interest with application to Texas

APPENDIX D – PROPOSED PRIORITY RESEARCH SUMMARIES

RANK: 1 – SPECIFIC TEXAS INTEREST

TITLE: UNDERSTANDING THE ROLE OF ENVIRONMENTAL BUFFERS IN SURFACE WATER INDIRECT POTABLE REUSE PROJECTS.

Description: Indirect potable reuse is defined as the augmentation of a drinking water source with reclaimed water, including passage through an environmental buffer. For surface water augmentation with reclaimed water, environmental buffers can include storage and blending in raw water reservoirs and passage through wetlands and rivers. Environmental buffers can provide additional treatment, and/or reduce the concentrations of contaminants in reclaimed water, and serve as barriers between potential threats and the drinking water consumer. Currently, the application of environmental buffers is based on professional judgment and precedent rather than knowledge-based science. This approach may be over- or under-protective of public health and the environment. Several major surface water indirect reuse projects have recently been implemented or are planned in Texas. Research is needed to better quantify the performance and benefits of environmental buffers utilized for surface water augmentation with reclaimed water. Specifically, there is a need to document contaminant attenuation and identify appropriate storage (detention) times and blending ratios for Texas applications.

Approach:

- Identify existing surface augmentation projects in Texas that use reclaimed water and their associated blending ratios and detention times.
- Identify planned surface augmentation projects in Texas that may use reclaimed water and ranges of blending ratios and detention times.
- Identify those compounds of greatest human health and environmental concern for indirect reuse and their levels in water that are of minimal risk based on available scientific information.
- Using conditions representative of the existing and planned projects, perform laboratory studies to quantify the impact of blending ratios and detention time on the attenuation of the target compounds of concern within these systems.

Benefits:

- Will develop guidelines for establishing environmental buffers that can be considered for surface augmentation projects in Texas and facilitate implementation of vital projects in *Water for Texas 2007* and future water plans.
- Will assure that indirect potable reuse projects are undertaken to provide reasonable protection of public health and the environment.

Duration: 2 years

Estimated Budget: $200,000

Opportunities for Collaboration: May be able to work with the WateReuse Foundation to obtain co-funding for the project under the Foundations' Research Partnership Program. The program sponsors research with other research organizations and institutions.

RANK: 2 – SPECIFIC TEXAS INTEREST

TITLE: EFFECTIVENESS OF TREATMENT WETLANDS IN IMPROVING RECLAIMED WATER QUALITY.

Description: Two major projects in the Dallas-Fort Worth area currently use constructed wetlands to provide treatment of effluent-dominated river water, prior to delivering the water to water supply reservoirs for subsequent reuse. It has been established that treatment wetlands provide outstanding habitat for a variety of aquatic and terrestrial species, including

migratory birds as well as numerous recreational and educational opportunities within the community. Treatment wetlands also are known to improve water quality by removing nutrients and suspended solids. Recent studies also suggest that treatment wetlands can be useful in the removal of trace organic contaminants present in effluent-dominated waters. However, there is a need to document the effectiveness of wetlands when used for indirect potable reuse projects and to identify management approaches that assure the long-term performance of wetland systems. This project will use existing wetland systems within Texas to study treatment effectiveness and evaluate operational strategies that can be used to enhance wetland performance.

Approach:

- Select one or more constructed wetland sites currently being used to provide treatment for an indirect potable reuse project.
- Identify wetland characteristics that potentially affect treatment effectiveness for contaminants relevant for indirect potable reuse (e.g. hydraulic retention time, short-circuiting, selective planting strategies, etc.)
    - Perform laboratory, pilot and field studies to quantify the treatment effectiveness of wetlands as related to the performance factors.
    - Based on findings of these studies, develop recommendations for enhanced design and operation of constructed wetlands for indirect potable reuse projects.

Benefits:

- Will provide information that can be applied to surface water augmentation projects in Texas and facilitate implementation of projects as defined in *Water for Texas 2007* and future water plans.
- Will help further quantify the treatment effectiveness of constructed wetlands for indirect potable reuse projects.
- Will provide valuable guidance for design and operational strategies of existing and future constructed wetland projects used for indirect potable reuse.
- Will help assure that indirect potable reuse projects are undertaken to provide reasonable protection of public health and the environment.

Duration: 4 years

Estimated Budget: $400,000

Opportunities for Collaboration: May be able to work with the WateReuse Foundation to obtain co-funding for the project under the Foundation's Research Partnership Program. The program sponsors research with other research organizations and institutions.

RANK: 3 – SPECIFIC TEXAS INTEREST

TITLE: USE OF MANAGED AQUIFER RECHARGE SYSTEMS TO FACILITATE WATER RECLAMATION IN TEXAS.

Description: Indirect potable reuse is defined as the augmentation of a drinking water source such as groundwater with reclaimed water and includes passage through one or more environmental buffers. Managed artificial recharge used for indirect potable reuse involves the infiltration or injection of reclaimed water into an aquifer under controlled conditions. The intent of managed aquifer recharge is to store and/or treat the reclaimed water, and in some cases to augment drinking water supply. Managed aquifer recharge may integrate an environmental buffer (such as blending and detention time underground) or natural treatment systems, such as soil aquifer treatment or riverbank

filtration. These natural treatment systems may offer significant advantages in combination with above ground engineered treatment systems for achieving a consistent high water quality at reduced costs and environmental impact. While dependent on specific project conditions, natural treatment systems typically do not generate residual byproducts for disposal, operate without the need for chemicals, have a low carbon footprint, and can be established and operated at low capital and operational costs. The Texas Water Development Board has recently funded a research grant to assess aquifer storage and recovery in Texas However, no managed artificial recharge projects using natural treatment systems have been implemented for indirect potable reuse in Texas. This project will explore the feasibility of managed aquifer treatment in Texas and the suitability of soil aquifer treatment and riverbank filtration for producing potable water quality using reclaimed water or river water that is highly impacted by wastewater discharges.

Approach:

- Draw from available literature to gather information on the performance of soil aquifer treatment and riverbank filtration when used as an environmental buffer for indirect potable reuse projects.
- Define the legal and regulatory feasibility of managed aquifer recharge in Texas.
- Evaluate the suitability and effectiveness of soil aquifer treatment and riverbank filtration as environmental buffers for managed aquifer recharge in Texas; identify areas with the greatest potential for managed aquifer recharge and the application of these environmental buffer technologies.
- Identify candidate projects for pilot studies of managed aquifer recharge in Texas. Define a general protocol for implementation of the pilot studies.

[I] *Texas Administrative Code, Title 30, Chapter 307*

Benefits:

- Will provide needed information that can be used to implement soil aquifer treatment or riverbank filtration projects.
- Will facilitate implementation of projects that can be used to meet goals in *Water for Texas 2007* and future water plans.
- Will define areas within Texas that are most suitable for development of managed aquifer recharge projects.
- **Duration:** 1 year
- **Estimated Budget:** $150,000

RANK: 4 – SPECIFIC TEXAS INTEREST

TITLE: UNDERSTANDING THE EFFECTIVENESS OF NUTRIENT REMOVAL PROCESSES IN REDUCTION OF CONSTITUENTS OF CONCERN RELATIVE TO INDIRECT POTABLE REUSE.

Description: Indirect potable reuse is defined as the augmentation of a drinking water source, such as a surface water reservoir, with reclaimed water. Based on nutrient control criteria in the 2010 Texas Surface Water Quality Standards[I], Texas wastewater utilities have a unique opportunity to jointly determine what types of wastewater technologies and operational protocols will meet the new regulations and provide a high quality reclaimed water that can be used for reservoir augmentation.

The Texas Commission on Environmental Quality is currently establishing new nutrient criteria for water bodies in Texas that will require wastewater utilities to install new technologies at wastewater treatment plants or modify existing treatment processes and/or operations to reduce the discharge levels of nutrients,

such as phosphorus and nitrogen. Given this situation, there may be opportunities to design and operate wastewater treatment facilities that will produce reclaimed water for indirect potable reuse in a manner that maximizes the reduction of nutrients as well as other constituents of concern. Research is needed to identify those compounds of greatest human health and environmental concern for indirect reuse and their levels in water that are of minimal risk based on available scientific information. Using this information, a diverse set of treatment schemes would be identified and evaluated in terms of treatment effectiveness, energy use, carbon footprint, cost, and benefits, with the goal of determining which options can best be used to produce reclaimed water for augmentation of water supplies in Texas. The proposed research would build on ongoing national studies that are close to completion, but would strategically fill in information gaps related to treatment effectiveness, cost, energy use, and reliability that are specific to Texas conditions and water quality needs.

Approach:

- Establish a priority list of compounds and thresholds for indirect reuse in Texas.
- Perform a literature search and review information related to removal of nutrients and the priority compounds. Of particular interest are two research projects:
    1. A Water Environment Research Foundation (WERF) sponsored project that is evaluating the removal of compounds of concern in wastewater, including treatment processes that are designed to remove nutrients (WERF CEC4R08). This project will be completed in 2011.
    2. A study conducted by the U.S. Geological Survey for Puget Sound that evaluated the removal of compounds of concern in wastewater using nutrient treatment technologies.
- Compile information on the energy use, carbon emissions, and cost and effectiveness of treatment systems that are capable of removing compounds of concern to meet threshold levels and nutrient goals. Compile similar information on advanced treatment systems, physical chemical treatment systems, and combinations of treatment that are specifically designed to remove priority compounds to threshold levels so that a comparison of relative costs and benefits can be made. As appropriate, use indexes to adjust costs to Texas conditions.
- Conduct laboratory and/or field studies of existing treatment plants to identify optimum technologies and operating conditions for reducing nitrogen and phosphorus to levels required by Texas nutrient criteria, and concomitant impacts on reducing the priority compounds.
- Identify opportunities for using these treatment systems in Texas for indirect reuse projects.

Benefits:

- Establishes information that can be used to plan and implement indirect potable reuse projects in Texas based on public health, environmental, financial, and social benefits.
- Identifies optimal treatment technologies and operating conditions for maximizing the reduction of nitrogen, phosphorous and constituents of concern in reclaimed water.
- Develops guidelines for cost effective and energy effective design and operation of treatment processes to remove nutrients and compounds of concern.
- Identifies cost savings, energy savings, reductions in carbon footprint, and benefits due to synergies of optimally removing compounds of concern and nutrients for indirect potable reuse projects.

- Facilitates implementation of vital projects in *Water for Texas 2007* and future water plans.

Duration: 18 months

Estimated Budget: $250,000

Opportunities for Collaboration: May be able to work with the WateReuse Foundation to obtain co-funding for the project under the Foundation's Research Partnership Program. The program sponsors research with other research organizations and institutions.

RANK: 5 – SPECIFIC TEXAS INTEREST

TITLE: UNDERSTANDING THE POTENTIAL FOR UTILIZING NANOFILTRATION AS A BENEFICIAL TREATMENT PROCESS RELATIVE TO RECLAIMED WATER IN TEXAS.

Description: Indirect potable reuse is defined as the augmentation of a drinking water source such as a surface water reservoir, with reclaimed water. One of the key parameters that can drive treatment requirements and costs for indirect potable reuse is salt and the need to prevent build-up in water supplies. There are specific treatment methods that remove salt from reclaimed water, but many of them have high energy requirements and produce brine wastes that are difficult to dispose of. Research is needed to select the most effective treatment schemes for salt removal and management to advance indirect potable reuse in Texas. One very promising option is nanofiltration. Nanofiltration provides benefits in terms of removal of salt and lower energy usage, but may not be capable of removing certain constituents that can impact water quality, such as nitrate. Potential applications of nanofiltration in Texas need to be identified and more fully evaluated in terms of treatment effectiveness, energy use, carbon footprint, cost, and benefits. The goal of the research would be to assess the potential role that nanofiltration could play in treating reclaimed water for augmentation of water supplies in Texas.

Approach:

- Establish a priority list of compounds and thresholds for these compounds and salts for indirect reuse in Texas.
- Compile information on the energy use, carbon emissions, and cost and effectiveness of commercially available nanofiltration systems for removing salt and the priority compounds of concern, and identify candidate systems for further evaluation.
- Conduct laboratory studies to evaluate the candidate nanofiltration systems and optimum operational conditions for reducing salts and priority constituents to meet the designated thresholds for reclaimed water.
- Identify pretreatment options that might preclude limitations for removing compounds not amenable to nanofiltration, such as nitrate.
- Identify opportunities for using these treatment systems in Texas for indirect reuse projects.

Benefits:

- Establishes information that can be used to plan and implement indirect potable reuse projects in Texas based on public health, environmental, financial, and social benefits.
- Identifies optimal applications of nanofiltration for removal of salts and priority compounds in reclaimed water.
- Develops guidelines for cost-effective and energy effective design and operation of nanofiltration processes to remove salts and priority compounds of concern.

- Identifies cost savings, energy savings, reductions in carbon footprint, and benefits due to synergies of optimally removing salts and compounds of concern for indirect potable reuse projects.
- Facilitates implementation of vital projects in *Water for Texas 2007* and future water plans.

Duration: 18 months

Estimated Budget: $250,000

Opportunities for Collaboration: This project was recently submitted by the Texas Water Development Board to the Bureau of Reclamation for inclusion in its Science and Technology program and was selected for funding.

RANK: 6 – SPECIFIC TEXAS INTEREST

TITLE: ORGANIZATIONAL, INSTITUTIONAL, AND PUBLIC AWARENESS FRAMEWORK TO ADVANCE WATER REUSE IN TEXAS

Description: Increasing demands from a rapidly growing population are putting a severe strain on water sources in Texas. Water reuse is one of the tools available to increase water use efficiency by reclaiming growing supplies of highly treated wastewater. *Water for Texas 2007*, the most recent statewide plan published by the Texas Water Development Board, summarizes expectations for growth of water reuse in Texas. With the addition of new water management strategies to existing supplies, water volumes available from reuse are projected to be 800,000 acre-feet per year in 2010 and increase to 1,630,000 acre-feet per year by 2060. An integrated planning framework is needed to successfully achieve these reuse goals given the unique organizational, institutional, water rights and regulatory structures in Texas. This research will develop a framework that includes 1) public awareness and outreach strategies, 2) reuse customer strategies (particularly for large volume users such as the electrical power industry), 3) organizational/institutional models that can effectively implement reuse, 4) and tools that allow utilities to make informed decisions in the selection of and investment in reuse options. The framework will build on successful water reuse efforts in Texas and other areas of the United States.

Approach:

- Document examples of successful and unsuccessful reuse projects in Texas and key states with extensive reuse programs (such as Florida, California, Arizona) in terms of:
  - How projects were selected (why the specific type of reuse was implemented versus other options).
  - How projects overcame critical legal (including water rights), political, institutional, technical, regulatory, public opposition and logistical issues.
  - The types of public and customer outreach and education undertaken (when was outreach conducted, what worked, what didn't work and why, key ingredients for success).
  - How projects were funded.
  - What are the costs and benefits (including societal if available) and how were those factors communicated to key stakeholders.
- Using this information, develop a framework that can be used by utilities (small to large) to select and implement reuse projects in Texas.
- Provide recommendations for institutional, financial or regulatory changes that may facilitate accelerated implementation of reuse in Texas.

Benefits:

- Provides a comprehensive planning framework that addresses issues, advantages, and obstacles to implement reuse projects in Texas based on case studies.
- Enables stakeholders to plan and implement reuse projects to meet the *Water for Texas 2007* goals without having to "reinvent the wheel" for each new start.
- Provides examples of how to deal with difficult legal and regulatory issues in Texas.
- The development of a transparent planning framework will be highly advantageous in working with regulators and other stakeholders.
- Provides a needed understanding for stakeholders of concerns and potential opposition that indirect potable reuse can evoke based on the original water source.

Duration: 2 years

Estimated Budget: $250,000

RANK: 7 – SPECIFIC TEXAS INTEREST

TITLE: DEVELOPMENT OF INTEGRATED WATER QUALITY MODELS FOR THE TRINITY RIVER SYSTEM

Description: The Trinity River is a critical water resource for Texas, providing potable water supply for much of the Dallas/Fort Worth and Houston metropolitan areas. The Trinity River Authority, water suppliers and dischargers concerned with water quality in the Trinity River basin have developed models to predict water quality in the river. The models are primarily used to support decisions about the control of oxygen-demanding constituents and management of the river. A significant amount of indirect potable water reuse, both planned and unplanned, occurs in the Trinity River system, with effluent accounting for the majority of the flow in the river in some seasons and approximately half of the water entering Lake Livingston on an annual basis. To assess the potential effects of water diversions and changes in water quality in the watershed, existing models can be adapted to include relevant constituents, such as trace organic contaminants and regulated drinking water contaminants. This information can be used to plan and implement new indirect reuse projects in conjunction with projected water management activities.

Approach:

- Identify existing models that can be used to predict concentrations of nutrients, dissolved oxygen and other water quality parameters in the Trinity River.
- Adapt the models to predict concentrations of wastewater-derived trace organic contaminants and other drinking water parameters in the river.
- Gather field data to verify model predictions. Modify the models if necessary.
- Conduct model runs to assess the impacts of different scenarios, such as diversions in the upper watershed, changes in flows and modifications/ upgrades in wastewater treatment systems.
- Identify key uncertainties in model predictions where additional information is needed to improve the models.

Benefits:

- Provide regulators and water service providers with a better understanding of the fate, transport and transformation of drinking water contaminants in communities that use Trinity River water.
- Provide regulators and water service providers with tools to plan and implement indirect potable reuse projects.

- Assess the effectiveness of different management options that could be used to improve water quality.
- Identify key uncertainties in predictive models.

Duration: 2 years

Estimated Budget: $350,000

Opportunities for Collaboration: Clean Rivers Program, Trinity River Authority, local utilities.

RANK: 1 - NATIONAL INTEREST WITH APPLICATION TO TEXAS

TITLE: COMPARATIVE AND RELATIVE HUMAN HEALTH RISK ASSESSMENT OF INDIRECT POTABLE REUSE IN TEXAS

Description: Increasing demands from a rapidly growing population are putting a severe strain on water sources in Texas. Water reuse is one of the tools available to increase water use efficiency by reclaiming growing supplies of highly treated wastewater. *Water for Texas 2007*, the most recent statewide plan published by the Texas Water Development Board, summarizes expectations for growth of water reuse in Texas. With the addition of new water management strategies to existing supplies, water volumes available from reuse are projected to be 800,000 acre-feet per year in 2010 and increase to 1,630,000 acre-feet per year by 2060. Indirect potable reuse projects are anticipated to be the primary application for advancing water reuse in Texas via surface water augmentation. Though multiple water reuse technologies appear to produce water that surpasses all available safety values, members of the general public have expressed concerns about the quality of such supplies. As such, successful implementation of water reuse projects depends on using sound science and communication regarding the quality and safety of reclaimed water.

The U.S. Environmental Protection Agency regulates the concentrations of approximately 90 substances in drinking water. Safety values are currently available for these chemicals and others under consideration for future regulation; however, values are not available for the full range of contaminants that may be present in drinking water, including constituents of emerging potential concern. This group of chemicals may include endocrine disrupting compounds, and pharmaceuticals and personal care products. These compounds may also be present in reclaimed water used for surface water augmentation. To advance water reuse in Texas, it will be critical to explain to the public what the presence of these compounds means in water with regard to public health. In order to generate this information, research is needed to develop safety values for key constituents of emerging concern in reclaimed water used for surface water augmentation as well as the estimated quantity of water that would have to be consumed to trigger an adverse health outcome. It will also be important for public outreach to compare the concentrations of these key constituents of emerging concern in drinking water derived from multiple sources, including tap, bottled, and recycled waters to the estimated safety values. This project could be conducted in concert with another priority project (Selection of appropriate chemical indicators and surrogates for indirect potable reuse projects in Texas).

Approach:

- Determine the suite of chemical contaminants that are most relevant with regard to indirect potable water reuse.
- Gather existing monitoring data for these compounds in Texas and collect new data to fill gaps in the available datasets.
- Evaluate the utility of predictive computer modeling to understand the presence of contaminants in reclaimed water.

- Collect available toxicity information from the literature for each compound; examples of sources include studies by the Water Research Foundation, WateReuse Foundation, the Australian Guidelines for Water Recycling Augmentation of Drinking Water Supplies, ongoing studies in the United Kingdom, and existing toxicological databases .
- Derive acceptable daily intake level and safe drinking water equivalent levels for each compound of emerging concern.
- Calculate the ingestion rate and quantity of water associated with potential for adverse effects.
- Use this information to develop outreach materials that explain the real significance of these compounds in water.
- Develop a plan to update this information as future compounds of concern evolve based on sales of products or the development of new testing methods.

Benefits:

- Provides useful information for public outreach programs for indirect potable reuse projects.
- Enables utilities to include information in reports to the public on the safety of water being provided (particularly in situations when an agency is asked to explain what it would mean if these chemicals are found in drinking water).
- Provides an agency with the opportunity to focus on possible source control or treatment management actions for compounds where potential risks may be of concern if they reach concentrations at or above the safety thresholds.
- Allows agencies to structure monitoring programs for indirect potable reuse projects that may have potential risks and the concentration range to target for analytical reporting levels.

Duration: 18 months

Estimated Budget: $200,000

Opportunities for Collaboration: May be able to work with the WateReuse Foundation to obtain co-funding for the project under the Foundation's Research Partnership Program. The program sponsors research with other research organizations and institutions.

RANK: 2 - NATIONAL INTEREST WITH APPLICATION TO TEXAS

TITLE: SELECTION OF APPROPRIATE CHEMICAL INDICATORS AND SURROGATES FOR INDIRECT POTABLE REUSE PROJECTS IN TEXAS

Description: Increasing demands from a rapidly growing population are putting a severe strain on water sources in Texas. Water reuse is one of the tools available to increase water use efficiency by reclaiming growing supplies of highly treated wastewater. *Water for Texas 2007*, the most recent statewide plan published by the Texas Water Development Board, summarizes expectations for growth of water reuse in Texas. With the addition of new water management strategies to existing supplies, water volumes available from reuse are projected to be 800,000 acre-feet per year in 2010 and increase to 1,630,000 acre-feet per year by 2060. A majority of the water supply attributed to water reuse involves indirect potable reuse projects, primarily via surface water augmentation. Successful implementation of these projects will depend on using sound science and appropriate technology which can be justified and defended to the citizens they serve. While a diversity of studies have been untaken or are underway to select chemical indicator and surrogate compounds that are representative of behavior during treatment, these

compounds may not be ideal in representing risk to human and aquatic health for indirect potable reuse projects that rely on surface water augmentation. Research is needed to develop this list of compounds, including a systematic review of 1) toxicology and 2) analytical sensitivity and reliability so that data can be dependably collected and used to evaluate indirect potable reuse projects. The final product will be a list of compounds that can be used to evaluate the efficacy of treatment and environmental barriers, and serve as indicators of classes of chemicals of public and ecological health concern. Work products will include a target list that identifies chemicals to be analyzed, sensitivity requirements including reporting levels (detection limits for purposes of reporting), and appropriate quality assurance/quality control to assure confidence in test results.

Approach:

- Identify a preliminary target list of constituents building on work conducted by:
    - The Science Advisory Panel established by the California State Water Resources Control Board, which is charged with developing recommendations for monitoring constituents of emerging concern in recycled water in potable reuse projects. The Panel's report was released in June 2010, and the State Water Resources Control Board will adopt monitoring recommendations in late 2010. This effort is also looking at exposure and toxicity information.
    - The Water Environment Research Foundation study "Diagnostic Tools to Evaluate Impacts of Trace Organic Compounds on Aquatic Populations and Communities: Phase I – Prioritization, Development and Testing of Site-Specific Framework (CEC5R08C)." This research is developing a priority list of trace organics and a relational database of trace organic exposure and ecological effects data. This work will be completed in 2011.
- Prepare a summary report of the State Water Resources Control Board Panel and Water Environment Research Foundation study findings and recommendations, including the list of constituents of emerging concern recommended for testing, test methods and sensitivities, and the screening process to identify new compounds for the list.
- Review this information in light of constituents of emerging concern occurrence data for Texas facilities providing reclaimed water for surface water augmentation (or groundwater recharge); if there are data gaps, collect additional occurrence and toxicity data.
- Develop recommendations for monitoring constituents of emerging concern for indirect potable reuse projects in Texas.
- To assure that the list of compounds and the approach are valid, convene an expert panel to review the recommendations.
- Develop a screening process to identify future constituents of emerging concern as information on health and ecological effects and available testing methods continue to evolve.

Benefits:

- Reduces the endless drive for testing of more and more constituents of emerging concern at lower and lower levels in reclaimed water and standardizes testing requirements for utilities.
- Will improve testing and quality of data used to evaluate and implement projects.
- Will provide important information for operation of projects and public outreach/education.

Duration: 18 months

Estimated Budget: $150,000

Opportunities for Collaboration: May be able to work with the WateReuse Foundation to obtain co-funding for the project under the Foundation's Research Partnership Program. The program sponsors research with other research organizations and institutions.

RANK: 3 - NATIONAL INTEREST WITH APPLICATION TO TEXAS

TITLE: ENVIRONMENTAL QUALITY OF WATER REUSE PROJECTS IN TEXAS

Description: With projected increases in water resource needs and inter-annual rainfall variability, environmental water reuse presents numerous opportunities to support habitat augmentation, restoration, and mitigation in Texas. In the past decade, numerous studies have been conducted to characterize the occurrence and concentrations of constituents of emerging concern, such as pharmaceuticals, personal care products, and endocrine disrupting chemicals, in surface waters, wastewater, and recycled water, often accompanied by heightened media attention. The presence of these compounds has raised public concern about the ecological health of streams and rivers. There remains a need to develop balanced, science-based environmental quality recommendations for protection of aquatic life for environmental enhancement and mitigation projects that use reclaimed water. Previous studies indicate that the existing methodologies used to characterize the environmental quality of water, such as the existing U.S. Environmental Protection Agency's recommended water quality criteria, ambient toxicity as measured by whole effluent toxicity tests, and biological assessments, may not be sufficiently robust for some constituents of emerging concern, particularly endocrine active substances. New approaches are being tested to address this knowledge gap. For example, the U.S. Environmental Protection Agency has approved alternative approaches to developing water quality criteria for protection of aquatic life for triclosan and ethinylestradiol. Some promising alternative biological assessment approaches exist, including in vitro cell culture and short-term fish assays that require shorter time periods to perform and are thus less costly. However a critical evaluation of current and emerging approaches to assess water quality of reuse projects is needed to identify those methods that can best be applied.

Approach:

- Review existing available environmental quality benchmarks for reclaimed waters such as U.S. Environmental Protection Agency, recommended water quality criteria and state standards and similar benchmarks developed in Europe and Canada.
- Examine the capabilities of various emerging biological and chemical assessment approaches for application to reclaimed waters to predict ecological effects of exposure to one or more classes of chemical contaminants relevant to reclaimed water.
- Based on the results of the review, one or more promising candidate techniques for near-term use or further development will be selected for further study to predict the ecological health effects of contaminants in reclaimed water, including validation with water quality conditions in the field.
- Develop recommendations for alternative indicators of reclaimed water quality for protection of ecological health.

Benefits:

- Promotes use of reclaimed water by reducing uncertainty associated with trace organics in reclaimed waters.

- Provides balanced, science-based approaches for assessment of environmental quality in water reuse projects.
- Provides recommendations for specific diagnostic approaches to define water quality in Texas reuse applications.

Duration: 2 years

Estimated Budget: $300,000

Opportunities for Collaboration: May be able to partner with the project team of the first phase of an ongoing study supported by the Water Environment Research Foundation entitled "Trace organic impacts on aquatic populations and communities". This is an excellent opportunity for national collaboration. There are also opportunities for collaboration with Canadian, Australian and United Kingdom researchers on this topic. May also be able to work with the WateReuse Foundation to obtain co-funding for the project under the Foundation's Research Partnership Program. The program sponsors research with other research organizations and institutions.

RANK: 4 - NATIONAL INTEREST WITH APPLICATION TO TEXAS

TITLE: DEVELOPMENT AND VALIDATION OF REAL-TIME MONITORING METHODOLOGY

Description: Increasing demands from a rapidly growing population are putting a severe strain on water sources in Texas. Water reuse is one of the tools available to increase water use efficiency by reclaiming growing supplies of highly treated wastewater. Successful implementation of these projects will depend on using sound science and appropriate technology which can be justified and defended to the citizens they serve. One of the keys to advancing the use of reclaimed water is to ensure that it is safe to use, particularly with regard to the absence of pathogenic microorganisms. New tools are needed to reliably and quickly assess the microbial and chemical quality of reclaimed water on a real-time basis, particularly for potable water reuse. Current analytical monitoring technology for microbial and chemical contaminants in reclaimed water results in a lag time of several hours or days before the results of the analyses are known. This can create practical problems and regulatory concerns by increasing the potential that improperly treated reclaimed water may be released for reuse. Real time online monitoring for chemical contaminants or surrogates would be advantageous for all types of reclaimed water, but would be particularly important for reclaimed water used for potable reuse. It would also be valuable in determining the effectiveness of various treatment processes for parameters that could be used as control measures. The state of the art of monitoring technology in the water industry has not been developed to the point where real time monitoring methods are commercially available and needs to be advanced to allow for rapid monitoring results for microbial pathogens and chemical contaminants and/or indicators/surrogates. This effort might be enhanced by reviewing technologies developed as part of the country's homeland security research program. The objective of this project is to develop a real time method or methods for microbial pathogens (or indicator organisms) and/or chemical contaminants (or surrogates) using either online analytical techniques that provide immediate feedback on reclaimed water quality and/or the effectiveness of treatment processes. Methodology that provides very rapid but not necessarily immediate feedback for parameters of interest may also be considered. The method(s) developed should be accurate, reliable, and capable of being integrated into computerized control systems at water reclamation facilities.

Approach:

- Review the literature to identify existing real time methodology that may be used for wastewater
- Identify new or existing technologies with state of the art mechanisms of detection
- Evaluate the potential for real time monitoring methodology to provide data in either real time or very rapidly after sampling by summarizing available and developing methods
- Identify technology gaps
- Identify criteria for evaluating real time monitoring results and appropriate operational responses to monitoring results
- Identify specific constituents or key parameters that can serve as indicators or surrogates
- Select one or more microbial pathogen, chemical contaminant, indicator organism, surrogate compound, or other parameter for development of a real time monitoring technique or techniques
- Develop real time methodology (or methodologies) and validate the effectiveness and reliability of the technique(s)

Benefits:

- Provides immediate feedback on water quality, thus reducing the potential for improperly-treated reclaimed water to be reused for non-potable or potable uses
- Allows immediate corrective action to be taken
- Can be used to as a tool to verify integrity of the treatment barriers
- Will provide assurance to regulators, utilities, reclaimed water users, and the general public that the use of reclaimed water does not present health concerns
- Will enhance confidence in the efficacy and reliability of advanced treatment processes used for potable reuse

Duration: 2.5 years

Estimated Budget: $300,000

Opportunities for Collaboration: May be able to have the WateReuse Foundation co-fund the project, as they have received similar proposals for real time monitoring in the past. The Water Environment Research Foundation and Water Research Foundation could also be approached to collaborate on the project.

RANK: 5 - NATIONAL INTEREST WITH APPLICATION TO TEXAS

TITLE: DEVELOPMENT OF QUANTITATIVE MOLECULAR METHODS FOR EVALUATING THE VIABILITY AND CONCENTRATION OF MICROORGANISMS

Description: Increasing demands from a rapidly growing population are putting a severe strain on water sources in Texas. Water reuse is one of the tools available to increase water use efficiency by reclaiming growing supplies of highly treated wastewater. Successful implementation of these projects will depend on using sound science and appropriate technology which can be justified and defended to the citizens they serve. One of the keys to advancing the use of reclaimed water is to ensure that it is safe to use, particularly with regard to the absence of pathogenic microorganisms. New tools are needed to reliably and quickly assess the microbial quality of reclaimed water. There have been advances in recent years in the use of molecular technologies, such as polymerase chain reaction, to rapidly detect bacterial pathogens, parasites, viruses, and indicator organisms in reclaimed

water. Many of these methods are not standardized, validated, or approved for reporting monitoring data. Additional work is needed to link these techniques to the viability of microorganisms. Further improvements are needed to make them more efficient and cost effective. This project should thoroughly review the literature to identify available methods and their use to assess the quality of reclaimed water. .

Approach:

- Review the literature to identify new or existing molecular methodologies that may be improved upon to allow determination of organism viability or concentration.
- Develop a white paper that summarize promising methods.
    - Identify the pros and cons of each methodology.
    - Determine the capabilities of the methods for use in reclaimed waters of differing qualities.
    - Determine ease of use, maintenance requirements, etc.
- Convene an expert workshop to discuss and agree on:
    - Methods that might be ready (or almost ready) to use for monitoring reclaimed water quality and the utility, pros, and cons of each method; for these methods identify efficiency of recovery, accuracy, reliability, potential interferences, and ability to be used for different water matrices.
    - Methods where further research is necessary and next steps.
- Based on the outcome of the workshop, select one of the recommended available methods for testing reclaimed water from different treatment schemes (secondary treatment, tertiary treatment, advanced treatment) and compare to results using conventional surrogate methodologies.

Benefits:

- Will assist with developing more rapid and accurate determination of the viability and concentration microorganisms in reclaimed water.
- Will develop data that can be used to better characterize the quality of reclaimed water and comparisons of treatment methodologies.
- Will allow determination of microbial concentration in different water matrices with less interferences/ problems than encountered with current methodology.

Duration: 2 years

Estimated Budget: $250,000

Opportunities for Collaboration: The WateReuse Foundation, Water Environment Research Foundation, and Water Research Foundation may be interested in co-funding this project.

RANK: 6 - NATIONAL INTEREST WITH APPLICATION TO TEXAS

TITLE: SAFETY OF RECLAIMED WATER USED FOR IRRIGATION OF PUBLIC LANDS AND RESIDENTIAL AREAS IN TEXAS

Description: Increasing demands from a rapidly growing population are putting a severe strain on water sources in Texas. Water reuse is one of the tools available to increase water use efficiency by reclaiming growing supplies of highly treated wastewater. *Water for Texas 2007*, the most recent statewide plan published by the Texas Water Development Board, summarizes expectations for growth of water reuse in Texas. With the addition of new water management strategies to

existing supplies, water volumes available from reuse are projected to be 800,000 acre-feet per year in 2010 and increase to 1,630,000 acre-feet per year by 2060. The use of reclaimed water for irrigation of public lands (public parks, golf courses, school yards, athletic fields, cemeteries, freeway medians) and residential areas will be a necessary part of the water reuse portfolio to meet these goals. Texas and several other states have developed water reuse standards for non-potable uses that include treatment process requirements and microbial and other water quality limits. However, no existing state regulations are based on risk assessment methodology. This has resulted in widely varying criteria among the states that have developed regulations and has raised issues and concerns (both real and perceived) by regulatory agencies, operating agencies, reclaimed water users, and the general public related to the scientific basis of water reuse regulations and, hence, the public health protection afforded by existing regulations. The focus of this project is to gather information and conduct a microbial quantitative relative risk assessment of the use of reclaimed water in Texas for spray irrigation of residential areas and public lands where public contact is expected. Irrigation of parks and residential property provides many benefits if the public can be assured a safe environment is maintained with wise water reuse practices. This investigation would provide a valuable resource for public outreach and awareness programs.

Approach:

- Collect data on pathogens (bacteria, viruses and parasites) in reclaimed water from a variety of water reuse facilities in Texas that meet current bacterial and operational water reuse standards and use reclaimed water for irrigation of public lands and residential areas.
- Use quantitative microbial risk assessment approaches to assess the safety of reclaimed water for irrigation of public lands and residential areas.

Benefits:

- Provides water and wastewater utility managers important supporting information to make informed risk-based management decisions about reclaimed water treatment, end uses, and management options.
- Aids regulatory agencies in evaluating public health risks associated with existing or proposed water reuse regulations.
- Reduced uncertainty regarding risk may lead to increased public acceptance of reclaimed water use.

Duration: 2 years

Estimated Budget: $350,000

Opportunities for Collaboration: May be able to work with the WateReuse Foundation to obtain co-funding for the project under the Foundation's Research Partnership Program. The program sponsors research with other research organizations and institutions.

RANK: 7 - NATIONAL INTEREST WITH APPLICATION TO TEXAS

TITLE: TOOLS TO EVALUATE THE ENVIRONMENTAL, FINANCIAL AND SOCIAL BENEFITS OF WATER REUSE IN TEXAS

Description: The 2007 Texas Water Plan includes a number of planned direct non-potable reuse projects that have not yet been implemented, primarily due to lack of funding or inability to justify the significant capital expenditures required to develop a non-potable system. There is a need to develop a clear, well-defined economic evaluation approach that can be used by Texas entities to justify (or reject) the value of these projects in relation to other water supply strategies. Triple bottom line analyses are very useful for evaluating water reuse in comparison to other water supply options

since triple bottom line analyses look at environmental, financial and social benefits in comparison to typical cost/benefit analyses. However, more work needs to be done in this area particularly to 1) make sure triple bottom line tools are effective and up-to-date and can be used to evaluate how large the environmental, financial, and social benefits are when reuse options are included in Texas community water supply portfolios and wastewater management efforts (regional water resource management perspectives); and 2) compile examples and guidance for how to objectively evaluate reuse alongside other community/regional alternatives.

Approach:

- Identify and articulate the important types of triple bottom line benefits that accrue to non-potable reuse projects in Texas and how they compare to benefits associated with other state water management strategies.
- Demonstrate how to portray and communicate triple bottom line benefits, as well as costs, in a triple bottom line context, when comparing reuse options to other alternatives.
- Provide specific guidance and examples of how to:
    - Identify and interpret sensitivity analyses that focus on key cost items that can impact cost levels and how options rank in an evaluation (such as energy costs, chemical costs, permitting).
    - Account for variations in how the final water quality and potential water uses across various options impact the overall water portfolio and wastewater management costs.
    - Identify how the cost accounting guidelines apply to other water supply and water resource management alternatives (including conservation, imported water, advanced wastewater treatment and discharge) so that all relevant options can be evaluated and compared on an equivalent cost basis.
- Develop case studies for Texas that:
    - Illustrate suitable costing approaches.
    - Reveal how inconsistent or inappropriate costing approaches would skew how reuse and other water supply options are ranked.
    - Illustrate how to estimate and communicate the key triple bottom line values that accrue to reuse customers in Texas, including reliability, local control benefits, community economic vitality, and ecosystem benefits

Benefits:

- Promotes use of reclaimed water by enabling more complete triple bottom line evaluations for the values provided by these options, as compared to other alternatives.
- Provides a way to accentuate the positive aspects of water reuse as a way to place the perceived drawbacks into perspective.
- Promotes fair and unbiased comparison of the true triple bottom line costs of water reuse options with other alternative supply options under consideration.

Duration: 2 years

Estimated Budget: $350,000

Opportunities for Collaboration: May be able to work with the WateReuse Foundation to obtain co-funding for the project under the Foundation's Research Partnership Program. The program sponsors research with other research organizations and institutions.

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